Waterproofing of Roofs of Residential Buildings in Saudi Arabia

by

Abdulaziz Omer Al-Ajaji

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES
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DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

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JUNE, 1996
This thesis, written by ABDULAZIZ OMER AL-AJAIJ, under the direction of his
Thesis Advisor and approved by his Thesis Committee, has been presented to and
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Date: 13.7.96
I dedicate this work to my parents,
my wife and children and
my brothers and sisters
ACKNOWLEDGMENTS

Many people have helped in making this work possible. The author wishes to take this opportunity to acknowledge some of these people and to express his gratitude for their assistance.

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بسم الله الرحمن الرحيم

خلاغة الرسالة

اسم الطالب الكامل: عبد العزيز بن عمر بن عبد الله العجاجي

عنوان الرسالة: العزل المائي لسقف المنازل السكنية بالمملكة العربية السعودية

الخصائص: هندسة وإدارة التشطيب

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هذا البحث يناقش أهمية السقف في المنازل السكنية بالمملكة العربية السعودية وأهمية عملية التسقيف مع التركيز على أهم جزء في عمل التسقيف الري وهو العزل المائي. وقد وقع استبيانين احدهما لملاء المنازل الآخر لمقاييس التسقيف في عدد من مناطق المملكة.

إن كثيراً من مالكي المنازل يضيع وقتاً كثيراً في البحث عن المواد الجيدة لجميع اجزاء السقف وفي النهاية يحصل على تسقيفًا غير مرض حيث يواجه كثيراً من المشاكل وهنا يدل على أن البحث يجب أن يكون عن المقاولات الجيد حيث أن الأغلبية العظمى من المشاكل تحدث من عمل التسقيف أو التصميم السيء.

وقد بُنيت نتائج البحث أن 36٪ من المنازل قد واجهت مشاكل رئيسية و37٪ قد واجهت مشاكل فادحة بحيث أن السقف بكامله قد أزيل وأعيد بناؤه من جديد وقد حلت هذه المشاكل نتيجة لممارسة طرق بناء وصيانة سبعة مثل عدم الصيانة أو التفشي الدموي للسقف، ميول سيء، استعمال مخارج مياه صغيرة الحجم، وضع صبه المقبول على سطح غير ثابت وبدون فواصل تمدد أو تقوية حديدية وكذلك تركيب العزل المائي على سطح غير مائل.

درجة الماجستير في العلوم

جامعة الملك فهد للبترول والمعادن

الظهران، المملكة العربية السعودية

يونيو 1997 م
THESIS ABSTRACT

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TITLE OF STUDY: WATERPROOFING OF ROOFS OF RESIDENTIAL BUILDINGS IN SAUDI ARABIA

MAJOR FIELD: CONSTRUCTION ENGINEERING AND MANAGEMENT

DATE OF DEGREE: JUNE 1996

This study investigates the construction practices of the most important element in a residential building, the roof, with great emphasis on the most important component in roofing, the waterproofing. There is a large variety of materials that are available in the market for each roofing component. Owners usually spend lots of time trying to have the best roofing by looking for the best materials for each roofing component and at the end they face problems. The study reveals that wasting time by trying to get the best materials is the wrong approach to having a good roofing system; rather the selection of a reputable contractor is much more vital. Problems caused by materials are insignificant compared to design and construction methods.

More than a third (36%) of houses encountered major roofing problems. Three percent encountered disastrous problems where the whole roof had to be dismantled and replaced by completely new roofs. These problems were faced as a result of bad designs and construction practices such as: poor inspection and maintenance, bad slope, use of small size of drainage outlets, installation of sloping concrete screed on a non-firm base with no reinforcement and/or expansion joints, having dead level roofs until problems occurred, and installation of waterproofing membrane on a non-sloped surface.

MASTER OF SCIENCE DEGREE

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS

DHAHRAH, SAUDI ARABIA

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CHAPTER ONE

1.0 INTRODUCTION

1.1 HISTORY

A house to reside in, get rest, sleep, eat, etc. is one of the necessities of life. A person needs a place to stay and get sheltered against burning sun, freezing winter, wild animals, rain, snow, frost, wind, etc. This was known since time began when Adam and Eve resided on this earth. For this purpose trees and caves were used as shelters. Then, man progressed from caves to shelters and developed the techniques of making shelters by using clay, stones and wood.

Among the advanced shelters is what is called a house. A house has many components and the most important component in any house is its roof. There can't be a house without a roof and if the roof has a problem then the problem must be dealt with immediately.

In previous centuries, man gradually became more advanced than before and the materials he used became complicated. In this century, some materials that are used in making buildings are manufactured by complicated chemical processes. Among the complicated materials are insulation materials.
1.2 INSULATION

Insulation materials were thought to be accessory materials here in Saudi Arabia. Recently, house owners have become aware of the importance of insulation to the extent that insulation is no longer considered accessory rather necessary.

1.2.1 IMPORTANCE OF INSULATION

Insulation materials including waterproofing are important because they save money in decreasing the electricity bill and in protecting the house. Also they make a house more comfortable. Above all they allow the owner to have control over the inside environment of his house.

1.2.2 TYPES OF INSULATION

There are many types of insulation. The most popular types are: thermal insulation, sound insulation and water insulation or (waterproofing).

1.2.2.1 Thermal Insulation

Thermal insulation was introduced in Saudi Arabia recently to promote comfort inside the house and to reduce electric energy consumption. It is designed against the hot sun of summer and the freezing temperatures of winter.
1.2.2.2 Noise Insulation

Noise insulation, referred to as sound or acoustic insulation, is designed to protect a house against high noise outside the building. Reasonably high sound reduction is best achieved by the use of concrete slab roofs having a dead weight of about 250 kg/m² or more with the addition of screed and plastering [1]. It is not used or designed very often for residential houses in Saudi Arabia.

1.2.2.3 Water Insulation or Waterproofing

Water insulation or waterproofing is the most important insulation to any house. It can be said that waterproofing is a must while other types of insulation are not. Waterproofing is a necessity while others are optional. Waterproofing means either to prevent water from coming or to hold it from going. For a given house, waterproofing can be used for floors, bathrooms, swimming pools, basements, foundations and the roof. The most important usage of waterproofing is its usage on the roof and that is why we are going to investigate this issue.

1.2.3 Places for Insulation

Many house components can be insulated, particularly the outside components. These components include: walls, doors, windows, floor and roof.
1.2.3.1 Wall Insulation

The most popular wall insulation are extruded and expanded polystyrene where they are used as a thermal and acoustic insulation. It is rare to find other materials or an air gap used. Therefore, owners have no problem in deciding wall insulation.

1.2.3.2 Door Insulation

Although important, door insulation is the least popular insulation in Saudi Arabia. Probably because of its insignificant area compared to the area of walls. If doors are to be insulated, door fabricators will usually install the insulation when fabricating the doors. Consequently, house owners do not have a problem selecting door insulation.

1.2.3.3 Window Insulation

Window insulation is important and popular here. It is done by having an air gap between two glasses, best known as double glass windows. This allows for thermal and acoustic insulation of the windows. So owners have no problem because they have no other choice.

1.2.3.4 Floor Insulation

In hot climate areas, soil temperature can reach 33°C at a depth of 3 meters. Floor insulation helps to reduce heat flow through the floor into the house. Extruded polystyrene is a common floor insulation. However, floor insulation is rarely used in Saudi Arabia.


1.2.3.5 Roof Insulation

Roof insulation is the most important, most complicated and most expensive insulation system. It protects the roof which in turns protects the whole house under it. It involves many types of materials such as: concrete, thermal insulation and water insulation (waterproofing). It also involves different techniques to assemble different materials together.

Owners definitely have a big problem understanding all details of different kinds of materials and techniques. Owners have problems in selecting the appropriate roofing system. They also have problems in knowing the important factors that the selection criteria involve. Because of that, owners have lots of roof insulation problems and lots of money is wasted every year which contributes to the national economy problems. Therefore, finding out the roofing problems and the size of these problems is very important in recommending the corrective actions that need to be carried out to eliminate or at least minimize these problems. Figures 1 and 2 show typical roof insulation system.
Figure 1: Typical roof insulation system [2].
Figure 2: Typical roof insulation system, side view [2].
1.3 ROOF

A roof can be defined as the covering and supporting framework on the top of a building which is designed and installed to provide shelter and sustain the building's interior environment [3]. A roof is the most complex element of a building enclosure; it is the construction enclosing a building from above [4]. It consists of: 1) roofing which is the outer covering of a roof, 2) ceiling which is the surface or covering of the underside of a roof, 3) a structure which is always necessary between roofing and ceiling to support them [4].

Most people everywhere, and Saudi Arabia is no exception, do not spend their time building houses. They build a residential house once or twice in their life time. The owner who is building a house for the first time often does not know much about building materials and practices. Usually, an owner when building a house for the second time does not repeat his mistakes that he made in his first house, and the learning curve continues for the third and so on. Although the contractor is the one who executes the work, the involvement of the owner is vital in producing a high quality house. A house that is built for an experienced owner is much more better than a house that is built for an inexperienced owner. Usually owners like to have the best quality materials and workmanship for their houses. That is high quality work with an affordable cost in all house components.

All house components are important and there cannot be a house without walls, roof, windows, doors etc. However, the most important component of a building is its
roof. Despite this, the roof rarely gets the attention it needs. It is usually noticed only when it leaks. Unlike walls, doors, windows, floors, etc., the roof is the least visible part of the structure and, on the basis of "but of sight, out of mind", has on many occasions not received the full attention of the designer and owner's maintenance that is worthy of to its importance [5]. In the past, residential building owners subconsciously neglected such an expensive component [6].

1.3.1 IMPORTANCE OF A HOUSE ROOF

A house roof is one of the most important parts of a house. A roof is commonly regarded as a building's single most costly component and it is the most vulnerable to the onslaught of climatic conditions [6]. It protects the whole house under it. Therefore, the house roof must be protected and given considerable attention. House roof protection is a complex operation. It needs knowledge and understanding of the things that the house will be protected against. To best protect the house roof, the roof assembly system which will be used must be given great attention. Careful selection of the roof assembly system that best fits a particular house must be made. In recent years, house owners in Saudi Arabia have become aware of roof protection, particularly against the hot climate in summer, cold weather in winter and rain water in different seasons.

1.3.2 AWARENESS OF OWNERS

Recently, owners have become aware of this issue; therefore, they tried hard to get the best protection for their house roofs. This awareness does not necessarily make them
succeed in selecting the best protection for their houses even if they try hard to do so. Most owners do not have a strong grasp of such a fairly recent idea. Owner awareness has increased the demand in the market for roofing materials.

The interest of house owners in roof-protection materials has encouraged suppliers to import and manufacture different kinds of these materials. That made the market full of different types of roof assembly components materials and services. In 1987, there were 300 to 500 commercially available roofing membranes world wide [7]. Today the figure exceeds 1000 membrane types. This makes it difficult for owners to decide about the best materials to use. An inexperienced owner is not in a position to choose the best system for his house. A/E can suggest to the owner some of the roof-assembly systems that he is familiar with. However, it is totally the owner's decision to choose the roofing system for his house.
1.4 STATEMENT OF THE PROBLEM

The purpose of this study is to investigate the prevailing problems of residential house roofs in Saudi Arabia and to provide recommendations regarding these problems; that is, to make an attempt to eliminate roof problems or at least to help minimize or delay early appearance of those problems. To do that, one has to investigate the prevailing practices of building roof assemblies, with regard to the types of materials used and the ways these materials are assembled.

We would like to know the criteria that owners based their selections upon. A roof assembly has many components. Each component has a cost and a function. The overall cost of the roof assembly should be reasonable and affordable. The overall function of the roof assembly should meet the owner's expectations with respect to effectiveness in protecting the building mainly against sun's heat and rain water.

In recent years (early 1990s), the quantity of rain was more than anybody had expected. Many house roofs leaked. If water got into the roof slab it initiated deterioration and ultimately lead to loss of structural integrity [1]. Some houses were new, yet they leaked to such an extent that owners had to redo the roofing with a completely new assembly. These problems caused litigation and a waste of time and money for owners, contractors, consultants, courts and government agencies.

From the recent problems of insulation systems, it can be deduced that owners did not know what they were getting when they decided to protect their house roofs. Lots of
money was wasted in making poor systems. Owners need guidance to aid them in selecting a good and cost effective system to protect their house roofs.

To have an effective roof assembly, good quality materials should be used for thermal insulation, waterproofing, screed concrete, protection layers, expansion joints, etc. However, it is not enough to have good quality materials; these materials need to be assembled in an effective way. Insulation should be assembled by trained, skilled, experienced and educated labor.

All house roof components are important and each one has a role to play in protecting the house; however, waterproofing is the most important component in a house roofing system. In this research, we will concentrate on roof waterproofing practices and problems in residential buildings. If we compare, for example, waterproofing with thermal insulation, we find that thermal insulation is used mainly to reduce the cost of energy while waterproofing is used to protect the whole house. Thermal insulation itself needs protection. If there is a problem with thermal insulation, it will not be felt except, probably, by an increase in the electricity bill. Problems of waterproofing are felt and would need instant action. If waterproofing problems are not dealt with immediately, the house suffers negative and serious consequences. Most roof problems are waterproofing problems; therefore, waterproofing systems and problems must be investigated in order to reduce the problems and have better systems.

The whole idea here is to prevent roof failure and/or to make the roof’s life longer. The roof is considered to have failed when it no longer satisfies the building’s occupants.
Chapter 1: Introduction

Usually this means that water has penetrated the roof in some manner that results in inconvenience, discomfort, hazard or economic loss [8].

1.5 ACCOMPLISHMENT

With the completion of this study, the prevailing roof waterproofing systems are now known with respect to materials and construction methods, and these are discussed in chapter 7. Also, the problems encountered by these systems are known and discussed in chapter 5. In addition, the recommended solutions are provided in chapter 8.

1.6 THE SIGNIFICANCE OF THE STUDY

This study has both theoretical as well as practical significance.

1.6.1 THEORETICAL SIGNIFICANCE

In theory, the study adds to the field of roofing for houses, particularly waterproofing. It shows how good some of the materials and construction methods are in practice and will lead to their advancement and development. It will lead to the understanding of roofing problems and solutions.
1.6.2 **Practical Significance**

In practice, the study will help owners decide the best roofing system for their houses which will lead to eliminating the early appearance of roofing problems. It will save owners' time and money. It will help contractor, A/E and consultants in providing good waterproofing systems. It will also help the national economy to save lots of money which otherwise would have been wasted.

1.7 **Overall Goal**

The overall goal of this study is the elimination of the early appearance of roofing problems that are associated with waterproofing in Saudi Arabia's residential buildings.

1.8 **Objectives**

In order to reach the overall goal the following objectives will be met:

1) Identify roofing components which exist in literature

2) Identify construction methods of roofing which exist in literature

3) Identify in detail different types of roofing membranes

4) Identify problems of roofing

5) Identify construction methods of roofing in Saudi Arabia
6) Find out the roofing problems associated with roofing membrane in Saudi Arabia's residential buildings.

7) Find out the most effective ways of preventing problems from happening and the solutions to problems that do happen.

1.9 SCOPE & LIMITATIONS

1.9.1 Scope

This study covers roof waterproofing in Saudi Arabia, mainly large cities in the three main provinces, Eastern, Central and Western. Actually, what applies to these provinces applies to other provinces as well. However, other provinces were not covered in the survey.

1.9.2 Limitations

The study will be limited to the following constraints:

- **Average-size residential villa**: The building has to be a residential villa. Including other types of buildings would make the range too big and the research endless.

- **Twelve years old**: The house has to have been constructed within the last twelve years. After ten years, it is expected that the waterproofing would have
problems due to aging. Also, the average maximum warranty period offered by suppliers is usually twelve years.

- **Complete construction**: The house has to be completed and not under construction. The roof work is not considered to be complete for villas under construction. It should also be at least one year old so that the house has gone through a one year cycle; just like a one year test.

- **Concrete roofs**: Concrete roofs are by far the most popular roofs in Saudi Arabia. It would not add much to our research to include other types of roofs such as asbestos roofs, zinc roofs, aluminum roofs, sheet metal roofs or fiberglass roofs, since they are rarely used in residential villas.

- **Flat roof**: Generally roof formation is either flat or pitched. Roofs are regarded as being flat when their angle of inclination with the horizontal does not exceed 10° [9]. They are also called low-slope roofs. Pitched roofs, however, vary in their inclination from 10° to 70° [9]. This study will consider the flat roof only. The flat roof is the most popular type of roof in Saudi Arabia. Even though other types of roof have recently increased, flat roofs remain dominant. In slanted roofs, for example, waterproofing is not challenged; therefore, including other types of roof will not help our research. Examples of types of roofs are shown below in Figure 3.
A. Flat Roof
B. Shed Roof
C. Gable Roof
D. Hip Roof
E. Gambrel Roof
F. Mansard Roof
G. Pyramid Roof
H. Conical Roof

Figure 3; Roof Types [10]
CHAPTER TWO

2.0 ROOFING COMPONENTS

There are many roofing components that constitute roofing other than the roof deck. These components can all exist in one roof but most of the time only some of them exist in a particular roof. These components include: thermal insulation, waterproofing, loading layer, flashing, mesh reinforcement, expansion joints, protection layer, tiles and sloping concrete screed. It is very important that all products and their application within the system are compatible.

The roof deck which serves as the base for the roofing system is not considered as a roofing component for the purpose of this research; however, its role should not be overlooked. Structurally, it transfers the weight of live and dead loads to the supporting columns, joints and foundations. Therefore, the house structure should be capable of supporting the load of the completed roofing system. It should not be forgotten that the primary purpose of the roofing system is to protect the roof deck and to make it more effective in protecting the whole house.
2.1 THERMAL INSULATION

Thermal insulation plays a major role in energy conservation. With high energy costs and the amount of energy consumed, particularly in summer, where energy demand for air conditioning is very high, thermal insulation cost can be justified. It is now almost recognized that thermal insulation is a must. The surface temperature of a building’s roof can reach 165°F during summer; a hot roof can contribute up to 40% of the heat present in a building [11]. S. A. Mirza [12] in a study by SASO indicated that there is 40% saving when thermal insulation is used. The Arabian Chemical Company (ACC) has made a study of the effect of the usage of thermal insulation material in a two-floor Saudi residential villa [13]. The results showed that the annual saving of energy consumption is approximately 16% from the roof insulation alone. Thermal insulation is not only saving energy but also increasing the building’s life which makes it of high value, and improving the comfort level of the building.

Thermal insulation materials include wood and cane fiber board, cork, cellular glass, glass fiber, mineral fiber, perlite, expanded and extruded polystyrene, polyurethane foam and boards, polyethylene polyvinyl chloride, composite urethane and fiber glass, composite urethane and gypsum, composite urethane and perlite, phenolic and composites of foam and fiber boards [14]. Figure 4 shows common thermal insulation materials.

Thermal insulation should not be laid below the sloping concrete since it will tend to float during application of the screed, and water from the screed may become trapped
in the insulation [15]. It must be noted that thermal insulation can create roofing problems if improperly selected or installed. The types of thermal insulation selected must be compatible with all other roofing components.

![Diagram of insulation materials]

Figure 4: common thermal insulation materials [4]

2.1.1 WHAT THE OWNER EXPECTED TO GET FROM THERMAL INSULATION

2.1.1.1 Thermal Conductivity

The owner needs a thermal insulation material that has low thermal conductivity (K-value) so that high thermal resistance (R-value) can be obtained. In low thermal conductivity materials, it is hard for heat to get through to the inside of the building. The owner needs good insulation material that contributes to house comfort and reduces the electricity bill.
2.1.1.2 Durable Material

Material that will last for a long time without losing its thermal conductivity characteristics; that is, long-term insulation efficiency.

2.1.1.3 Compressive Strength

Thermal insulation should be strong enough to withstand walking and at least light use for AC maintenance, i.e. good mechanical strength. This is important especially in inverted roof systems where thermal insulation is directly walked on.

2.1.1.4 Water Absorption

Materials of thermal insulation should have low water absorption properties and low moisture absorption. 1% average when tested according to ASTM D-2842 is acceptable. This is important especially in inverted roof systems where thermal insulation is directly in contact with the atmosphere when humidity is high.

2.1.1.5 Resistance to Aging and Rotting

Thermal insulation materials should resist aging, i.e. thermal conductivity should not change so quickly. Thermal conductivity of thermal insulation materials for roofing lies within the range of 0.027-0.031 W/m·K (0.19-0.21 BTU in/sq ft h °F) during the process of five years aging.
2.1.1.6 **Dimensional Stability**

Thermal insulation materials should be stable. One way to make the boards stable is to make ship lap at the edge of each board.

2.1.1.7 **High Resistance to Thermal Cycling**

Thermal insulation should have some thermal resistance to thermal cycling; that is, to extreme changes in temperature. This is important especially in inverted roof systems where thermal insulation is exposed to temperature extremes.

2.1.1.8 **Low Cost**

Thermal insulation materials should be available at an affordable cost. The very reason for having thermal insulation is to save energy and in reducing the energy consumption of a given house, obviously the electricity bill is reduced. Therefore, the cost of thermal insulation should not exceed the energy saving.

2.1.1.9 **Other Properties**

In addition to the above properties, thermal insulation should be compatible with other roofing components. It should be fire resistant and impact resistant.

2.1.2 **Thermal Insulation Types**

There are many types of thermal insulation materials and each material differs from others with respect to properties. The most important property is the thermal conductivity.
of the insulation material which is measured in W/M °C. The smaller the thermal conductivity the better the insulation characteristics of the material. The following table shows thermal conductivity of some thermal insulation materials.

**TABLE I**

**THERMAL CONDUCTIVITY [4, 16]**

<table>
<thead>
<tr>
<th>INSULATION MATERIAL</th>
<th>THERMAL CONDUCTIVITY (W/M°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyurethane</td>
<td>0.020</td>
</tr>
<tr>
<td>Extruded Polystyrene</td>
<td>0.032-0.037</td>
</tr>
<tr>
<td>Expanded Polystyrene</td>
<td>0.037-0.045</td>
</tr>
<tr>
<td>Glass Fiber</td>
<td>0.033-0.045</td>
</tr>
<tr>
<td>Phenolic Foam</td>
<td>0.050</td>
</tr>
<tr>
<td>Polyisocyanurate Foam</td>
<td>0.023</td>
</tr>
<tr>
<td>Mineral Wool</td>
<td>0.040</td>
</tr>
<tr>
<td>Glass Wool</td>
<td>0.040</td>
</tr>
<tr>
<td>Phenolformaldehyde Foam</td>
<td>0.032</td>
</tr>
<tr>
<td>Foam Glass</td>
<td>0.050-0.060</td>
</tr>
</tbody>
</table>
2.1.2.1 Polystyrene

There are two major types of polystyrene that are commonly used as thermal insulation materials for buildings. These are expanded polystyrene and extruded polystyrene. Polystyrene is so common here that it has become a big business. There are at least five manufacturers of polystyrene in Saudi Arabia. Polystyrene will not accept the heat of a bitumen gas torch without melting. Figure 5 shows polystyrene boards that are ready to be installed in a residential house in Al-Khobar.

Figure 5: Polystyrene boards, ready to be installed in a residential house in Al-Khobar.
2.1.2.1.1 Extruded Polystyrene

Extruded polystyrene is formed from a plastic polymer (polystyrene). The raw material, styrene, is made from derivatives of coke and crude oil; closed cells are integrally formed within the insulation material during the expansion process [17]. The continuous extrusion process allows a tight and complete skin to form on each side of the insulation board. A solution of blowing agent in molten polystyrene is formed in an extruder under pressure; the extrusion process produces a continuous flow of material containing interconnecting closed cells [17]. The extruded solution is forced through an orifice into ambient temperature and pressure conditions; the blowing agent then vaporizes and causes the polymer to expand to about 30 times its original size [17].

Extruded polystyrene that is used for roofs usually has a density of 35 kg/m$^3$. The standard thicknesses available are: 25, 30, 40, 50 and 60 mm. The most common thickness is 50 mm. The standard width and length for extruded polystyrene boards are 60 cm and 125 cm respectively.

2.1.2.1.2 Expanded Polystyrene

Expanded polystyrene is formed from a plastic polymer (polystyrene). The polymer is impregnated with a foaming agent which when heated creates a uniform closed cell structure filled with air [17]. The raw material, styrene, is made from derivatives of coke and crude oil; the styrene is polymerized to form polystyrene [17]. A solution of blowing agent and polystyrene is expanded up to 40 times by steam in a pre-expander. The expanded boards are then stabilized in curing bins and cut into the desired sizes.
Expanded polystyrene is used like extruded polystyrene but cheaper and less effective. The difference between the two is that the grains of the first are bigger than those of the second. This makes expanded polystyrene's performance lower than that of extruded. Therefore, expanded polystyrene is cheaper than extruded.

2.1.2.2 Polyurethane

Polyurethane is a solid or spongy cellular thermal insulation material produced by the reaction of a polyester, such as glycerin, with a diisocyanate, such as toluene diisocyanate, while carbon dioxide is liberated by the reaction of a carboxyl with the isocyanate [18]. A small amount of catalyst is added to the mixtures during the early stages of the reaction to help the chemical reaction and act as a blowing agent [19]. The blowing agent which remains as a low pressure gas in the closed foam cells is a fluorocarbon with a very low thermal conductivity [19]. Polyurethane's closed cell structure minimizes water absorption.

The first commercial plastic appeared in the early 1950's. The usage of polyurethane was slow at the beginning but gradually gained momentum as its advantages became more evident. Polyurethane has the lowest thermal conductivity of any commercial insulation material [16]. It is also used as a soundproofing. This type of insulation can be used in two main forms: ready made boards and liquid spray.
2.1.2.2.1 Polyurethane Boards

In Saudi Arabia, polyurethane boards are manufactured by Sappco-Texaco (SAPTEX) in Riyadh. These boards have closed-cell structure, which means moisture absorption is negligible [20]. Both sides of the polyurethane boards are integrated with polyurethane-coated glass fiber tissue. Saptex can supply polyurethane boards as gypsum composite boards, perlite composite boards and plywood composite boards.

2.1.2.2.2 Polyurethane Foam Spray

Polyurethane foam is sprayed in-situ and applied to the roof. It is made from two components: a polyisocyanate and a polyhydroxyl. "The components also contain catalysts, a surface-active agent, and a blowing agent, which is normally a fluorocarbon refrigerant. The refrigerant gases have large molecules that do not transfer heat readily and are easier to hold in the plastic material. Normally refrigerants R-11 and R-12 are used. The reaction of the two components produces a large amount of heat which expands the gas, thus producing the cells. The catalyst controls the speed of the reaction. The surface-active agent acts in controlling the cell structure and allows production of a foam with a fine cell structure, which is necessary for a good thermal insulation. Mixing of the components is done either in spray nozzles or by a number of more or less secret processes. After mixing, the urethane expands 30 to 40 times in volume. This can be accomplished in one or two rises. When both R-11 and R-12 are used as the blowing agents, the material rises as the R-12 vaporize and then rises a second time when the R-11 vaporize" [21].
Polyurethane foam can be applied to any shape or configuration of the roof surface, and its monolithic structure eliminates leaky joints as well as seams [22]. Polyurethane foam is light in weight; light weight material is needed specially in the case of reroofing where the roofing load that can be carried by the existing structure must be considered. Installation of polyurethane foam should not be done on a humid or windy day or in the presence of water.

Water acts as a reactive blowing agent; the reaction between water and isocyanate component of the polyurethane chemical system generates carbon dioxide (CO₂) gas [23]. Water can be present in three different forms: water, moisture and humidity. To prevent water presence, spraying should not be performed during rainfall. To prevent moisture effects, polyurethane foam should not be sprayed on a moisture contaminated roof surface. Moisture can be detected by using detection paper, a chemically treated paper that turns purple upon contact with water; it is very sensitive to small amounts of moisture [23]. To prevent the effects of humidity, it should be field monitored with a psychrometer. Readings should be taken before the spray operation commences and regularly while spraying [23].

After the roof is cleaned and primed, it is sprayed in one or two passes to a thickness of 1 1/2 inch; having a 1-inch thick pass would be better than two passes with a thicker roofing because this would eliminate the chance of the two foam layers not adhering to each other [20]. This system is usually exposed; therefore, a waterproofing layer is sprayed over it. This is a complete system which includes thermal and water insulation.
Chapter 2: Roofing Components

Al-Babtain Polyurethane Manufacturing Co. Ltd. has been spraying polyurethane foam on Saudi Arabia's roofs for more than a decade. Many other contractors are now in the market doing this type of polyurethane system. The major advantage of a sprayed system is its ability to be applied around difficult or unusual shapes and the fact that it is self flashing. Despite its advantages, polyurethane roof test data showed that the roofs are 19 to 28 percent less energy efficient than expected on the basis of thermal performance claimed by insulation manufacturers according to NRCA study [24].

2.1.2.3 Fiber Glass

Arabian Fiberglass Insulation Co. Ltd. (AFICO), Dammam, manufactures many thermal and acoustical insulation materials which are installed on roofs, ceilings and walls. Two products are used in roofing with nominal density of 112 kg/m³.

2.1.2.3.1 AFICO Roof Deck Board

These are rigid glass fiber boards designed specifically for use with loose-laid ballasted single-ply roofing membrane systems [16]. It is uniformly textured inorganic glass fibers bonded together by non-water soluble resin and formed into rectangular boards. The boards are placed directly on the roof deck covered with a single-ply elastoplastic membrane.
2.1.2.3.2 AFICO Roof Insulation

These are rigid glass-fiber boards used for structural roof decks. They are composed of uniformly textured inorganic glass fibers bonded together by non-water soluble resin and formed into rectangular boards of heavy density.

2.1.2.4 Rock Wool

These are rigid or semi rigid rock wool slabs manufactured by Jordan Rock Wool Industries Co. Ltd., Amman Jordan, and Saudi Rockwool Factory in Riyadh. These slabs are made from inorganic materials with no tendency to absorb water from the atmosphere. Azel Rock Wool Insulation Products Factory in Madina manufactures Azel rock wool slab which is semi rigid insulation material. It consists of chemically inert fibers spun from molten basalt rock and bonded with thermosetting agent.

In addition to its thermal insulation property, rock wool is also acoustic insulation material. Rock wool resists chemical reaction, weather changes, microscopic germ growth, rodents and fungus. The facing material for rock wool slabs is fiber glass veil, bituminous kraft paper, aluminum foil, floating paper, wire mesh, polyethylene and corrugated card board [25]. Rock wool is available in slabs or rolls of fibers. Rigid panels are used for roofs.

2.1.2.5 Wood Fiberboard

This is the first type of board extensively used for roof insulation. These boards are manufactured by a felting process from an aqueous suspension of wood and other
vegetable fibers compressed to form a rigid insulation board [26]. It is not used or offered in Saudi Arabia.

2.1.2.6 Cork

Cork is formed from pure granulated cork, compressed, steam baked and held together by the natural cork gum [26].

2.1.2.7 Mineral Wool

Mineral wool is manufactured from volcanic rock melted at extremely high temperature and mixed with a small amount of resins as a binding agent.

2.1.2.8 Foam Glass

This is a solid substance like boards manufactured by melting the glass then injecting it by a ballooning material. This operation produces millions of closed cells that are full of air.

2.1.2.9 Polysocyanurate Foam Board

Polyisocyanurate foam board is made from polysocyanurate-based chemicals and manufactured in the form of rigid foam boards which are usually sandwiched between asphalt-saturated organic or inorganic felt facer sheets [17].
2.1.2.10 Perlitic Board

Perlitic board thermal insulation is a rigid board manufactured from expanded volcanic minerals combined with organic fibers and waterproofing binders [17]. Expanded perlitic ore is the principle ingredient in perlitic board which is mixed with water cellular fiber and a small amount of asphalt and then placed in an oven or dryer to form the insulation board [17]. Figure 6 shows perlitic boards ready for installation in a residential house in Dammam.

Figure 6: Perlitic boards are prepared for installation on a house in Dammam.
2.1.2.11 Urea Formaldehyde

Urea formaldehyde is mixed in situ with material that helps in making foam, compressed air and water. The operation is done by pumping these materials by special equipment with compressed air [27]. Usually the density is 12 to 40 kg/m³. Urea formaldehyde foams are not only thermal but also acoustic insulation material.

2.1.2.12 Phenolformaldehyde

This material usually is in the form of boards with a density of 30 to 50 kg/m³.

2.1.2.13 Foamed Phenolic

Foamed Phenolic became available as one of the good thermal insulation materials in the 1970s. It is considered to be a better insulator than glass wool or mineral wool and about the same as polystyrene. Phenolic foams are usually manufactured by the acid-catalyzed polymerization of Phenolformaldehyde resins in the presence of a blowing agent and a cell control agent.

2.1.2.14 Cellulose Fiber

Cellulose fiber comprises mainly two types of ingredients, newsprint and chemical retardants [4]. It is manufactured from recycled newsprint and cardboard or virgin wood which is pulverized to fiber form and treated during processing by various chemicals [4]. Common chemicals used in the treatment of cellulose fiber are boric acid, borax, aluminum
sulfate, ammonium sulfate, calcium sulfate/carbonate etc.[4] The first and the most widely used manufacturing technique of cellulose fiber is the dry process [4].

2.1.2.15 Cellular PVC

This material is usually in the form of boards. It has good water permeability resistance. But it is usually very expensive.

2.1.2.16 Cellular Glass

Cellular glass roof insulation is rigid insulation material composed of heat-fused, closed glass cells [17]. It is produced by combining crushed glass with a cellulating agent and the mixture is placed in a mold and heated in a furnace to approximately 950°F [17]. At this temperature the glass turns to a liquid, the cellulating agent decomposes and the mass material expands to fill the mold with millions of interconnecting closed cells holding inert gas [17].

2.1.2.17 Composite Board

Many insulation materials are prefabricated to form a unified, bonded multi layer thermal insulation material. These materials typically are perlite, fiber board, plywood and gypsum. Composite board roof insulation materials are produced by laminating a base layer of common insulation material to a controlled plastic chemical foam core and then facing the top layer with either an asphalt saturated felt or glass fiber facer sheet [17]. Then the three components are fed into a continuous production line so that the plastic
foam expands between the base layer and the facer sheet to produce a single composite insulation board [17].

2.1.2.18 CICO-LITE

CICO-LITE is a natural aggregate obtained by crushing volcanic rocks. The aggregate particles have cellular structure. It has been introduced recently. CICO-LITE aggregates can be used in the main concrete pouring or it can be used in sloping screed replacing the normal aggregates to give the screed thermal insulation characteristics. It can be used in making regular blocks and hordi.

2.1.3 WAYS OF ACHIEVING THERMAL INSULATION PROPERTY

Thermal insulation for a building can be achieved in three ways: under the roof deck, within the roof deck, and over the roof deck.

2.1.3.1 Thermal Insulation Under the Roof Deck

Thermal insulation can be achieved under the roof deck by using a false ceiling, rock wool, fiber glass and insulation boards fixed to the ceiling. Sometimes this is referred to as cold roofs where thermal insulation is provided at ceiling level. Ventilation is normally required between the roof deck and the false ceiling, see Figure 7.
2.1.3.1.1 False Ceiling

The gap between the ceiling and the false ceiling materials can be considered as a thermal insulation system. It is an insulation from inside. Many materials are used as a false ceiling some of them are used alone while some are used in conjunction with some thermal insulation materials. Gypsum boards underlayment, glass fiber, ceiling panels and thermal insulation materials as the false ceiling materials can all be used in false ceiling applications.

2.1.3.1.2 Thermal Insulation Materials

Thermal insulation materials can be used from inside the house. They can be fixed to the ceiling directly laminated with good appearance materials from inside or they can be used when fixed to gypsum boards.
2.1.3.2 Thermal Insulation Within the Roof Deck

Thermal insulation can be achieved within the roof deck by using light weight hordies. On the roof, hordi blocks are used to fill the spaces between steel bar beams. They are traditionally made from sand, cement and small gravel. The great majority of houses in Saudi Arabia have this kind of hordi blocks. However, there is a noticeable acceptance of some new types of hordi blocks. These materials are lighter in weight than the traditional hordies. Using these hordies will lessen the load of the roof deck and will provide thermal insulation property to the roof deck. Two commonly used types of hordies are red clay hordi and expanded polystyrene hordi.

2.1.3.2.1 Clay Brick Hordi

Particularly known as red clay because it belongs to the red clay family of blocks. Baked clay hordi has gotten some acceptance specially during the boom period a decade ago. This type of hordi blocks are light in weight compared to the traditional hordi, but its greatest merit is its built-in thermal insulation properties. The Research Institute of KFUPM had made a study and found that a clay brick hordi roof decreases electrical energy consumption by 17% [29]. Figure 8 shows different types of red clay hordi.
Figure 8: Different types of red clay hordi [30]
2.1.3.2.2 **Expanded Polystyrene Hordi**

Al-Hajry Insulation Industries and Al-Sahil Al-Sharqi Polystyrene Factory manufacture expanded polystyrene thermal insulation materials. Among their line of products are polystyrene hordi blocks. This type of hordi is not only light in weight but also a thermal insulation material. Its biggest drawback is the high cost compared to the traditional hordi. Also it is difficult to blister. It needs to be enforced by wire mesh or false ceiling must be utilized. This adds more to its already high cost. See Figure 9.

![Figure 9; Expanded polystyrene hordi installed on roof [31].](image-url)
2.1.3.3 Thermal Insulation Above the Roof Deck

Thermal insulation can be achieved above the roof deck. In fact, this way is the most common way of thermally insulating a building. Thermal insulation within the roofing can be achieved in two ways: by using light weight materials in the sloping screed and by using independent thermal insulation materials for the purpose of thermal insulating only.

2.1.3.3.1 Thermal Insulation Within the Sloping Screed

Sloping screed can be used to have three important advantages: insulating value, the ability to be sloped-to-drain and improved fire resistance. When used as a thermal insulation, sloping screed is made with light weight materials or light weight aggregates. These materials include: light weight concrete, perlite and vermiculite.

2.1.3.3.1.1 Light Weight Concrete

Light weight concrete (LWC) is used to produce an inexpensive light weight insulating roof screed and provide a finish suitable to receive a waterproofing membrane. LWC is stable, aerated, cellular concrete building material with densities varying from 300 kg/m$^3$ to 650 kg/m$^3$ compared to 35 kg/m$^3$ of polystyrene. The usual LWC density that is used for flat roof is 500 kg/m$^3$ with coefficient of thermal conductivity of 0.09 W/m °C.

It consists of a honeycomb of concrete enclosing a system of small strong-walled air cells which resist the absorption of water. Its thermal conductivity is approximately four times less than polystyrene. Therefore, it is not considered as a good thermal insulation material. If it is used as the only thermal insulation material, then it should be
good enough to be useful. Some owners use another thermal insulation material in addition to LWC. The materials that constitute LWC are ordinary Portland cement, clean sharp sand, clean water and foaming agent. LWC is manufactured at the job site by mixing of its constituents and then pumped to the roof.

LWC contains more moisture than other roofing substrates which may contribute to problems with the roofing system. Therefore, it should incorporate providing underside venting and topside pressure relief. It should be sufficiently cured, from 7 to 15 days to allow light foot traffic without damage to the surface [32]. Figures 10, 11 and 12 show LWC mixing and installation.

Figure 10: Mixing and pumping of light weight concrete.
Figure 11: Pouring of light weight concrete on the roof.

Figure 12: Spreading of light weight concrete
2.1.3.3.1.2 Perlite

Perlite is a natural material made of stones that are rich with aluminum selicate which has thermal insulation characteristics. It is a naturally occurring siliceous volcanic glass with a concentric layered structure [33]. It is a type of glassy volcanic rock originating from lava.

The perlite stones are crushed and blended to very small aggregates, dried and graded. When perlite grains are subjected to heat near to their softening point 1600°F (870°C), the combined water rapidly vaporizes causing the expansion of aggregates 4 to 20 times their original volume [34]. The expansion process creates countless air voids which give it light weight and thermal insulation characteristics. When combined with Portland cement and water, perlite aggregates constitute a light weight thermal and sound insulation material.

Perlite properties vary according to the mix design which produces the dry density. For most uses, as a proper balance between insulation value and compressive strength a cement/perlite ratio of 1:6 volume mix is recommended with dry density between 384-448 kg/m³ with a thermal conductivity of 0.08-0.09 w/m°C [34].

Perlite can be used in many applications including: floor fills, floor decks, walls and roof decks. Perlite concrete roof deck insulation is used as a base for waterproofing membrane just as the conventional slope-to drain concrete screed. Roofing membrane should be applied when the perlite concrete has been cured for a minimum of three days. Figure 13 shows the installation of perlite.
2.1.3.3.1.3. Vermiculite

"Vermiculite is the name given to platy micaceous minerals that are hydrous silicate of aluminum, magnesium, and iron. When heated to temperatures of 1200 to 2000°F (650 to 1100°C), the water trapped in the flakes of vermiculite ore turns to steam and forces the micaceous plates of the material to exfoliate in an accordion-like fashion. This exfoliation of the thin plates causes the volume of vermiculite to increase up to 30 times the original volume making a material that is suitable for insulation" [33]. These are natural layers of stones that are rich in iron silicate, aluminum and magnesium. They are light cubed aggregates between 5 to 10 mm in volume.
2.1.3.3.2 Independent Thermal Insulation

Independent thermal insulation can be used for the sole purpose of thermal insulating of the house roof. Any of the thermal insulation materials mentioned in the previous section can be used. They can be used under or above the sloping concrete screed or the waterproofing materials. However, it is recommended that they are installed above the sloping concrete screed to avoid cracking of the sloping screed.

2.2 WATERPROOFING (SEE CHAPTER 3)
2.3 LOADING LAYER OR TOP LAYER

The selection of the type of loading layer depends on the intended use and the desired appearance of the roof top. Loading layer can be either removable or non-removable.

2.3.1 REMOVABLE LOADING LAYER

Removable loading layer is the roof top layer that can be removed easily. There are many materials that can be used as a removable loading layer such as non-fixed or loose tiles; however, the most common material is gravel.

2.3.1.1 Loose Tiles

Loose tiles are used in inverted roof system to facilitate easy waterproofing membrane inspection.

2.3.1.2 Roof Mate - Roof Tile

The Arabian Chemical Company Ltd. has manufactured an insulating roof tile. Each tile consists of 20 mm concrete topping fully adhered to extruded polystyrene piece giving thermal insulation and roof finish in one element. The tile exhibits a tongue and groove on two parallel sides. See Figure 14.
2.3.1.3 Gravel

Gravel, sometimes referred to as aggregates or ballast, is crushed stone, crushed slag or water worn gravel that are defined by ASTM D1863 [35].

There are many reasons for having gravel added, among which are: 1) It adds a measure of protection to materials against ultraviolet radiation attack and degradation of some physical properties of some materials. 2) It adds some weight against wind uplift and buoyancy.

Gravel should be laid evenly over the entire area. It must be applied in sufficient quantity and of a quantity within the dead load capacity of the structure. In ballasted
and/or inverted roof systems, the gravel is spread over the roofing to a thickness of 50 mm. The approximate weight of ballast is between 50 and 80 kg/m². The usual diameter for gravel is 5/8" to 1 1/4" [36]. Small 3/8" ballast would block the drainage outlets, specially if these outlets are small in size.

The roofing system that utilizes gravel as a loading layer is usually referred to as ballasted system. In single-ply application, ballasted system is generally the cheapest system to install. Ballasted roof is usually considered in low wind areas. Concrete roof decks can usually carry the dead load of the gravel without affecting the designed live load of the deck [36].

2.3.2 Non-Removable Loading Layer

Non-removable top layers are the traditional roof top that have caused lots of trouble by making it difficult to find the sources of roofing problems. Concrete slabs are very common non-removable loading layers.

2.3.2.1 Paving Slab

Paving slab can be used as a protection layer instead of gravel or other removable layer. When used, it should have a minimum thickness of 4 cm [36]. Sloped concrete slab could be used as a non-removable loading layer.
2.3.2.2 Fixed Tiles

Fixed tiles can be used as a non-removable loading layer. Actually, it is the most common loading layer in Saudi Arabia. There is evidence that fixed tiles, when installed properly, can be a very good protection layer.
2.4 SEPARATION/PROTECTION LAYER

The separation or protection layer is used to protect either the thermal insulation materials or the waterproofing membrane. The protection layer is laid loosely and overlapped by 10 cm.

The top of thermal insulation boards should be covered by a protection layer. Fiber mesh will prevent fine particles of gravel grains from migration into the board joints or under the insulation boards. It also helps in preventing bouncy problems in case of unequal granular distribution or reduced gravel depth. It will protect the boards from mechanical damages. It will also prevent any contact between incompatible materials.

Protection sheets should be installed under the waterproofing membrane in order to protect it from mechanical damage which would result in puncturing the membrane by nibs projecting from rough concrete surface [28,36].

There are many types of materials that are used as protection layers. The selection of these materials depends upon the type of loading layer used, i.e. removable or non-removable. Some of the protection layer materials include polyester, polyethylene or glass fiber.

2.4.1 SEPARATION MATERIALS USED WITH REMOVABLE LOADING LAYER

When removable layer is used, the insulation boards should be covered with a filtration layer to retain any fines which might otherwise wash down and harm the
membrane or silt up rainwater outlets [20]. Some filtration layer materials that are available in the market are: Typar, Polyfelt and Alyaf.

2.4.1.1 Typar

This is a spun bonded geotextile that is manufactured by EXXON Chemical Co. It is a non-woven permeable separator. Depending on properties, there are seven grades of TYPAR: 3151, 3201, 3301, 3341, 3401, 3601 and 3801.

2.4.1.2 Polyfelt

Polyfelt is a geotextile that is manufactured by Polyfelt Ges. m. b. H. in Austria and Polyfelt Inc. in Evergreen, Alabama. This product is manufactured in a range of grades to meet the demand of any geotextile application. Depending on properties, polyfelt grades are: TS21, TS22, TS420, TS500, TS550, TS600, TS650, TS700, TS800, TS006, TS007, TS008 and TS009. All polyfelt grades are manufactured from highly U.V. Stabilized Polypropylene.

2.4.1.3 Alyaf

Alyaf is a needle punched non-woven polypropylene fiber used for a wide range of geotextile application. It is manufactured by Alyaf Industrial Co. Ltd. in Dammam, Saudi Arabia.
2.4.2 Separation Materials used with Non-Removable Loading Layer

With non-removable loading layer, other types of sheeting are used. Those types do not have filtration characteristics.

2.4.2.1 Building Paper

Building paper is used as a protection layer.

2.4.2.2 Polyethylene Sheeting

With non-removable loading layer, polyethylene sheeting is used as a protection layer. Unfortunately, many plastic sheetings are sold without specification sheets.

2.4.2.3 Polyester Felts

Non-woven polyester mat, 120-140 gm/m² polypropylene felt is acceptable to be used as a separation layer.
2.5 OTHER ROOFING COMPONENTS

Even though the major components of roofing are: waterproofing, thermal insulation, loading layer and protection layer, other roofing components should not be overlooked. Other roofing components could include: sloped concrete screed, flashing and expansion joints.

2.5.1 SLOPING CONCRETE SCREED

After making the basic concrete pouring for flat roofs, it is usually not enough to drain water off the roof. Therefore, another concrete pouring which should be sloped toward the drains must be made.

Sloped concrete screed is essential for roofing. Its function is to give roofing a certain slope in order to drain the roof, mainly from rain water. Sloped concrete screed could be used as a non-removable loading layer.

A large thickness of the sloped concrete screed should be avoided because: 1. The cost of materials and labor increases with thickness, 2. The dead weight of the large thickness may increase the structural size and reinforcement, 3. A large volume of water for mixing will be required; most of it will be trapped when the waterproofing cover is laid, drying out will be slow.

Screed material may be selected from regular sand/cement mortar mixed in the ratio 4:1 where a considerable amount of water is used; therefore, it should be adequately
cured before roofing is applied. Normal Portland-cement-and-sand screed should not be laid less than 20 mm thick. Sloping screed is not always made from regular concrete. Other screed materials are: aerated screed which is a mixture of cement, water and foaming emulsion combined to constitute a cellular material; light weight aggregate screeds cement bonded; light weight aggregate screeds bitumen emulsion bonded; perlite/bitumen screeds; light weight concrete screed; and perlite screed. Light weight screed used for thermal insulation must not be of less thickness than that required for adequate insulation function: a minimum of 40 mm [1].

Maximum and minimum thickness of all screeds should be shown on drawings [1]. Arrows showing the general direction of roof falls are not sufficient [1].

2.5.1.1 Concrete Sealant

Concrete sealant is a chemical compound that is mixed with concrete to give it good waterproofing characteristics.

2.5.1.1.1 Conplast Prolapin

An example of concrete sealant is Conplast Prolapin. It is manufactured by Fosam Company Ltd. in Jeddah, Saudi Arabia, a subsidiary of Fosroc Corporation, UK. It is an integral waterproofing admixture in liquid form to waterproof concrete and cement/sand mixes. The range of conplast prolapin includes:
A. CONPLAST PROLAPIN 031

This is for screeds, renderings and mortars. It is a red/pink liquid that contains an air-entering plasticiser and hydrophobic material which facilitate spreading, reduce cracking and reduce crazing.

B. CONPLAST PROLAPIN 421

This is a red liquid which is added to concrete to inhibit the passage of water. It contain a non-air entering plasticiser to assist optimum compaction. It is added at the rate of 6 liter per 1 m³ of ready mix concrete.

C. CONPLAST PROLAPIN POWDER S

D. CONPLAST WP10

This is a waterproofing admixture for cement.

E. BCI-ADMIX W2

This is an integral waterproofer which is a permeability-reducing admixture in liquid form for use in all types of mortars and concrete mixes, particularly ready-mixed concrete such as sloping concrete screed. It is based on a blend of ions chain carboxylic acids. It is manufactured in Dammam by BCI and distributed by CMDC.

2.5.2 EXPANSION JOINTS

Roof expansion joints are used to minimize the effect of stresses and movement of the roof and to prevent these stresses from splitting or ridging the roof membrane [37]. The wide temperature range experienced in rigid concrete roof slabs of extensive area will cause significant expansion and contraction. Expansion joints should be designed to
accommodate the expansion and contraction of the concrete. Therefore, the entire roof should be subdivided by expansion joints.

Expansion joints are used with non-removable loading layer if it is a concrete slab or fixed tiles. Al-Diab [27] recommends installing expansion joints only for roofs that have an area more than 300 m².

Structural expansion joints are installed on flat roofs to protect the roof from stress forces. They should be installed at the following locations [10]:

1. Where the deck structure changes direction.
2. Where a new roof has been added to an existing one.
3. Where two dissimilar deck materials join.
4. Where there is difference of elevation of two adjoining decks.
5. Where roof frame member changes directions.

Expansion joints have two main components, the filler and the sealant.

2.5.2.1 Expansion Joint Filler

The gap between expansion joints has to be filled by a flexible filler up to a depth of 1 inch. Expansion joint fillers are usually made of wood or strong paper. There are a variety of thicknesses, but the most often used is 18 mm. Another kind of expansion joint filler is a solid spongy rod that is made from a flexible hose that comes in different diameters. Some brands of expansion joint filler are:
A. Horn-Boards

This is an asphalt impregnated fiber composed of tough resilient cellulose fiber bonded together with a uniform impregnation of bituminous binder [38]. This product is manufactured by Tamms Industries.

B. Korkpack

Korkpack is a joint filler suitable for filling expansion joints. It is manufactured from graded and selected cork granules bound with high grade bitumen by Grace Construction Products of United Kingdom. The cork is encased between two layers of tough asphalt paper to produce a robust, chemically resistant board.

2.5.2.2 Expansion Joint Sealant

The gaps between concrete slabs and fixed tiles that are made for expansion joints are usually potential sources of water penetration. Usually the highest 2 cm in the expansion joint gap are left for sealant. Therefore, all expansion and movement joints should be sealed with special sealant such as Nitoseal 200 or Nitoseal 220. Sealant depth must never exceed joint width. The sealant must be stopped 5 mm below flush so that during contraction the sealant does not protrude above the surface. Some examples of available products are:

A. CICO JOINT 300 THIOKOL 2C

This is a two-part polysulphide polymer based compound manufactured by Construction Chemical Division of Commercial Investment Corporation C.I.C in Jeddah, Saudi Arabia.
B. DYmeric

This is a non-sag joint elastomeric sealant which is made of Epoxidized Polyurethane. It comes in white, black, bronze and beige. DYmeric is supplied in steel cans containing base and curative. It is then mixed with the desired color.

C. NITOSEAL 240

This is a multi-component polyurethane-based joint sealant manufactured in Saudi Arabia by Fosam Company Limited. It is supplied as three components already in the correct mix ratio. These components are: base material, hardener and color pack. They should be mixed together for five minutes.

2.5.3 CANT STRIP

Cant strip (fillet) which is made from sand and cement should be utilized where horizontal and vertical surfaces meet. It is required for wall and curb flashing. The purpose of the cant strip is to soften the angle formed between horizontal and vertical surfaces and to provide support for the base flashing [10]. If the cant strip is not provided, a void would be formed between the waterproofing membrane and the corner of the structure. The waterproofing would then be unsupported and likely to split if there is traffic in the area, particularly if the upstand material had become hard and brittle after several years of service [26]. Cant strip can be made from fireboards or high density polyurethane; however, sand and cement are the usual materials. The size of the fillet is 5 cm X 7.5 cm or 7.5 cm X 7.5 cm.
2.5.4 Flashing

Flashing is a very important roof component. Its function is to support the waterproofing system of the roof. Flashing is used to do the difficult job in the roof when two different materials intersect. Flashing is exposed to sever weather and to damage from roof traffic. Therefore, it is the most common source of roof leaks. Flashing materials should be compatible with the roofing membrane. Flashing failure results from faulty design, poor field application and defective materials. It needs more attention than other roofing components.

2.5.4.1 Flashing Components

Flashing components include: base flashing, Counter flashing and flashing sealant.

2.5.4.1.1 Base Flashing (Flashing Membrane)

Base flashing is usually one meter wide ultraviolet-resistant membrane which is fully bonded to the parapet, the cant strip, the roofing membrane and the roof deck. Base flashing should overlap the roofing membrane by at least 10 cm and it should extend to the parapet at least 10 cm above the top roofing layer. It can be protected by tiles or stones, if desired.

2.5.4.1.2 Counter Flashing

This is referred to as metal strip or aluminum flashing because the common material used is aluminum. It is used with waterproofing membrane alongside the
perimeter to fix the edge of the base flashing to the parapet. Adequate counter flashing should overlap the top of base flashing. It should cover all ends of the roofing membrane. All metal must be properly secured and sealed.

The most successful material for counter flashing is lead for it allows movement in relation to the upstand which it covers but it is usually ruled out on the ground of cost [26]. Copper or super purity aluminum are used as alternatives. In Saudi Arabia aluminum is the only common material for counter flashing.

Counter flashing can be installed in many ways. It can be installed 3 cm inside the parapet or it can be installed over a low parapet to form capping for the waterproofing materials. Sometimes, grooves are made in the parapet in addition to metal or as independent to do the same function as counter flashing. Counterflashing has many different shapes. See Figure 15.

![Diagram of counter flashing]

**Figure 15:** Counterflashing [39].
2.5.4.1.3 Flashing Sealant

Flashing holds the membrane to the vertical end but it does not prevent water from coming between the wall and the waterproofing membrane. So, flashing sealant must be used to seal the gap between the membrane and the wall. The most common flashing sealant material is silicon and polyurethane.

2.5.4.2 Flashing Types

Flashing types are as many as the locations that flashing is to be used. Mainly critical locations on the roof such as penetrating pipes, parapet, upstands, AC foundations, drainage outlets, and all other terminating ends. See Chapter 4 for construction details.

2.5.4.3 Flashing Membranes

Flashing membranes are membranes which are ultra-violet resistant and weather resistant. They can be used for all flashing types such as drains, pipes, parapet, etc. An example of these membranes are:

A. Elastiflash

This is an elastomeric flashing compound manufactured by Bitumat Company Limited. It is a cold applied rubberized bitumen cement formulated with ductile bitumen rubber, mineral stabilizers and special additives [40]. It is used for roof flashing, flashing details, roof curbs, vent pipes and sky lights.
B. Solarshield

Solarshield is a cold applied self-adhesive, heavily textured aluminum membrane which can be used as a solar reflective flashing or protection for exposed roofing membrane [40]. It is manufactured by Grace Construction Products of UK and distributed in Saudi Arabia by Bitumat Company Ltd.

C. EPDM-FORMFLASH

EPDM-Formflash is a self-curing EPDM rubber strip adaptable to irregular shapes and designed to flash the system details [41]. It is manufactured by Firestone.

2.5.5 REINFORCEMENTS

Reinforcement can be used in roofing in two areas: the sloping concrete screed and waterproofing membrane, specially the liquid applied type.

2.5.5.1 Steel Reinforcement

Steel reinforcement is used for sloping concrete screed in order to prevent or minimize cracks from happening to the screed.

2.5.5.2 Fiber Reinforcement

Many types of fiber reinforcement materials can be used to improve the tensile strengths of liquid-applied waterproofing materials. Many other waterproofing membranes have built-in enforcement. Fiber reinforcement materials can also be used to improve the
flexural and tensile strengths and energy-absorption and spall-resistance properties of the low density concrete [33]. See Figure 16.

Figure 16: Fiber reinforcement [28].

2.5.6 Adhesives

Adhesives are usually used in lap joints or to fully adhere non-bituminous single-ply roofing membranes to the substrate.

2.5.6.1 Bonding Adhesive

Bonding adhesive is usually neoprene based adhesive used to bond single-ply membranes such as EPDM.
2.5.6.2 Splice Adhesive

Splice adhesive is usually butyl based adhesive designed for field splicing of single-ply membranes such as EPDM.

2.5.7 Sealants

There are many types of sealants which are usually used for non-bituminous single-ply membrane systems.

2.5.7.1 Lap Sealants

This is a black EPDM sealant used to seal and mechanically protect the exposed edge of all field fabricated membrane splices [41].

2.5.7.2 Water Block Sealants

This is a butyl based sealant designed to provide a watertight seal when used under compression [41].

2.5.7.3 Fastener Sealant

This is a high strength sealant designed to seal the heads of mechanical fasteners; it prevents unscrewing of the fasteners and damage to the cover strips [41].

2.5.7.4 Pourable Sealant
This is a two-part, polyurethane based sealant designed to fill and seal penetration pockets [41].

2.5.8 ACCESSORIES

There are a lot of accessories that are needed depending upon the roofing system used. A few important accessories are highlighted below. (See Figure 17)

Figure 17: Some roofing accessories [42].
2.5.8.1 Termination Bars

This has an extruded aluminum profile used to attach and seal flashing termination at parapets and upstands [41].

2.5.8.2 Fasteners

There are various types of fasteners used to mechanically secure termination bars and/or insulation boards to the substrate [41]. They are also used to attach the roofing membrane in mechanically adhered systems. Figure 18 shows concrete fasteners.

Figure 18: Fasteners that are suitable for poured concrete [17].
3. CHAPTER THREE

3.0 WATERPROOFING

Waterproofing is defined as the treatment of a surface or structure to prevent the passage of water under hydrostatic pressure [43,44]. Waterproofing is used in many applications such as swimming pools and water tanks. It is also used in residential buildings, particularly on foundations, basement, kitchen, bathrooms and the roof. Waterproofing is an essential integrated component contributing to the building’s safety and durability, protecting concrete against accelerated aging and decay [45]. Although the usage of waterproofing is necessary for many building’s components, it is even more essential to the roof.

Anyone using waterproofing materials for roofs should understand that making the roofing system is a big investment, which if not made properly can result in very costly consequences; water can cause the deterioration of the concrete and its reinforcement.

Waterproofing is the most important component in a roofing system. “No roof insulation, regardless of its thermal efficiency, should endanger the life of the roof membrane which is the most important component of the system” [46].
In Saudi Arabia 30 years ago, waterproofing was used only in government and companies' buildings. During the last 30 years, many things have happened that have contributed to the usage of waterproofing in residential buildings. There was and still is an educational revolution with people acknowledging the importance of good education. The standard of living has risen sharply and people now can afford to pay for a good state of the art waterproofing system which was beyond the thinking of the ordinary house owner. Technical advancement in the country and good communication systems with the outside world make local entrepreneurs bring foreign companies to manufacture waterproofing materials locally.
3.1 Properties of Waterproofing Systems

Waterproofing systems must have special properties in order to satisfy the intended usage. Among those properties are the following:

1. Waterproofing membrane should keep the water from penetrating the building

2. Durability: Roofing membrane should be durable to protect the roof as long as possible

3. High tensile strength

4. Flexibility: It should be flexible to expand and contract with the roof as it moves

5. Compatibility: It should be compatible with other roofing components

6. It should maintain certain dimensional stability [2]

7. Accept normal structural movement

8. Impermeability

9. Resistance to aging

10. Resistance to fatigue and tear

11. Resistance to impact and puncture and occasional foot traffic

12. Simplicity in installation

13. Resistance to ultra-violet radiation

14. Elasticity

15. Non-cracking

16. It should fill hairline cracks and form seamless layer with excellent bonding properties

Figure 19 shows a specimen under tensile strength test.
Figure 19: Tensile strength test.
3.2 COMPONENTS OF WATERPROOFING SYSTEM

We can say that the waterproofing system on the roof consists of 3 main components. Each component has a role to play in supporting the whole system. These components are: the primer (if applicable), the main waterproofing material and the flashing.

3.2.1 THE PRIMER

The primer is a liquid material that is poured on the roof before the main waterproofing material is installed. Its purpose is to suck up the dust and to help in improving the adhesion of the main waterproofing material to the roof deck and to fill the concrete pores.

Usually primer is applied after stirring in an average of 0.40 kg/m² [27] one day before the installation of the membrane. If a noticeable change of color has occurred after the primer has cured, an additional amount of primer should be added to the effected areas. The change of primer color is often attributed to: lack of thorough stirring before use; the surface to which it was applied is too porous; or the amount of primer at the effected location is too little. The primer must not be applied on wet surfaces; the surface should be left to dry completely for whatever time it takes up to one month. Rough roofs need more primer than smooth roofs. Each waterproofing material has its own primer
type. The manufacturer of the main waterproofing material must be consulted in order to get the proper primer.

The primer that is used for bitumen based waterproofing material is usually a bitumen, that is manufactured to comply with ASTM D-41, melted in a solution. This solution evaporates quickly after application.

For fully bonded membrane application, the primer should be applied under the fully bonded membrane; that is, the whole roof must be primed. In the case of loose laid roofing, it is applied only in the locations where the membrane will be welded to the concrete surface such as parapet, upstands, pipes and other critical locations. Primer can be applied by mop, brush or roller.

Some trade marks of primers available in the market are:

A. DERMA Primer

This is a bituminous liquid primer manufactured by Dermabit Waterproofing Industries Company Limited in Jubail. It is made from oxidized bitumen distilled out of light Arabian crude mixed with a solvent [47]. It seals porous surfaces and improves adhesion of bituminous membrane to the roof deck. It should be thoroughly stirred before use and applied by brush, roller or sprayed at a rate of 200 grams/m² - 300 grams/m² [47].

B. AWAZEL Primer

This is a cold applied bitumen which complies with ASTM D41. It improves the bond of bituminous materials to the substrate and binds any dust particles. It seals porous surfaces. This product should be stirred thoroughly before usage and then may be applied by brush, roller or spray [48]. It should be allowed to dry before torching commences.
C. Bituprime / Bitufast

These are cold applied bituminous roofing primers manufactured by Bitumat Company Limited in Dammam. Bituprime should be allowed to dry after application and before application of subsequent layers. Bitufast is an asphalt primer which is fast curing. They can be applied by brush, roller, squeegee or airless spray.

3.2.2 THE MAIN WATERPROOFING MATERIALS

There are many types of waterproofing materials. These types differ in their applications and components. The most common types are: polymer modified bitumen; hot bitumen; hot rubberized bitumen; elastomeric membranes- EPDM, butyl rubber and PVC [49]. The major types are the asphalt-based materials, liquid applied membranes and non-bituminous single-ply membranes.

Most roofing membranes contain three elements: waterproofing, reinforcement and surfacing [50]. The waterproofing includes bitumen and synthetic rubber or plastic. Reinforcement includes organic or glass fiber felts, polyester fabrics or high density polyethylene carrier. Reinforcement holds the waterproofing agent in place and provides tensile strength [50]. Surfacing materials such as aggregate or mineral granules and aluminum foil protect the membrane from sunlight and traffic [50].
3.2.2.1 Asphalt-Based Materials

When heated, asphalt becomes a liquid with good bonding properties. Therefore, it has been used as a waterproofing material for a long time. People of Mesopotamia used bitumen 5000 years ago as a waterproofing material [27].

The asphalt is produced from natural asphalt lakes, coal tar and crude oil distillation in refineries. The last is the main source of bitumen production. Actually now bitumen is obtained from crude oil in refineries by fractionated distillation in large columns in which the crude is heated until the lighter components vaporize and condense to form naphtha, kerosene and lubricating oils; bitumen remains as an end product at the bottom of the distillation column [51]. Asphalt consists mainly of carbon and hydrogen. Other chemical elements which are found in asphalt in a low scale are nitrogen, sulfur and oxygen.

Asphalt-based bitumen is the most common waterproofing material in Saudi Arabia; perhaps because the raw material is an oil refining by-product which is processed in the Eastern Province. At least, there are three large manufacturers of asphalt-based bitumen rolls in Saudi Arabia: namely Awazel, Dermabit and Bitumat. It can be applied both hot and cold.

Asphalt is considered to be one of the most important waterproofing material. However, there are some limitations to asphalt-based membranes which are: 1. It should not be worked on during wet weather conditions; 2. To prevent slipping and softening of the bitumen, the membrane should not be exposed to prolonged periods of sunlight before covering [43]; and 3. It should not be installed at low ambient temperature. Asphalt
cannot withstand very high and low temperatures. At high temperatures, asphalt becomes very soft while at low temperatures it becomes brittle which makes it vulnerable to breaking. To avoid these problems, oxidized and modified bitumen were invented.

3.2.2.1.1 Hot Bitumen (Asphalt)

In this system, hot bitumen is heated inside its drum or special boiler and when it becomes a liquid it is poured on the roof without any reinforcement.

Heating bitumen at high temperatures for long periods of time may reduce the softening point of asphalt and raise the softening point of coal-tar [17]. However, there is no damage to bitumen if heated at high temperatures for short periods of time. Actually, to achieve complete fusion and strong bonding of the plies, bitumen must be heated at high temperatures [17]. Bitumen should be applied at the equiviscous temperature (EVT) which is a temperature at which a viscosity of 125 centistokes is attained, plus or minus 25°F.

Bitumen leaving the refinery has a low temperature resistance. To increase the temperature resistance and to achieve the elasticity required for waterproofing materials, it is necessary to modify the bitumen either by oxidation or by mixing it with polymers [45].

3.2.2.1.1.1 Oxidized Bitumen Liquid

To oxidize bitumen, it is preheated and circulated through a furnace until it reaches 190/230 °C. The oxidation towers are filled to the desired level and air is fed in causing the reaction which allows the operating temperature of 230/300°C to be reached [45].
When the required characteristics are achieved, which is known by periodic testing of samples, the process is interrupted.

To use oxidized bitumen as the main waterproofing material, the proper primer should be applied to the roof. After the primer becomes dry, oxidized bitumen is heated to 200°C-210°C and then applied in two layers crossing each other on the roof approximately 1.5-2.0 kg/m² [27].

There are many types of oxidized bitumen classified according to their softening and penetrating points. For example, Asphalt 60/70, 80/25 and 115/15; the first number is the softening point while the second is the penetrating point which is the result of penetration test. The second number indicates the hardness of bitumen; the smaller the figure the harder the bitumen. The most suitable for roofing is asphalt 115/15 because its softening point is 115°C and its penetrating point is 15°C. This asphalt type is used with strengthening materials such as glass fiber, polyester and jute in making oxidized bitumen sheets. Oxidized bitumen has limited elasticity and being thermoplastic in nature, it becomes soft at elevated temperatures and brittle at low temperatures [49].

3.2.2.1.1.2 Modified Bitumen Liquid

In order to give asphalt better properties than those of oxidized bitumen, the idea of mixing bitumen with modifiers was conceived. That was in the early 1960s in Europe, particularly Italy. Thermoplastic or polymeric additives are added to the asphalt to alter its softening point and improve its cold temperature flexibility, elongation and other
properties. In the early 1960s, bitumen was modified with rubber which gives it a softening point of 120°C and an elasticity of more than 300% [49].

Bitumen is considered modified because of the elastomers and polymers mixed with the basic asphalt; the approach of modifying asphalt is a mechanical rather than chemical process, the finished material is a blend of ingredients, not a completely different compound [52].

3.2.2.1.2 Reinforced Bitumen Sheeting

To make bitumen stronger with a reasonable resistance to high and low temperatures, it is reinforced with a carrier which can be glass fiber, woven glass fiber or polyester. Polyester is considered to be better than other carriers. Glass fiber carrier is better if used in large areas because it has good dimensional stability. Bitumen sheets are produced by spreading the carrier on both sides with oxidized or modified bitumen. Therefore, reinforced bitumen is either oxidized or modified. Polyethylene sheet is usually attached on the bottom side of the sheet which will be adhered to the roof. These sheets are made in different thicknesses depending on the system and customer requirements. The common membrane thicknesses are 2 mm, 3 mm and 4 mm.

3.2.2.1.2.1 Reinforced Bitumen Sheeting Components

Reinforced bitumen sheeting has many components such as asphalt/modifier mixture, reinforcements, top surface and bottom surface. (See Figure 20)
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Figure 20: Reinforced bitumen sheets components[47]

3.2.2.1.2.1.1 Mixture of Asphalt and Modifiers

This is the waterproofing agent which is the most important element in the roofing membrane. The most common bitumen modifiers are air, atactic polypropylene (APP) and styrene butadiene styrene (SBS).

3.2.2.1.2.1.1 Air

Hot air is used to modify the properties of bitumen and the result is what is called oxidized bitumen.

3.2.2.1.2.1.2 APP Modifier

Atactic polypropylene is the most widely used modifier because it is an inexpensive by-product of making polypropylene [53].
3.2.2.1.2.1.1.3 *SBS Modifier*

Styrene butadiene styrene is a synthetic rubber which is used on a smaller scale than the previous modifier. SBS possesses elasticity greater than APP-modified products and it is more flexible at low temperatures.

3.2.2.1.2.1.2 Reinforcements

Reinforcements provide stability to the roof membrane. They hold the waterproofing agent in place and provide tensile strength to the membrane.

The two support materials most typically used are fiber-glass mat and polyester sheet [54]. Some membranes are being produced with both types of reinforcement. Each type of reinforcement contributes some unique properties to the overall performance characteristics of the membrane.

3.2.2.1.2.1.1 *Polyester Reinforcement*

Polyester gives the membrane a good mechanical performance and high ultimate elongation. It resists rotting and allows easy application. Polyester mats increase puncture and tear resistance and enhance the membrane’s ability to stretch and move with the roof.

3.2.2.1.2.1.2 *Glass Fiber*

Fiber glass is strong, inelastic and very lightweight. It will not distort dimensionally as does polyester. It will not, however, produce a fully elastic membrane [54]. Fiber glass
reinforcements offer high tensile strength which helps hold the membrane together when subjected to typical rooftop stresses.

3.2.2.1.2.1.3 Surfacing

Surfacing materials protect the waterproofing and reinforcement elements from weather exposure and provide other properties such as: fire resistance, traffic, reflectivity and hail protection [17].

3.2.2.1.2.1.3.1 Top Surface

The top surface of bitumen membrane can be covered in many ways. For a protected system, polyethylene film and fine sand are usually used. On the other hand, slate or granule, polyester foil or aluminum foil are used as a top cover for exposed systems. These top layers resist ultra-violet radiation and environmental effect.

3.2.2.1.2.1.3.2 Bottom Surface

The bottom surface of the membrane can be covered by polyethylene film or fine sand. For self-adhesive membrane, adhesive with release paper is utilized at the bottom of the membrane.

3.2.2.1.2.2 Reinforced Bitumen Sheeting Types

Among the many reinforced bitumen sheetings are commercial felts, oxidized bitumen and modified bitumen sheeting.
3.2.2.1.2.2.1 Commercial Felt Sheetings

These bitumen membranes have low quality carriers such as paper, jute or glass fiber. Oxidized bitumen is usually used with it. These are usually low quality membranes with low cost. These membranes are usually thin with 1 mm or 2 mm thickness.

Some of the currently available brands in the market are as follows:

A. AWAZELFELT

This is the felt for multi layer systems, such as built-up roofing, used with hot bitumen as bonding compound. It is manufactured by Arabian Waterproofing Industries “Awazel” in Riyadh. Awazelfelt is a group of oxidized bitumen roofing felts conforming to ASTM D226. The carriers can be 120 grams/m² non-woven polyester, 125 grams/m² polyester glass scrim, 300 grams/m² organic paper felts, 60 grams/m² glass fiber, 200 grams/m² jute fabric and glass fiber mat. Surfaces are finished with fine mineral and sand suitable for bonding in hot bitumen. Awazelfelt PY20N, SG20N, ASO, ASCO, AGM, Type IV and jute are all used in built-up roofing in 3 or more layers bonded in bitumen conforming to ASTM D312, ASTM D226 or ASTM D249 [48].

3.2.2.1.2.2 Oxidized Bitumen Sheetings

To give bitumen good characteristics, hot air (oxygen) is passed on the bitumen on special columns at specified temperatures. This operation makes bitumen more viscous and less permeable.
Oxidized bitumen membranes consist of many layers of oxidized bitumen and in the middle the carrier which is usually glass fiber mat, woven glass fabric, glass fiber or polymer film. Oxidized bitumen can be used as one or more layers or it can be used in making built-up roofing. Oxidized bitumen can withstand temperatures as high as 120°C.

Some of the available brands in the market are as follows:

A. **AWAZELBAHN**

This has oxidized bitumen coating for bonding with hot bitumen or gas torch. The carriers used in this product are glass fiber mat, woven glass fiber, polyester glass scrim or non-woven polyester. This group of oxidized bitumen membrane can be 3, 4, or 5 mm thick. It is supplied with both faces surfaced with polyethylene film for torch application. Awazelbahn includes different types of membranes with slightly different properties. These types include, PYN, GV, GG, SG, POLYFOL and MINERAL. These are manufactured by Arabian Waterproofing Industries “Awazel” in Riyadh, Saudi Arabia.

B. **Torchbond**

This is an oxidized bitumen waterproofing membrane manufactured by Bitumat Company Limited. The reinforcement is 60 grams/m² glass fiber mat. It is applied by torch welding, loose laid or fully bonded methods. Available thicknesses are 3, 4, or 5 mm.

C. **Polybond**

This is an oxidized bitumen waterproofing membrane manufactured by Bitumat Company Limited. The reinforcement is non-woven polyester. It is applied by gas torch or hot bitumen. Available thicknesses are 3, 4, or 5 mm.
3.2.2.1.2.2.3 Modified Bitumen Sheeting

Bitumen can be improved further and that is by mixing it with polymers and elastomers. This was made first in the mid 1960s in Italy.

Modified bitumen membranes consist of bitumen, modifiers such as Styrene Butadiene Styrene (SBS) and Atactic polypropylene (APP), reinforcement polymers such as fiber glass, woven/non-woven polyester and a combination of the two, occasionally fillers and sometimes factory-applied surfaces such as granules and aluminum foil. Stabilizers are added for ultra-violet protection. Additional chemicals are added to improve the strength, resistance to flow at high temperature, toughness and flexibility of bitumen. There are considerable differences among modified bitumen membranes. They vary in reinforcement, thickness, type and quality of asphalt, surface protection and in many different subtleties of formation [53].

Atactic Polypropylene (APP), which is a by-product of isoatactic polypropylene, and Styrene Butadiene Styrene (SBS) and polybutadiene are polymers or elastomeric resins which are commonly used as bitumen modifiers. The addition of modifiers increases the softening point of asphalt to higher temperature [42].

Asphalt and modifiers are mixed together in large tanks with mechanical mixers and powerful shakers and heated by heat exchanging coils and external jackets in which diathermic oil circulates [42]. Then the mixture is piped to a coating basin through which the carrier is impregnated with the mixture at a preset thickness to form a permanent bond between the carrier and the mixture [42].
Mixing operation makes bitumen more viscous than the oxidized type. In addition to elastomeric resins of APP and SBS, stabilizers and antioxidants are also added to the asphalt. This mixture gives the membrane an excellent resistance to atmospheric agents, to aging, shape stability at high temperatures, high adhesion strength and easy workability. The aim is increasing the softening point and decreasing the penetration point. Bitumen used in roofing should have a high softening point, specially in hot climate areas.

Modified bitumen membrane can be reinforced internally or externally or it can be made without reinforcement. Reinforcement materials are usually the following: polyester, fiberglass, combination of fiberglass and polyester or metal foil. Fiberglass gives stability to the membrane and prevents elongation and stretching because of its high tensile strength. Polyester is tough material and has superior puncture and tear resistance.

3.2.2.1.2.2.3.1 **APP Modified Bitumen Sheeting**

For APP modified membranes, the ingredients generally include copolymer or homopolymer APP, isostatic polypropylene (IPP), limestone filler and asphalt [54].

APP membranes have the ability to elongate and absorb stresses and do not oxidize as rapidly as SBS membranes [55]. They provide a strong adhesion and a less expensive solution to roofing applications [42]. APP is superior in resisting ultraviolet radiation. APP membranes tend to be better suited to warmer climates [54].

The carrier for these membranes can be polyester, glass fiber mat, polyester with glass fiber and glass fiber with plastic. Polyester carrier is considered to be the most suitable carrier for APP modified bitumen with a softening point as high as 155°C and a
penetrating point as low as 15. Polyester carrier gives APP membrane greater resistance to the roof expansion and contraction. The membrane can elongate to 40% of its original length. In APP membrane, the reinforcement is located in the top portion of the sheet because the lower portion of the sheet will be melted to the substrate.

APP-modified membranes can be torch applied but are usually not compatible with mop application [54].

3.2.2.1.2.2.3.2 SBS Modified Bitumen Sheeting

Styrene Butadiene Styrene (SBS) modified membranes generally consist of one of the many specific types of SBS available, limestone filler and asphalt [54]. These sheets consist of a number of thin layers with glass fiber carrier in the middle. The reinforcement in the middle or lower portion of the sheet is added to accommodate the weatherproofing and aging on the top [55]. The top surface is covered with polypropylene or aluminum or granules while the bottom surface is covered with silicon paper which is easily taken out at the time of installation. The softening point of SBS sheets can go as high as 120°C and as low as 30°C. SBS membranes are suitable for either torch or mop application.

SBS membranes have better tolerance than APPs with respect to cold weather. They tend to be better suited to cold climate. Generally, they are more elastic than APP. Therefore, SBS is more appropriate in locations where expansion and contraction is a major consideration.

SBS membranes are not resistant to UV light, and therefore, they require a top coating of granules or other UV-resistant material [54]. This type of membrane is usually
covered because they cannot withstand the ultraviolet radiation. However, with good quality SBS and an experienced contractor's installation and good detailing, there is evidence that SBS can be exposed. In Riyadh Palace Hotel, SBS was exposed for 14 years with only hairline cracks. It lost part of its elastic properties obviously due to aging [56].

3.2.2.1.2.2.3.3 Ethylene-Copolymerized Bitumen (ECB)

This is a 50/50 blend of a copolymer of ethylene and butyl-acrylate and bitumen [57].

3.2.2.1.2.2.3.4 Some Modified Bitumen Sheeting Brands

There are many brands available in the market such as the following:

A. ASPHALTOPLAST

This bituminous waterproofing and damp-proofing membrane is manufactured by DWI Dermabit Waterproofing Industries Company Ltd. in Jubail, Saudi Arabia. It is a torch applied membrane manufactured with one of two types of reinforcements: 60 g/m² fiberglass fleece or 180 g/m² non-woven polyester mat. It is supplied in rolls 1x10 meters with the two surfaces covered with thin polyethylene film.

B. POLYFLAME

This is an APP modified bitumen torchable membrane manufactured by Bitumat Company Ltd. Dammam, Saudi Arabia. It is prefabricated with multilayered design consisting of spun bond polyester coated on both sides with modified bitumen. The bitumen is modified with polypropylene thermoplastic polymer. The reinforcement is 200
grams/m² non-woven polyester fabric. It comes in 10-meter long rolls with 1-meter wide and 3,4 and 5 mm thick. It is finished with slate granule surfacing when used exposed. Granule color is black but other colors can be worked out (red, green and gray) with talc surfacing for covered roof and granule surfacing for exposed roof. Polyflame is installed by torch welding method, loose-laid or fully bonded to substrate. It can be used as a single layer roofing system.

C. ECOGUM

Ecogum roofing and waterproofing membranes are manufactured with either fiberglass or non-woven polyester reinforcements that are impregnated and coated with a mixture of polymer modified bitumen [58]. It comes in rolls with a size of 1 X 10 m. To be applied, the roof should be mopped with primer first and the primer should be left to dry for one day. Then the membrane is unrolled while heating the lower surface with propane gas torch causing surface melting and adhesion to primed roof. Another way of application is by pouring hot primer at 232°C to the roof and unrolling the membrane on hot primer. Ecogum membranes can be applied mechanically by nailing the membrane to the deck. Ecogum is manufactured by Dermabit Waterproofing Industries Company Limited in Jubail, Saudi Arabia. Ecogum has a range of products; Fiberglass type has EG 1.5 F, EG 2 F, EG 3 F, EG 4 F; Polyester types are: EG 3 P and EG 4 P.

D. TORCHSEAL

This is a resin modified bitumen torchable membrane manufactured by Bitumat Company Ltd., Saudi Arabia. The reinforcement is non-woven polyester. The finish is
either polyethylene foil or granule for exposed application. Available thicknesses are 3, 4, or 5 mm.

E. AWAZELAST

This is a polymer modified APP plastomeric bitumen membrane with a thickness of 3, 4, or 5 mm. It is a soft product with carrier of glass fiber, woven glass fiber fabric, polyester and polyester glass. The membrane is surfaced with mineral for exposed roof or polyethylene film on both sides for torch application. Used in two layers; however, they can be used as a single layer in inverted roofs. AWAZELAST group of membranes includes many types such as: PYE, Desert Shield, PYL, GGE, GVE and SGE. The designation PY indicates a non-woven polyester carrier. These membranes differs in their reinforcement and slightly in properties.

F. Dermabit 4250

This is a high performance APP modified bituminous waterproofing membrane modified with plastomers and reinforced with heavy duty non-woven continuous thread polyester fabric core [47]. The membrane is finished with fine sand on the top surface and a burn off polyethylene film on the bottom surface or polyethylene on both sides. This membrane is best applied by heat bonding using propane gas torch. It may be loose laid, spot bonded or fully bonded.

G. Dermabit 4200

This is an APP modified bituminous waterproofing membrane reinforced with a core of polyester fabric, 200 grams/m² woven/non-woven with continuous thread which gives the
membrane excellent mechanical properties. During manufacture, the core is impregnated with the coating mixture.

H. DERMABIT FIBREPOL

This is an APP modified bituminous waterproofing membrane with double reinforcement. The reinforcements are 200 grams/m² woven/non-woven polyester carrier and 60 grams/m² fiber glass mat. Polyester carrier absorbs all abnormal stresses transferred by the structure to the membrane. The fiber glass mat is situated just below the top surface to give stability and aging resistance to the membrane.

I. ELASPHALT 3170, 4170, 5170

These are SBS modified bituminous roofing and waterproofing membranes reinforced with a 180 grams/m² of non-woven polyester that gives them dimensional stability and resistance to puncture. The surface finish can be sand, polyethylene film or slated. The first number in the designation indicates the thickness of the membrane in mm. They are manufactured by Dermabit Waterproofing Industries in Jubail.

J. ELASPHALT 2050, 3050, 4050

These are SBS modified bituminous roofing and waterproofing membranes reinforced with a 60 grams/m² of fiber glass that gives them dimensional stability and resistance to puncture. The surface finish can be sand, polyethylene film or slated. The first number in the designation indicates the thickness of the membrane in mm. They are manufactured by Dermabit Waterproofing Industries in Jubail.
K.  GLASFLAME

This is an APP modified bitumen membrane manufactured by Bitumat Company Limited. The mixture consists of a blend of polypropylene thermoplastic polymers and distilled bitumen. The reinforcement is 60 grams/m² glass fiber mat. The finishes are talc, slate granule or aluminum foil. Available thicknesses are 3, 4, or 5 mm. It is installed by torch welding, loose laid or fully bonded to substrate.

L.  FIBERLON

This is an APP modified bitumen membrane manufactured by Bitumat Company Limited. The carrier is 180 grams/m² non-woven polyester core. The finish is black with a very thin polyethylene foil on both sides. Available thicknesses are 3, 4, or 5 mm.

M.  DERMABIT 2050, 3050, 4050

This roofing membrane is modified with thermoplastic resins, stabilizers and antioxidants. It is reinforced with a core of fiberglass fleece. The 2050 is 2 mm in thickness while 3050 is 3 mm and 4050 is 4 mm.

N.  Polyflex

This is an APP modified waterproofing membrane manufactured by Bitumat Company Limited, Dammam, Saudi Arabia. It is reinforced with 180 grams/m² non-woven polyester. Available thicknesses are 3, 4, or 5 mm. Finishes are black with talc for covered application or granule finish for exposed application.
3.2.2.1.3 Bitumen Emulsion

This rubberized cold applied waterproofing membrane can be applied with brush, roller, spray, etc. It is usually used as primer or as top coat for bitumen roofing such as a protection coating for built-up roofs and other exposed surfaces. Its standard spec. is ASTM D1227. ASTM D1227 classifies bitumen emulsion into four types: emulsified asphalt prepared with mineral collide emulsifying agents, emulsified asphalt prepared with mineral collide emulsifying agents containing asbestos fibers, emulsified asphalt prepared with mineral collide emulsifying agents containing fibers other than asbestos, chemical emulsifying agents and mineral fillers and emulsified asphalt prepared without fibrous reinforcement.

3.2.2.1.3.1 Glass Fiber Reinforced Asphalt Emulsion

Glass Fiber Reinforced Asphalt Emulsion is composed of two or more layers of coated ply felts over which a heavy application of asphalt emulsion with glass fiber reinforcement is applied by spray [17].

There are many brands available in the market such as the following:

A. Everflex

This is a cold applied single component elastomeric waterproofing membrane which is manufactured by Soil Stabilization Materials Factory (Sandfix) in Jubail, Saudi Arabia. It is applied at the rate of 1 m² per liter to give dry film thickness of 650 microns.
B. BCI-ADMIX BE / BCI-RBE

This is a bituminous anionic solution formulated from selected bitumen to produce a stable, ready to use cold applied emulsion. BCI-RBE has 10% added rubber latex. BCI bitumen emulsion should not be left exposed. It should always be covered. It is manufactured by Basic Chemical Industries (BCI) and distributed by Chemical Marketing and Distribution Company Ltd. (CMDC) in Dammam’s first industrial city.

C. CICO Proof RP

This is a rubberized bitumen emulsion for cold application. It is made in Jeddah, Saudi Arabia, by Commercial Investment Corporation C.I.C. It is applied in two coats. The first coat can be diluted with 50% of clean water and the second coat is full strength. After its application, it dries to a tough flexible black membrane with a minimum thickness of 1 mm.

3.2.2.2 Solution Based Liquid Applied Waterproofing Membranes

The second major type of waterproofing materials is the liquid-applied type. Liquid application means no joints in the membrane. Liquid applied waterproofing membranes are applied as fully adhered membrane systems. They are either single or two-component materials. They solidify by either evaporation of the solvent or chemical curing. They are classed as either low or high solids [39]. A low solid fluid contains a high proportion of solvent required to deposit the solid lifting the membrane material after the solvent evaporates [39]. Most liquid applied materials are combined with plasticizers, stabilizers and pigments.
Liquid applied systems have the advantage of conformity to irregular roof surfaces, ease of application and continuity of the membrane without seams.

These materials are applied cold. They can be applied by using trowel, brush, roller, squeegee or spray gun. There should always be a first coat that is used as a primer. This coat should have a very low density so that entrapped air can escape. There are two major base materials for this kind; polyurethane and acrylic.

3.2.2.2.1 Polyurethane-Based

Polyurethane is considered one of the best waterproofing materials. It is expensive and usually not exposed. However, it can be exposed if desired as can be seen in Figure 21.

Figure 21: A roof covered by liquid-applied polyurethane.
Some available brands in the market are as follows:

A. **TREMPROOF**

This is a one-part elastomeric tar modified polyurethane waterproofing membrane. It is applied by roller, trowel, squeegee or spray to the substrate. It should be applied continuously and finished with a wet film thickness of 1.5 mm. It should be left to dry 48 hours before water or flood test is conducted. This product is manufactured by Tretol Ltd. U.K.

B. **SPECTACOAT**

This is a single pack polyurethane resin compound pigmented in a selected color (black, gray or cream). It is manufactured by Spectrum Chemical Limited U.K. It can be applied by brushing, rolling or spraying. Two coats are recommended. The first coat is to be applied in straight up and down strokes. The second coat of Spectracoat should be applied at right angles to the first coat.

C. **BLACK PU**

This is a one component liquid cold-applied membrane based on modified polyurethane resin. It is available in three colors: black, white and aluminum. It reacts with moisture in the atmosphere and forms an impervious rubberized membrane that resists water. This product was used in King Fahd International Airport here in the Eastern Province and supplied by Tasqeef.
D. CICO COAT PROOF 200

This is 100% solid polyurethane waterproofing system which is manufactured by Commercial Investment Corporation C.I.C in Jeddah, Saudi Arabia. It is a one component moisture curing elastomer.

E. ROOFTEX

This is a polyurethane based membrane for roofing. It has a black color and can be applied by brush, roller, rubberized squeegee or airless spray. It cures within 24 hours to a tough rubber-like finish. After the preparation of the roof, all critical locations such as right angles should be prestriped with initial coating of Rooftex 1 kg/m². Then the roof should be thoroughly inspected for any visible cracks which should be prestriped with a coat of Rooftex. Thereafter, the first main coat of Rooftex is applied at a minimum of 0.5 kg/m² application rate. After allowing overnight curing, the final coat is applied at 1 kg/m². After one week curing, thermal insulation boards and gravel should be laid to cover the Rooftex. Rooftex is manufactured by Conren-Floorlife Ltd. U.K.

F. VULKEM Products [59]

Mameco International Inc. of Cleveland, Ohio, makes lots of waterproofing products. Many of them are VULKEM products, distributed in Saudi Arabia by Al-Nafea Trading Establishment.

VULKEM 201&222 are a bitumen modified polyurethane membranes. VULKEM 201 is a one-component moisture curing elastomer while VULKEM 222 is a two-component chemically curing elastomer. They can be applied by roller, trowel, spray or squeegee. This product has a black color and should be covered; it should not be used as
an exposed surface. VULKEM is manufactured by Mameco Industrial Inc. in Cleveland, Ohio.

107 is a fluid-applied elastomeric polyurethane membrane which is coal-tar free. It is a one component moisture curing elastomer. It is applied by a roller, trowel, squeegee or spray and cure to form a black continuous seamless membrane. It should not be left exposed.

VULKEM 350/351 is a liquid polyurethane which is usually exposed. VULKEM 351 finish is applied after 350 base has cured.

VULKEM 450/451: VULKEM 450 is a one part liquid polyurethane which reacts with atmosphere moisture to form an elastomeric waterproofing membrane. VULKEM 451 is a one part aliphatic urethane coating which resists ultra-violet radiation.

VULKEM 797 is a polyurethane coating system designed specifically for application over sprayed-in-place polyurethane foam insulation. It is a one-part, one-coat fast curing polyurethane coating.

H. NITOPROOF 600

This is manufactured in Saudi Arabia by Fosam Company Ltd. This is a single component pitch modified polyurethane which cures by reaction with atmospheric moisture to give a tough elastomeric waterproofing membrane [60]. Since Nitoproof 600 is a polyurethane based waterproofing material, it must be covered against ultra-violet radiation.
Chapter 3; Waterproofing

I. CEMTEC BLACK PU

This is a one-component, liquid cold applied waterproofing membrane based on modified polyurethane resin. It is manufactured in Saudi Arabia by Construction Materials Industries Company (CMCI). It reacts with moisture in the atmosphere and forms an impervious rubberized membrane that resists water, oil and other air pollutants [61].

J. BCI-WPM

BCI waterproofing membrane is a single component liquid cold applied membrane made of polyurethane resin. It reacts with moisture in the atmosphere and forms an impervious rubberized membrane. It is manufactured by Basic Chemical Industries (BCI) and distributed by Chemical Marketing and Distribution Company Ltd. (CMDC) in Dammam’s first industrial city.

K. ELASTO-DECK 5001 / Liquid P.U.

These two products are liquid applied, single component, moisture cured polyurethane elastomers manufactured by Construction Materials Chemical Industries (CMCI) in Dammam. They are used as a covering over spray applied polyurethane foam insulation roofing. Available colors are gray, tan, beige, white and black. A membrane thickness of 1 mm results from the application of one liter per square meter. Technical specifications for these two products differ.

L. DELTA 851

This is a coke tar polyurethane. The membrane results from the reaction of two components. It is applied as a cold liquid with a roller, brush, squeegee or spray with one or two coats.
3.2.2.2 Acrylic-Based

Acrylic-based is usually white in color. It is like white paint. Most paint manufacturers make acrylic-based waterproofing material. It is normally exposed. If this type of waterproofing material is used, fiber reinforcement is recommended.

Some available brands in the market are as follows:

A. SHERWIN WILLIAMS

This is an elastomeric white acrylic polymer coating for protection of roofs. It has a water based binder. This product is ready to apply by brush or airless spray. The minimum coating thickness should be 0.75 mm. Recoating can be done after 24 hours but no more than three days should elapse between the application of successive coats.

B. BRUSH BOND

This is a two component acrylic polymer modified cementatous coating of concrete surfaces, manufactured by Fosam Company Limited. It is supplied in ready mix kits requiring the addition of water and mixing on site. It consists of special cement, graded aggregates and additives supplied in powder form together with a liquid component of blended acrylic copolymers and wetting agents. Brush Bond liquid concentrate is poured from the plastic container into the supplied metal drum. An equal volume (4 liters) of clean water is added and the mixture should be mixed. The powder should be added gradually to the liquid. It can be applied by a stiff brush, roller, spray or trowel. The number of coats depends on the traffic on the roof. Each coat has a thickness of 1 mm. Up to 4 coats can be used...
C. MANGUM

This is an elastomeric acrylic resin material made in Italy and distributed by Mustafa Al-Atrash Establishment in Dammam. The primer coat should be diluted with 50% of clean water. For the following coats, the product is used in its original density. At least 2 kg/m² of Masgum is required. Masgum can be reinforced between coats with non-woven fabric, fiberglass etc. The finished color is white.

D. ROOFGUARD

Roofguard is a one component, liquid, cold applied waterproofing membrane based on plasticized modified acrylic resin. It is manufactured in Saudi Arabia by Construction Materials Chemical Industries (CMCI) in Dammam. It is applied as a full coat by roller. Then, glass fiber matting is laid onto the first coat while still wet. Then another coat of roofguard is applied after the first coat is fully dry. It cures on exposure to atmosphere.

E. DIATHON

Diathon is an acrylic-based material that is used by Al-Babtain establishment to cover their thermal insulation material which is sprayed polyurethane. Diathon is sprayed over the polyurethane foam and left exposed.

F. ROOFCRYL

Roofcryl is an acrylic membrane which is a water-tight highly elastic material. It is manufactured by Akazo Coatings NV in Belgium.
G. ROOFMATE

Roofmate is a chemically modified acrylic base coating without plasticizer manufactured by Construction Materials Chemical Industries (CMCI) in Dammam. It is applied by roller or brush with two coats. It resists ultraviolet degradation.

H. ROOFCOTE

This is a cold applied liquid, single component designed from 100% acrylic polymer resin emulsion. It can be applied by brush, roller, trowel or squeegee. It is applied in two coats with a rate of 1 liter/m² to give a dry film thickness of 650 microns. It is manufactured by BCI and distributed by CMDC in Dammam.

I. Binachem LA-2000

This is a cold applied elastomeric waterproofing membrane designed from 100% acrylic polymer resin emulsion [62]. Approximately 1 liter is needed for each 1 m² to give a dry film thickness of 500 micron. Its elongation is 250%. It complies with ASTM C-836. It is manufactured by Binachem Construction Chemicals.

J. Maxelastic

This is an elastic acrylic coating manufactured by Drizoro Waterproofing, a Spanish Company. It comes in the form of a thixotropic paste ready for use [63]. It provides a coat of 1 mm thickness if 1.5 kg is applied for each 1 m².

K. DK-CRYL

This is a plastic roof coating material which has been made from synthetic polymer and additives to improve workability and strength. It is manufactured by Building Chemical Industry Co. Ltd. (BCIC) in Dammam.
L. Synroof / Synroof Hi-build

Synroof is an elastomeric single pack roofing compound, based on special acrylic polymers [40]. When applied it forms a seamless, joint free watertight plastic membrane. It is manufactured by Bitumat Chemicals in Dammam, Saudi Arabia. The first coat should be diluted with 20% of water and it is considered the primer which should be allowed to dry before the application of the second coat.

M. Duracoat

This is an acrylic based material which is used as a protective coating for polyurethane foam insulation. It can also be used with other types of roofs. It is manufactured by Bitumat Chemicals in Dammam, Saudi Arabia.

N. Synplast

This is an elastomeric waterproofing coating for most types of roofs. It is manufactured by Bitumat Chemicals in Dammam, Saudi Arabia.

O. Syncoat

Syncoat is a synthetic elastomeric waterproofing coating which provides a tough flexible membrane. It is suitable for application to most types of roofs. It is manufactured by Bitumat Chemicals in Dammam, Saudi Arabia.

3.2.2.3 Epoxy Resin

Epoxy resin is not very commonly used in roofing. However, it has been used on a very small scale as can be seen in Figure 22.
Figure 22: A roof coated with epoxy resin.

Very few epoxy resins brands are suitable for roofing, such as:

A. WETCOTE

Wet coat is a general purpose 2 pack epoxy resin based membrane. It is manufactured by Sealcrete Products Ltd., England.
3.2.2.4 Elastomer-Based

Elastomer-based materials can be applied as a liquid. These materials include Neoprene and Chlorosulphonated Polyethylene. Their standard specification is ASTM D3468. Ready made elastomers-based membranes are discussed in the next section.

3.2.2.3 Single-Ply Membrane (Non Bituminous)

Non-bituminous single-ply membranes have gained acceptance in the past few decades. Single-ply membranes have many advantages and that is why they are gaining acceptance and replacing the traditional built-up roofing systems. Among these advantages are: low weight, high elasticity, high reflectivity, resistance to roof traffic and ease of roofing unusual contours [64]. However, they also have specific problems such as loss of integrity of adhesive bonded seams, and repair and patching of materials whose surfaces may be significantly altered by aging [64].

There are four areas that contribute to their performance: compounding, mixing, shaping and curing. Compounding begins with selection of the base polymer or blends of polymers whose known inherent properties will approach the required design performance [3].

Non-bituminous single-ply membranes can be divided into two groups, elastomeric and thermoplastic materials.
3.2.2.3.1 Elastomeric Materials

An elastomer is a macromolecular material that returns rapidly to its approximate initial dimensions and shape after substantial deformation by a weak stress and subsequent release of that stress [65]. Elastomeric single-ply membranes can be divided into vulcanized and nonvulcanized elastomers.

3.2.2.3.1.1 Vulcanized (Cured) Elastomers (Thermosets)

Vulcanization is a chemical reaction of sulfur (or other vulcanizing agent) with rubber or plastic to cause cross-linking of the polymer chains; it increases strength and resiliency of the polymer [18].

To improve their physical properties and thermal stability, vulcanized elastomers, also known as thermosets, experience chemical cross-linking of the polymers during the manufacturing process [55]. After that curing process takes place it cannot be changed.

A vulcanized elastomer can only be bonded to itself with the use of adhesives. They cannot be seamed on site by hot air or solvent welding methods [28]. The joints can be made by contact adhesives, hot melt adhesives and tacky tapes techniques.

Thermoset membranes are made from polymeric composition which include EPDM and neoprene. A standard specification for these materials is ASTM D4637.

3.2.2.3.1.1.1 Ethylene Propylene Diene Monomer (EPDM)

EPDM is an elastomeric single-ply roofing membrane which originated and has been used in the United States of America since the 1960s. The first membranes were
manufactured in the mid-sixties from formulations of EPDM polymer, carbon black, processing oils, processing aids and curing agents [41].

EPDM is a synthetic compound produced from ethylene, propylene and a small quantity of diene monomer. It is elastomerized by using vulcanized materials or Chloro Sulphonated Polyethylene such as Hypalon. EPDM sheets are usually black and white in color.

EPDM is considered to be an excellent roofing material with a good long term performance. In some formulations, EPDM remains flexible between -75°F and 300°F [39]. However, EPDM is a rubber material that is susceptible to weather and heat degradation until carbon black is added [55]. Once carbon black is added, it can resist ultra-violet so usually it is used as an exposed system.

EPDM can be either reinforced or non-reinforced. It is installed in many ways: it can be fully adhered, loose laid or mechanically anchored.

Advantages of EPDM

1. It can be manufactured in very large sheets (50 X 100 ft).
2. Roofs can be installed quickly with few seams.
3. It possesses outstanding resistance to heat and moisture.

Disadvantages of EPDM

1. Not flame resistant.
2. Poor chemical resistance.
3. Absorbs large quantity of oil.
4. Loose stability over time.
The following are some EPDM brand names.

A. FIRESTONE RUBBER GARD

This is a cured single-ply synthetic roofing membrane made of ethylene, diene, terpolymer. It has a thickness of 1.15 mm. It elongates in excess of 400% which easily accounts for building movements. It can withstand UV; therefore, it can be exposed to direct sunlight. There are four Firestone EPDM systems which are:

1. Fully Adhered: This is a light weight system with design flexibility. It is used for irregular roof shapes and any roof with limited load-bearing ability. Thermal insulation boards are laid on the substrate, then bonding adhesive. After that EPDM membrane is laid with splice adhesive and lap sealant at any overlapping work.

2. Loose-Laid Ballasted EPDM: In this system, gravel ballast is used to hold the membrane; therefore, no bonding adhesive is used. EPDM sheets are also loose laid over the substrate. Splice adhesive and lap sealant are used only at the overlapping locations. A minimum of 50 kg/m² of ballast is laid over the protection mat.

3. Mechanically Anchored EPDM Sheet Roofing System: This system is designed for roofs that cannot carry the additional load of ballasted system. EPDM is anchored by battens that are installed in the seams of the adjoining sheets. Adjoining EPDM sheets are overlapped 180 mm to cover the batten strip and spliced with adhesive to form a continuous watertight membrane.

4. Protected Membrane Roofing System: In this system the membrane is laid directly on the substrate and the thermal insulation boards are placed over the membrane.
A protection layer from a loose fabric is laid over the insulation and a minimum of 50 kg/m² of ballast is laid over the protection mat.

B. Sure-Seal EPDM

Sure-Seal EPDM membrane was first produced by Carlisle SynTec Systems in the mid-1960's and it is still being produced and used. It resists long term exposure to UV. It also resists hot and cold temperature with a good temperature range between 85°C and -30°C. It can be supplied reinforced or without reinforcement. It can be installed mechanically, fully bonded with adhesive or loose laid. Its standard thickness is 1.14 mm or 1.52 mm.

C. HyChoice

HyChoice is another roofing system that is made by Carlisle SynTec Systems which can be fully adhered to the roof or mechanically fastened. It is a 0.45 inch thick scrim reinforced with Chlorosulphonated polyethylene (CSPE). The membrane cures by exposure to moisture and sunlight.

D. Hertalan EPDM Sheeting

Hertalan is a synthetic rubber sheeting manufactured by Hertel bv-Kampen of the Netherlands from EPDM rubber compound. This product is fully resistant against atmospheric exposure under all climatic conditions.

3.2.2.3.1.1.2 Neoprene

Neoprene, or chloroprene rubber (CR), consists of rubber, oil, and carbon black [55]. It is the oldest general purpose synthetic rubber. Neoprene roof sheets are usually 30
to 120 mils thick. The membranes can be made plain without reinforcement or with
reinforcing fabric. Neoprene is not commonly used for residential buildings in Saudi
Arabia.

Advantages of Neoprene
1. Flame resistant.
2. Good weatherability.
3. Good resistance to heat, oil and solvents.
4. Good chemical resistance because of the chlorine in the polymer.

3.2.2.3.1.2 Nonvulcanized (Noncured) Elastomers

These elastomers are not physically cured during manufacturing; they may cure
naturally by exposure over some period of time where they become thermosets [55].
Therefore, time and exposure cause the membrane to cure to some extent and become
more resilient. Included in this category of roofing membranes are CPE, CSPE or
Hypalon, PIB, and NBP. The chlorine improves flame, chemical and oil resistance.
Standard specifications for these materials are ASTM D5019 and ASTM D4811.

3.2.2.3.1.2.1 Chlorinated Polyethylene (CPE)

CPE membrane can be reinforced or non-reinforced. Its range of thickness is
between 40 to 48 mils. It is flexible and does not require the addition of plasticizers.

Advantages of CPE
1. Flame and chemical resistant.
2. Good weatherability and ozone resistance.


3.2.2.3.1.2.2 Chlorosulphonated Polyethylene (CSPE)

This is a self-curing nonvulcanized membrane which can be reinforced with polyester. Finished thickness may be 30 to 60 mils. During roof exposure, curing or cross-linking occurs. "Cross linking may also occur spontaneously from heat, moisture and light if the sheet is left out in the sunlight. Cross linking can be a problem because the chemistry can interface with field seaming. If the membrane cross links before the heat welding takes place, the material will cure before the seam bond" [55]. CSPE conforms to ASTM D1418.

Advantages of CSPE

1. Exhibits strong resistance to weather and chemicals.

2. Inherently ozone resistant.

3. Good adaptability to a variety of roof shapes and substrates.

Some available brands are:

A. Hi-Tuff

This is a fully-encapsulated, scrim reinforced roofing membrane made from Hypalon, Du Pont's Chlorosulphonated polyethylene (CSPE) heat-weldable synthetic rubber. Hi-Tuff is manufactured by J. P. Stevens Elastomeric Corp. of Northampton, Massachusetts. It is hot air welded with semiautomatic equipment that can produce
permanently fused, watertight seams as strong as the membrane itself [66]. Hi-Tuff is reinforced by polyester scrim for strength, durability and dimensional stability.

B. Hypalon

Hypalon is the Du Pont registered trade name for chlorosulphonated polyethylene (CSPE) which is a synthetic rubber resistant to ozone and ultra-violet attack [28]. It was introduced by Du Pont in 1951. The polymer is manufactured by Du Pont in the USA and UK.

C. Hylam Reinforced

This is a Hypalon roofing manufactured by Dunstable Rubber Company Ltd. “drc” of Dunstable, UK. Rolls are welded together by heat or solvent depending on climatic conditions. Polyester scrim reinforcement is laminated between two plies of Hypalon synthetic rubber. Roll lengths are available up to 30 meters with roll width of 1 meter. Thicknesses are between 0.75 mm and 1.50 mm. Reinforced membranes are used for mechanically fixed and for loose laid ballasted installations [28].

C. Hylam Hypalon/roofin, Laminate

This is a Hypalon roofing manufactured by Dunstable Rubber Company Ltd. “drc” of Dunstable, UK. Hypalon laminate consists of Hypalon laminated to latex-bound mineral fiber backing [28]. The laminate is primarily used for fully adhered applications. It is distributed in Saudi Arabia by Roofing and Insulation Company Limited (TASQEEF) in Al-Khobar.
3.2.2.3.1.2.3 Polyisobutylene (PIB)

This is made of isobutylene and other polymers. It exhibits good resistance to weathering, ultraviolet light and radiant heat [55]. Usually, PIB membranes are laminated to a non-woven synthetic fleece.

3.2.2.3.1.2.4 Nitrile Alloy (NBP)

NBP membranes are compounded from butadiene-acrylonitrile copolymers with other proprietary ingredients [55]. Typically, they are reinforced with polyester and range in thickness between 30 and 45 mils.

Advantages of NBP

1. Exhibits excellent tear and puncture resistance.
2. Good weatherability.
3. Good flexibility at low temperatures.
4. Low water vapor permeability.
5. Good resistance to chemicals.

Disadvantage

- Sensitive to aromatic hydrocarbons.

3.2.2.3.2 Thermoplastic Materials

Thermoplastic is a material with a linear macromolecular structure that will repeatedly soften when heated and harden when cooled. There is no cross-linking or vulcanization in this kind of material as compared to thermosets. They are welded together
with heat or solvent resulting in a very strong bond. Generally, they are reinforced. A major advantage of thermoplastic materials is their ability to be seamed readily on site using hot air or solvent welding techniques. Thermoplastic formulations include PVC and EIP.

3.2.2.3.2.1. Polyvinyl Chloride (PVC)

PVC polymers were originally produced in Germany in the early 1960s. Membranes of this type of material are produced by the polymerization of vinyl chloride monomer, a gaseous substance resulting from the reaction of ethylene with oxygen and hydrochloric acid [17].

Polyvinyl chloride (PVC) resin is a plastomeric single play roofing membrane. It is considered to be a good roofing membrane. The PVC resin requires the addition of other compounds such as plasticizers and stabilizers to produce the desired physical properties. PVC sheet membranes may become embrittled and shrink from loss of plasticizer; it is plasticizer that makes PVC softer, more flexible, more extensible and tougher [39]. They can be reinforced with glass fiber or polyester or they can be made without reinforcement. The unreinforced PVC may face shattering, i.e. embrittlement resulting in cracks due to stress. Standard specifications for PVC sheet roofing are ASTM D4434, D5019 and D5036.

To formulate the PVC lap joints, chemicals or heat might be used. PVC membrane thickness ranges between 40 and 48 mils. Usually, PVC is installed loose laid. However, it can be installed fully adhered to the substrate by using bonding adhesive.
Advantages of PVC

1. Resistant to bacterial growth.
2. Resistant to extreme weather conditions.
3. Resistant to fire.
4. Seaming capability.

Disadvantage

- Chemically incompatible with bituminous membranes.

Some available brands in the market are as follows:

A. INSUWRAP Products

In Saudi Arabia, the only manufacturer that produces PVC single ply membranes is Insulation and Wrapping Products Company Limited “Insuwrap”, in Riyadh. This manufacturer gets its raw materials from SABIC. It manufactures many PVC roofing membranes.

*Insuwrap Type WP* is a roofing membrane that is used where gravel is used as the loading layer. This membrane is not UV stabilized; therefore, it needs to be covered. The joints are welded by solvents and hot air. It is not compatible with bitumen.

*Insuwrap Type WMR-UV* is a roofing membrane that is UV stabilized; therefore, it can be left exposed. The joints are welded by solvents and hot air. It is not compatible with bitumen.

B. SARNAFIL

This is a PVC single-ply roofing membrane produced by Sarna Polymer Inc. of Switzerland and marketed in Saudi Arabia by E. A. Al-Juffali and Brothers. Its chemical
composition and production process has been designed for flat roofs. Sarnafil is UV resistant and can be applied on the roof top completely exposed [67].

Sarnafil roofing is manufactured without stress by a unique coating process. Sarnafil G uses a non-woven glass fiber base to eliminate shrinkage. A flexible PVC coating is fused on both sides. Sarnafil S uses a robust polyester base designed for exposed mechanically fastened installation. Sarnafil has an ultimate elongation of 250% to accommodate most structural movements. Sarnafil has been around for more than 20 years which makes it an internationally recognized roofing membrane.

C. TROCAL

This is a plasticized PVC sheet manufactured by Dynamit Noble of UK, which has been in use for about 30 years in UK. The material has the ability to accept over 300 percent extension before rupture.

3.2.2.3.2.2 Ethylene Interpolymer (EIP)

This is a thermoplastic compound consisting of ethylene interpolymer, stabilizers, pigments and antioxidants [55]. EIP membranes are usually 32 mils thick and reinforced with polyester fabric.

Advantages of EIP

1. Good resistance to fire, chemicals and oil.

2. High tear strength.
3.2.3 Other Waterproofing System Components

In addition to the primer and the main waterproofing material, the roof waterproofing system needs other components to work properly. Among these components are: cant strip, flashing and accessories. These components were discussed in chapter 2.
3.3 STORAGÉ & HANDLING OF WATERPROOFING MATERIALS

3.3.1 STORAGE

Waterproofing materials should be stored in a covered area, not necessarily ventilated or air conditioned. At the work site and in temporary storage, care must be taken to protect the waterproofing materials against sunlight and ultra-violet radiation [42]. They should be stored in a vertical position on a sufficiently smooth floor so that the lower edge won’t be damaged.

3.3.2 HANDLING

Membranes should be shipped on pallets and shrink-wrapped in heavy duty polyethylene sheeting. If the rolls are supplied loose, they must be loaded and unloaded individually to and from the truck by hand. They should not be allowed to fall or be thrown from the truck. When stacking pallets over each other, a separation board is recommended. DWI, a membrane manufacturer, does not recommend stacking more than two pallets high.

Figure 23 shows a few good practices of storage and handling and Figure 24 shows bad storage and handling practices.
Figure 23: Proper storage and handling practices [40, Dermabit]

Figure 24: Bad storage and handling practices.
4. CHAPTER FOUR

4.0 CONSTRUCTION METHODS

Having discussed all roof assembly components, now how can we now put them together, as a system, in an effective way? There are many ways of putting all these components together. One way is to put thermal insulation under waterproofing. Another way is the reverse, i.e. putting thermal insulation above waterproofing using different types of thermal insulation and waterproofing materials.

The importance of good construction methods surpasses the importance of the quality material. In a lecture at KFUPM, Sidney Slade of Awazel Company stated that 60% of Awazel work is reroofing work and almost all of these cases were caused by poor design. So each roofing component has to be put the right way in the right location. But before that, the roof has to have the right preparation with regard to smoothing, sloping, flashing and draining.

Waterproofing statistics show that the waterproofing material used is not the important factor, rather the construction methods and the experience of the waterproofing workers who make the installation. Statistics show that 67% of roofing problems were attributed to labor, 30% were attributed to the construction methods and only 3% were attributed to materials [68]. Therefore, specification writers usually do not specify the materials so much as specify experience of the roofer.
4.1 ROOF SURFACE PREPARATION

First of all, the concrete has to be fully cured and in place for at least 14 days, preferably 28 days. Therefore, waterproofing work should not commence less than 14 days after concrete pouring.

NRCA dryness test is recommended. This is done by heating 1 pint of bitumen to 400°F and pouring it on the surface of the deck. If the bitumen foams, the deck is not dry enough. After the bitumen has cooled, it should be stripped. If the bitumen is cleanly peeled from the deck, then the deck is not dry enough to start the roofing work.

Another surface dryness test that is also suggested by NRCA is to place a pane of window glass on the concrete surface for a minimum of two hours of midday sunshine, adequately sealing the pane edge with tape. At the end of the two hour period, the underside of the glass should be checked. If moisture droplets have formed on the underside, the surface is not dry enough to apply the membrane.

In addition, the roof must be prepared well to accept the chosen waterproofing system. The surface must be clean, smooth, dry and free from dust, dirt, sand, chipping, loose debris and other contamination such as oil, wax, grease etc. or any foreign matter which might affect adhesion. Low areas, voids, honeycombs, rock pockets and excessive rough areas should be filled with applicable patch material to smoothen the roof and high spots should be ground off.
Chapter 4: Construction Methods

Sometimes it is essential to put a separation layer directly on the roof deck. This can be polyester, polyethylene or 2-mm-thick bitumen membrane to protect the bottom surface of the main waterproofing membrane. As an alternative to the separation layer on the roof deck, the roof can be plastered with a layer of plastering made of sand and cement in conjunction with bonding agent.

Cracks must be filled by crack filler before the application of waterproofing system. All cracks, expansion joints and cant strips must be treated. Also, proper flashing around the perimeter, penetration and all critical locations must be provided. Standing water should not be permitted.

4.1.1 Cracks On The Roof

If the live crack is less than 1.5 mm wide, then it should be filled with crack sealant. If the width of the crack is more than 1.5 mm, then it should be chased out to 7 mm wide and 13 mm deep. Then it should be injected with appropriate joint sealant. Hairline cracks and small holes can be ignored. See Figure 25.
Figure 25: Typical crack treatment [69].
**4.2 SLOPE**

The surface should be sloped to provide positive drainage to the drain paths and to prevent ponding. The slope should be right and enough. The slopes are extremely important since an efficient slope will not allow water to stay on the roof. SASO requires the slope not to be less than 1%. In most European and other countries, the requirement is 2.5% to 3% according to Sidney Slade of Awazel. Uniform Building Code specifies 2% as the required slope. Slope can be formed inherently in the roof deck structure or it can be created by a separate screed. Inadequate slope can result in localized ponding which may lead to a gradual build-up of silt and fungus growth [28].

The covering may depend for its effectiveness on the ability of the structure to provide the required pitch or falls for the run-off of water. A steep pitch is essential to enable water to travel downward and towards the eaves without penetrating its thickness. Small tiles and slates with multiple vertical butt joints also demand a steep pitch for water shedding.

In addition to the main roof slope, attention should be given to all critical areas on the roof such as upstands, penetrations and drainage outlets. These locations should be provided with proper flashing and slope to avoid water ponding around them.

**4.2.1 Slope-to-Drain**

Unless roofs are sloped to drain over roof edges, roof drains should be installed at each low point of the roof [70]. The slope can be accomplished by many different
methods. The most common way is by adding a sloping concrete screed after the roof deck has cured. Adding sloping screed would increase the entrapped moisture within the roof and increase the cost and weight load of the roofing system. The most economical way of providing slope is to slope the structural framing and deck. Other methods include light weight concrete and perlite. These two materials also have thermal insulation characteristics. A common way of sloping is to provide the slope with fixed tiles if they are used as the top layer of the roof.

Figure 26 shows roof slop to interior drains.

Figure 26: Roof sloped to interior drains [39].
4.3 DRAINAGE

Positive drainage is defined by the NRCA as “the drainage condition in which consideration has been made for all loading deflections of the deck, and additional roof slope has been provided to ensure complete drainage of the roof area within 24 hours of rainfall precipitation” [71]. The drainage is extremely important since efficient drainage will get rid of water as soon as water reaches drainage outlets. Therefore it is desirable to drain water off the roof as quickly as possible by providing adequate slope and drainage outlets.

Bad drainage was the suspect cause for roof falls in a school in Taiwan killing 26 students and injuring 84 [72]. Most of the roofing problems in flat roofs in Saudi Arabia relate in some way to bad drainage.

To properly design the drainage of a roof, the rainfall intensity in inches/hour for the geographic location of the building site must be considered in addition to the roof area that contributes to each roof drain and the drainage outlets placement [73]. The drainage system, the piping and couplings must be designed to withstand the pressure head resulting from the height of the roof if the drainage outlets are connected to a closed system. If the drainage outlets are opened to the atmosphere, there is no need for this consideration. A blockage can be at the drainage outlet opening at the roof or it can be anywhere in the drainage piping. In Saudi Arabia, most drains are draining to the atmosphere; therefore, the potential blockage would be at the roof. Rain water usually carries dust and sand in big quantities creating a significant flow of mud in the outlets [32].
In his M. S. Thesis, page 25, Al-Shiha said that waterproofing and drainage are items where contractors lack experience. In addition to the fact that designers overlook waterproofing, waterproofing and roof drainage are two items where contractors lack experience; most of the items are performed wrongly and inadequately, resulting in water seepage through the roof ceiling [74].

The drainage condition should be evaluated before covering the roof. Serious drainage problems may be related to slope or improper drain placement [75]. Drainage can be positioned towards the outer edges and into external gutters. Another location for gutters is within the main roof area. The roof drainage system must be designed to take into account the locations of any expansion joints so that they won’t block the way to the drainage outlets.

4.3.1 Drainage Outlets

Drainage outlets are the most vulnerable part of the roof. To obtain proper drainage, drainage outlet should be located at the right level, which is at each low point and in each collection valley of the roof. Drains should be made lower than the roofing level or the same level as the main concrete pouring. To avoid ponding of water around outlets, the outlets should be surrounded by a concrete depression of not less than 1.5 cm deep and with a radius of 15 cm plus outlet radius [32].

Drainage outlets can be installed at the perimeter of the roof or they can be fixed onto the roof deck at all low points. If drainage outlets are located inside the roof (i.e. interior type) at several locations, areas near columns which are usually high points will be
avoided. A roof which directs rainwater to discharge beyond the perimeter walls is inherently less likely to fail than one which is internally drained [28]. It is better to locate the outlets well clear of upstands and roof penetrations so that proper flashing can be achieved around these locations. Figures 27, 28, 29, 30 and 31 shows a few types of drainage outlets.

Figure 27: Drainage outlets [76].
Figure 28: Drainage outlet at the parapet, opening w/o strainer at the parapet.

Figure 29: Drainage outlet at the parapet, opening with strainer at the parapet.
Figure 30: Drainage outlet at the parapet, opening away from the parapet.

Figure 31: Interior drainage outlet with strainer.
4.3.1.1 Drainage Outlet Quantity

Sidney Slade of Awazil [15] indicated that "Recently an architect came to Awazil with a design in which a 6000 m² roof has only one rainwater outlet. The water was expected to travel 52 meters. To comply with SASO standard minimum 1% slope, this would need a sloping screed from 4 cm to 52 cm thick, with an average thickness of 35 cm. Storm water could build up to overflow the parapets and could take up to 3 days to clear. By introducing a second outlet, the average screed thickness would be reduced to 17 cm, while, introducing a third, centrally placed outlet, the average screed thickness would become 10.5 cm [15]". Therefore, the number of drain outlets should be given great attention in order to select a sufficient number of drain outlets. A minimum of two drains should be used to ensure runoff if one drain becomes clogged [73]. A task in many reroofing projects may be to add drains [77]. It should be understood that adding drains alone, with already defined drainage regions, should be accompanied by an increase in the effective outlet opening [77].

4.3.1.2 Drainage Outlet Size

Drain pipe size should be large enough to get rid of water quickly. The fall pipes must be so spaced as to clear the whole roof surface of rainwater as quickly and evenly as possible [78]. For a typical residential villa drain pipes should not be less than 3" in diameter. They should be checked regularly to make sure that they are clean.

To calculate the drainage outlet size, the following three basic factors need to be known: contributing roof area per drain, rainfall rate and roof slope [39]. So, the drainage
outlet size = rainfall rate X contributing roof area; go to Table 2 below to select the size. Reference [28] gives sizing of drainage pipes based on the maximum area of roof to be drained and, assuming a rainfall intensity of 75, mm/hr the following sizes were recommended:

150 m² of roof requires a 3-inch down pipe

300 m² of roof requires a 4-inch down pipe

900 m² of roof requires a 6-inch down pipe

The outlet at the roof deck should have a plane area not less than 1 1/2 times the down pipe size.

**TABLE II**

**PIPE SIZING FOR DRAINAGE OUTLETS [39]**

<table>
<thead>
<tr>
<th>Pipe diameter, in.</th>
<th>Flow Capacity for storm drainage systems, gpm</th>
<th>Horiz. storm drainage piping</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Slope, in./ft.</td>
</tr>
<tr>
<td></td>
<td>Roof drain and vertical leaders</td>
<td>%</td>
</tr>
<tr>
<td>2</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>2½</td>
<td>54</td>
<td>48</td>
</tr>
<tr>
<td>3</td>
<td>92</td>
<td>110</td>
</tr>
<tr>
<td>4</td>
<td>192</td>
<td>197</td>
</tr>
<tr>
<td>5</td>
<td>360</td>
<td>278</td>
</tr>
<tr>
<td>6</td>
<td>563</td>
<td>446</td>
</tr>
<tr>
<td>8</td>
<td>1208</td>
<td>958</td>
</tr>
<tr>
<td>10</td>
<td>863</td>
<td>1217</td>
</tr>
<tr>
<td>12</td>
<td>1388</td>
<td>1958</td>
</tr>
<tr>
<td>15</td>
<td>2479</td>
<td>4958</td>
</tr>
</tbody>
</table>
4.3.1.3 Installation of Drainage Outlets

Drainage outlets should be located at the lowest point on the roof. The sloping concrete screed should be 10 to 15 cm away from the drainage outlets so that sunken areas are created around them. The following steps are recommended when installing drainage outlets:

1. The primer should be applied on sunken areas and 20 cm of sloping screed.
2. Pieces of roofing membrane with holes equal to the size of the outlets should be installed in the sunken areas and fully bonded to the roof deck.
3. Other pieces of membrane should be rolled like a cylinder so that they can be placed inside the drainage outlets for about 12 cm and outside for about 12 cm, and they should be bonded with torch to the drainage outlets and the first piece of the sunken area.
4. A third piece for each drainage outlet is welded to the rest of the surface area and to the sloping screed.

See Figures 32 and 33 for typical drainage outlet installations.
Figure 32: Typical installation of drainage outlets [27].
Figure 33: Typical drainage outlets [27].
4.3.2 DRAINAGE OUTLET CONSTRUCTION DETAILS

Figures 34 to 41 show construction details for some of the common roofing systems.

![Diagram of drainage outlet construction details](image)

Figure 34: NRCA Drain details for built-up roofing [79].
Figure 35: NRCA Drain details for modified bitumen roofing [79].
Figure 36: NRCA Drain details for PVC roofing [79].
Figure 37: NRCA Drain details for EPDM roofing [79].
Figure 38: Dermabit Drain details for inverted gravel finish roofing [47].
Figure 39: Dermabit Drain details for inverted sand/cement screed finish roofing [47].
Figure 40: Dermabit Drain details for conventional/exposed roofing [47].
Figure 41: Dermabit Drain details for non insulated/exposed roofing [47].
4.4 ROOFING/WATERPROOFING SYSTEMS

Roofing systems can be accessible or non-accessible. Their accessibility depends on their resistance to puncture and mechanical damage. They can contain thermal insulation or they can be made without thermal insulation. They can be conventional or inverted depending on the location of the thermal insulation materials with respect to the waterproofing material.

Waterproofing material can be covered by a loading layer or if it is a weather resistant membrane it can be left exposed without a loading layer. Waterproofing material can be bituminous or non-bituminous depending on the material used. Roofing systems can be single-ply, double-ply or multi-layer depending on the number of waterproofing layers used. Roofing systems can be loose laid, partially adhered or fully adhered depending on how much of it is attached to the roof deck.

Any combination of these characteristics can constitute a roofing system. For example, a loose laid single layer protected system is made by loose laying technique, has single layer waterproofing membrane and the membrane is protected by thermal insulation and/or a loading layer. A loose laid, covered, double layer roofing system differs from the previous system in the number of layers of waterproofing membrane. A protected built-up roofing system is protected by thermal insulation and/or loading layer with three or more roofing layers.

Exposed single layer systems, exposed double layer systems and exposed built-up roofing are all exposed to the atmosphere, where they should be protected against ultra-
violet radiation by mineral granule, aluminum paint or aluminum foil. Most exposed systems are non-accessible and their access is strictly limited to that necessary for maintenance purposes.

A good example of roofing systems is built-up roofing system; therefore, it will be elaborated in some details. For other systems, only a sketch will be shown. Other examples of roofing systems include:

- Loose laid and nailed systems.
- Fully adhered and spot bonded systems.
- Spray applied polyurethane.
- Ballasted Systems.
- Liquid-applied membrane systems.
- Bituminous membrane systems.
- Single-ply non-bituminous membrane systems.
- Mas-Mechanically anchored systems (offered by Firestone for roofs which can not carry the additional load of ballasted systems)
- B.I.S-Batten-In-The-Seam system (offered by Firestone for roofs which can not carry the additional load of ballasted systems and where the use of smaller EPDM sheets is more practical). Membrane panels are mechanically attached with battens placed in the seams of adjoining sheets.

There is no one roofing system that performs universally better than the others. The selection key is knowing what factors affect roof performance and choosing the materials that best accommodate the unique challenges each installation presents [52].
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The roofing system should remain intact for extended periods of exposure to continuous cycles of moisture, heat, ultraviolet radiation and environmental pollutants [52]. It should withstand other hazards not related to the weather, such as building movement and foot traffic accompanying the installation and maintenance of rooftop mounted equipment such as AC units and water heaters [52].

Al-Subaie [80], in his assessment of built-up roofing and other roofing systems in the residential houses in the Eastern province has concluded that the most appropriate waterproofing system is the liquid applied system due to its easy application. Figure 42 shows a typical roofing system.

Figure 42: Typical roofing system [Dermabit, 42].
4.4.1 CONFIGURATIONS OF ROOF SYSTEMS

Roofs may be insulated or non-insulated. Roofs that are insulated fall into one of two main roof systems configurations with respect to the location of the waterproofing membrane within the roof system. These system configurations are the traditional and the upside-down roof systems.

4.4.1.1 Insulated Roofs

4.4.1.1.1 The Traditional Roof System

With the traditional roof system, sometimes referred to as conventional roof, the waterproofing membrane is laid above the thermal insulation materials.

If water seeps through and gets trapped below roof tiles for a considerable time, even if leakage does not occur immediately, the thermal insulation will probably become saturated and may no longer function [15].

The traditional flat roof typically consists of the following components in order from the very bottom, the concrete roof deck:

1. Concrete Roof Deck
2. Sloping Concrete Screed
3. Vapor Barrier (Optional)
4. Thermal Insulation
5. Waterproofing Membrane
6. One-inch Sand Layer
7. Separation Layer
8. Flooring Concrete Layer
9. Loading Layer (Flooring)

Figure 43 shows an example of a conventional roofing system.
Figure 43: Exposed Conventional Roofing System [Dermabit, 47].
4.4.1.1.2 The Upside-down Roof System

With the upside-down roof system, sometimes referred to as the inverted roof, the waterproofing membrane is laid directly onto the roof deck followed by thermal insulation material.

In spite of its name, the upside-down roof system is considered to be the right system. It has been applied for over 15 years in the US and Europe and 8 years in the Middle East. It has been gaining popularity since it was recommended in most of thermal insulation literature.

The typical components of the inverted roof are as follows in order starting from the roof deck:

1. Concrete Roof Deck
2. Sloping Concrete Screed
3. Mopping Asphalt or Primer
4. Waterproofing Membrane
5. Separation Layer(Optional)
6. Thermal Insulation
7. Separation Layer(Optional)
8. Loading Layer (gravel, screed, tiles etc.)

Figure 44 shows three inverted roof systems with different loading layers.
Figure 44: Three inverted roofs with different loading layers [ACC, 36].
4.4.1.1.2.1 Advantages of the Upside-down Roof System

There are many advantages to the inverted roof system, and they mostly relate to the protection of the waterproofing membrane. The waterproofing membrane is well protected in inverted roof systems from:

- Extreme thermal stresses
- High ultraviolet exposure
- Mechanical stresses

In addition:

- Life expectancy is substantially increased
- Aging is reduced

Maintenance:

- Cost of maintenance is significantly reduced
- Easier maintenance

4.4.1.2 Non-Insulated Roofs

Non-insulated roofs do not contain thermal insulation; therefore, their components do not include thermal insulation materials. Typical components are as follows:

1. Concrete Roof Deck
2. Sloping Concrete Screed
3. Waterproofing Membrane
4. Separation Layer
5. Sand
6. Separation Layer
7. Reinforced Flooring Concrete Layer (at least 2" thick)
8. Loading Layer (Flooring)
4.4.2 LAYERS OF ROOFING/WATERPROOFING SYSTEM

4.4.2.1 Single Layer System

In this system, there is only one layer of roofing membrane. This layer can be either loose laid or fully bonded. If this membrane is bitumen based, then it should be APP modified with polyester carrier and 4 mm thickness. This is the most common type of system. Few owners use more than one layer except in the case of asphalt and jute systems. Among roofing systems that fall into this category are:

- Inverted roof with single layer; see Figure 61.
- Protected single layer membrane; see Figure 62.
- Non-accessible loose laid protected/covered single layer system; see Figure 63.
- Accessible loose laid protected/covered single layer system; Figure 64.
- Single layer system covered by fixed tiles; See Figure 65.
- Exposed single layer system.

4.4.2.2 Double Layer System

There are two layers of roofing membrane in this system. The lower layer can be partially bonded with nails or bitumen, fully bonded or loose laid. The upper layer is usually bonded to the lower layer by gas torch or by using hot oxidized bitumen. Among roofing systems that fall into this category are:

- Double layer waterproofing to inverted roof with first layer loose laid; See Figure 66.
Exposed double layer system; See Figure 67.

Protected double layer system; see Figure 68.

Non-accessible protected/covered double layer system; see Figure 69.

Accessible protected/covered double layer system; see Figures 70 and 71.

4.4.2.3 Multi-Layer System

In this system, three or more 2 mm-thick layers are used to make the roofing. The roofing layers are fully bonded to the roof structure by hot oxidized bitumen liquid or partially bonded by hot bitumen that gets to the roof structure through the holes that are made in the base perforated membrane. Built-up roofing is the oldest and most common multi-layer roofing system.

4.4.2.3.1 Built-up Roofing System

4.4.2.3.1.1 Background

Conventional built-up roofing is hot applied and constructed in layers on the site. It is an old system which is made of two or multiple layers of thin asphalt sheets of oxidized bitumen and reinforcement. Since 1844, built-up roofing has been the most common form of waterproofing; today, there are more than 50 billion square feet of built-up roofing in service in the United States alone [81]. BUR systems are almost 155 years old and own a long and successful track record in a wide variety of situations [52].
4.4.2.3.1.2 Built-up Roofing Components

Built-up roofing system is a good system which consists of two components: a lot of roofing bitumen from asphalt or coal tar and many reinforcing plies.

4.4.2.3.1.2.1 Bitumen

The roofing bitumen plys the role of being the waterproofing and adhesive agent of the system [81]. It can be either asphalt that meets the criteria in ASTM D312 or coal tar bitumen that meets the criteria in ASTM D450 [81]. Bitumens are either a product of petroleum refining asphalt or a product of the cocking process of coal-coal tar pitch [81]. If the bitumen is from asphalt, it is usually one of asphalt types I, II, III, and IV which should meet the current ASTM standard D312. Bitumen liquid type IV and 115/15 are used for built-up roofs on inclines not exceeding 25% slope and Type III and 85/25 on inclines not exceeding 12.5% slope [82]. Generally, the recommended asphalt temperatures at the point of application are between 350 and 450°F.

4.4.2.3.1.2.2 Reinforcing Felts

The ply felts provide the bitumen with the ability to be built up into a monolithic membrane which can resist the stresses of normal building movement and thermal changes [81]. Roofing felts can be asphalt/organic felts, coal tar/organic felts, asphalt impregnated glass felt, coal tar impregnated glass felt or polyester [81]. They also can be fiber glass, paper felt or jute. Due to oxidized bitumen’s limited elasticity, reinforcements such as organic felt or glass fiber should be used.
4.4.2.3.1.3 Application & Performance

Built-up roofing can be hot mopped or it can be cold-applied using different types of bitumen. For hot mopped, bitumen for bonding built-up roofing felts is heated to a temperature between 200°C and 250°C. Bitumen is heated inside special boilers which can be supplied by the manufacturers. In lots of cases, bitumen is heated in drums and when it boils it is poured on the roof. The first layer or base sheet is perforated and loose laid on the screed. Hot bitumen of 85/25 type should be poured on the base sheet penetrating it and causing it to be partially bonded since the hot asphalt will go through the holes, that are made in the felts, to the roof deck. If built-up roofing is to be exposed, bitumen 115/15 should be used instead of bitumen 85/25, which is used in the case of covered or protected built-up roofing. When the job is completed, mineral aggregate is spread over the top coat of bitumen. Alternatively, a granule-surfaced roofing sheets can be installed as a top layer.

NRCA of America has carried out studies about the performance of built-up roofing over a period of more than 100 years. Some contractors and manufacturers give the traditional multi-layer built-up roofing a 15 year warranty if it is exposed and 20 years if it is covered. The overlapping of the multi-layers makes a thick cohesive single structural unit. Built-up roofing has many shortcomings such as low temperature brittleness and an inability to accommodate substrate movement [64].

Among roofing systems that fall into this category are:

- Protected/covered built-up roofing system; see Figure 72.
- Built-up roof with gravel finish; see Figure 73.
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- Exposed built-up roofing system see Figure 74.

4.4.3 Roofing Installations

4.4.3.1 Roofing Application

Roofing is either hot or cold applied. Hot application involves heating of the asphalt or the membrane. Cold application doesn't involve heating.

4.4.3.1.1 Hot-Applied Membrane

Bitumen which is hot-applied can be covered and protected from the atmosphere or it can be designed so that it can withstand exposure to the environment. Hot applied roofing systems include hot mopping, traditional built-up roofing and torch-on applications.

4.4.3.1.2 Cold-Applied membrane

Cold-applied membrane is more expensive than the hot-applied. It is supplied with adhesive so that it can stick to the roof surface. It is usually much thinner than the hot-applied. For cold application of bituminous membranes, the primer that should be used is ASTM D-3019 type III asphalt primer. Squeegee is used to coat the substrate. Cold applied roofing systems include mechanically adhered systems, self adhesive systems and almost all liquid applied roofing systems. Figures 45 and 46 show cold application for insulated and non-insulated roofing systems.
Figure 45: Cold application of non-insulated roof [Dermabit, 42].

**Figure 46: Cold application of insulated roof [Dermabit, 42].**
4.4.3.2 Covered/Exposed Roofing

Waterproofing materials can be covered and protected from atmosphere or they can be designed to withstand exposure to the environment.

4.4.3.2.1 Covered Roofing

Covered roofing is one that has its waterproofing materials covered by a loading layer such as tiles or gravel. Most bitumen and polyurethane waterproofing are required to be covered. If they are left exposed, they will become stiff and brittle and their joints will deteriorate. These types of roof are usually accessible unless the loading layer is removable. If the waterproofing is bitumen-based, then bitumen 85/25 is used in covered or protected roofing work.

4.4.3.2.2 Exposed Roofing

An exposed roof is one in which the waterproofing material forms the roof finish [15]. Some types of roofing materials are supplied with a rough surface that can withstand the harsh environment. These types of roof are usually non-accessible. Their access is strictly limited to maintenance purposes. Exposed roofing surface must have good weatherability characteristics. If bituminous waterproofing material is used, then bitumen 115/15 should be used.
4.4.3.2.2.1 Granular Surface

The principle functions of roofing granules are: to prevent degradation of the asphalt coating, to provide color and decoration to the surface, to improve the impact resistance to hail and roof traffic and to improve the fire resistance of the roofing [35].

Natural tests were made on exposed granule finish SBS elastomeric bitumen at two different locations in France [83]. After 20 years of exposure, it was found that elasticity, softening point, penetration and cold flexibility are all within the acceptable limits of UEAtc Directive requirements. Also after 10 years of exposure, the same material shows acceptable aging condition at Jacksonville, Florida and Brazzaville, Congo [83]. The closest to Saudi Arabia’s environment is Brazzaville which shows that after 10 years, the softening point was 100°C, the elasticity was 55%, the penetration at 25°C was 38 and the cold flexibility was -20°C [83]. All these values are beyond the acceptable requirement. This gives us more confidence in using exposed granule finish SBS modified bitumen in Saudi Arabia. Some available brand names that are designed for exposed roofing systems are:

A. DERMABIT 4170 Slated

This high performance roofing membrane is produced with a layer of natural slate flakes embedded on the top surface with the scope of protecting the membrane from UV radiation and aging while providing an aesthetically finished waterproofed surface [47]. This membrane is designed for use as a top layer in a multi-layer system. It also may be used as a single layer system.
B. DERMABIT 4200 Slated

This is an APP modified bitumen reinforced with a core of 200 grams/m$^2$ non-woven polyester with upper surface self-protected by a layer of natural slate flakes (granules) [47]. It is used in an exposed system application as it is protected against UV radiation.

C. ASPHALTOPLAST Slated

This is a torch applied membrane manufactured by DWI with reinforcement of 180 grams/m$^2$ non-woven polyester mat.

4.4.3.2.2.2 Aluminum Paint/Foil Surface

Aluminum paint or foil is used for exposed roofing membrane because it resists the ultra violet radiation. It is manufactured from bitumen, aluminum powder and special chemical solutions. Aluminum paint is a solvent-based paint with a leafing type of aluminum pigment. See Figure 47.
A. **ELASPHALT 2050, 3050 AL**

This is an SBS modified bitumen waterproofing membrane which is laminated with a strong aluminum foil for exposed system application and flashing purposes giving excellent reflection properties and mechanical protection. This is manufactured by Dermabit Waterproofing Industries in Jubail. The first number in the designation indicates the membrane thickness in mm.

B. **DERMABIT 2050, 3050 AL**

This is an APP modified bitumen waterproofing membrane which is laminated with a strong aluminum foil for exposed system application and flashing purposes giving excellent reflection properties and mechanical protection. This is manufactured by
Dermabit Waterproofing Industries in Jubail. The first number in the designation indicates the membrane thickness in mm. It can be used as a cap sheet in a multi-layer system where it is torched to the layer beneath it. It also can be used as a single-ply roofing membrane.

C. DERMAGUARD

This is a solvent based bituminous aluminum paint formulated with reflective aluminum flakes which reflect the sun’s rays, minimizing the external surface temperature. It can be applied by brush, roller or spray after a thorough mixing and periodical stirring.

4.4.3.3 Adherence to the Roof Deck

The roofing membrane can be either partially or fully adhered to the roof deck.

4.4.3.1 Spot Bonded

Spot or partially bonding is used to minimize the transmission of stresses from the structure or screed to the membrane [48]. In spot bonded system, the roof and the areas of upstands should be primed and allowed to dry thoroughly. A perforated membrane is laid loose in position with butt joints. A coat of hot bitumen is poured over the entire surface so that the bitumen penetrates the perforates and causes spot welding. Further layers of unperforated membranes should be installed.

4.4.3.2 Fully Bonded (Fully Adhered)

A fully bonded system is completely attached to the substrate so that the membrane movement is restricted. In fully bonded systems, the entire area should be
primed. Then, the membrane is heated by gas torch from the bottom across the entire width of the roll and stuck to the primed concrete structure as it melts. This system requires extensive hand work; therefore, it is usually the most expensive to install.

For non-bituminous single-ply membrane, solvent-based and water-based adhesives are used for fully adhered installation. The adhesive should be stirred until it becomes uniform, then applied to the substrate and left to dry for 3 hours. The sheets should be aligned in their proper position with overlapping of the adjacent sheets for 6 cm. Then sheets should be folded in half and bonding adhesive applied to the back of the sheets and the top side of the deck in the case of solvent-based adhesives. Adhesive coated sheets should be rolled onto the prepared substrate. The other half of the sheet should be coated the same way. This operation should be repeated for all sheets. In case of water-based adhesives, adhesive should be applied only at the top of the deck. Ensure total bond between the membrane and the substrate in a manner that minimizes the occurrence of voids and wrinkles by applying position pressure to all areas utilizing a roller. Lap areas should be welded by hot air or by chemical fusion. Adhesives should be applied according to manufacturers’ instructions. Adhesive should not be allowed onto the joint area.

4.4.3.4 Installation Methods

The following steps should be considered when installing roofing membranes:

1. Sheets should be in good condition when brought to the site and directly before installation. Sheets should be visually inspected for defects prior to setting into location.
2. Installation should be in such a way not to damage the substrate.

3. Installation should start at the high point of the roof and work to the lowest point.
   This is to avoid the possibility of water penetrating under the completed roof system [84].

4. Field seams should be oriented to the direction of water flow when possible.

5. Precautions must be taken where incompatible material contact each other [82].

6. Some plasticized PVC is incompatible with bitumen; therefore, a separation layer must be used to prevent interaction between bitumen and PVC

7. Some thermal insulation materials are incompatible with PVC roofing membranes [82].

4.4.3.4.1 Installation of Roofing Membranes

When installing the already manufactured roofing membranes, there are two major factors that make the difference between good and bad roofing: the selection of the installation method of the roofing membrane to the roof deck and the correct method of doing the lap joints between adjacent roofing sheets.

4.4.3.4.1.1 Roofing Membranes

There are many methods of installing roofing membranes such as torch-on, mop-on, loose laid, mechanically fastened and self-adhering.
4.4.3.4.1.1.1 Torch-On Installation Method

After the roof deck is cleaned from dust or dirt etc., it is then coated with primer with 200-300 grams/m² depending on the porosity of the surface. The primer should be left to dry for 24 hours. The membrane is then unrolled and placed in the correct position where it is to be torched on later [47]. The membrane is then re-rolled without changing the given orientation and unrolled again while heating the lower surface by propane gas torch to the application temperature, thus causing surface melting and subsequent adhesion to the primed surface [47]. During each stage each roll must overlap the next by at least 10 cm at the longitudinal laps and a minimum of 15 cm at the end laps [47]. Total adhesion must be insured on the 10 cm overlaps between membranes.

Application temperature below 150°C (310°F) may cause poor adhesion and in excess of 260°C (500°F) may result in degrading of the asphalt and causing changes in the physical properties of the roofing asphalt [42]. Therefore, torching or hot mopping should be within these limits. The membrane should not be overheated to a point that smoke starts to come out. The propane torch should be used with extreme caution with well trained workers. Avoid holding the flame too long in one area of the substrate or membrane.

An advantage of torch-on installation is the fact that as a fully adhered system it would be possible to trace a leak to the source point such as an open joint or crack occurring on the structured element [44].

Torching should not start before the primed surface is cured, i.e. the solvent base primer has evaporated. A typical torching operation is as follows:
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1. Place the membrane in the correct torching position.

2. Re-roll the membrane to about half of its length without changing its orientation.

3. Unroll the membrane and heat it from the bottom by the propane gas torch.

4. Re-roll the second half of the membrane and heat it from the bottom completing the laying of one roll.

5. Make the same torching procedure for the second roll and all remaining rolls until the roof is covered bearing in mind the 10 cm lap joint that has to be maintained between each adjacent rolls.

6. Torching of the overlapping area consists in heating the contact line of the two membranes and then pressing the upper membrane on to the lower one using a plaster roller.

Figures 48, 49, 50, and 51 show examples of torch-on applications.
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1. Waterproofing membrane
2. Primer
3. Sand/Cement screed to slope Base Sheet
4. Concrete deck Insulation boards

Figure 48: Torch-on application of non-insulated roof [Dermabit, 42].

1. Waterproofing membrane
2. Base Sheet
3. Insulation boards
4. Sand/Cement screed to slope
5. Concrete deck

Figure 49: Torch-on application of insulated roof [Dermabit, 42].
Figure 50: Torch-on application in progress.

Figure 51: Torch-on application in progress [Dermabit, 47].
4.4.3.4.1.1.2 Hot Mop-On Installation Method

A membrane can be fully bonded by being unrolled onto poured hot bitumen. This is used specially when doing built-up roofing. Therefore, this is a fully bonded method. For hot mop application of bituminous membrane, bitumen (ASTM. D-321 type III asphalt) is heated in a kettle to a temperature of 230°C (450°F) and then mopped on or poured on the laying surface at a rate of 800-1000 grams/m². The membrane is then positioned in the proper manner and unrolled immediately over the hot bitumen [47].

While unrolling the membrane, hot bitumen is poured at the seams to ensure a properly sealed overlap joints [47]. Subsequent rolls are set alongside the first, overlapping by a minimum of 10 cm at the side laps and 15 cm at the end laps. In this type of application, installation of the membranes should immediately follow the asphalt application. Figures 52, 53, and 54 show examples of hot-mop applications.
① Waterproofing membrane
② Primer
③ Sand/Cement screed to slope
④ Concrete deck

Figure 52: Hot-mop application of non-insulated roof [Dermabit, 42].

① Waterproofing membrane
② Primer
③ Base Sheet
④ Insulation boards
⑤ Sand/Cement screed to slope
⑥ Concrete deck

Figure 53: Hot-mop application of insulated roof [Dermabit, 42].
4.4.3.4.1.1.3 Cold Mop-On Installation Method

This is a method used for fully adhered systems usually for non-bituminous single-ply membranes. It is done by using adhesives instead of primer or asphalt in the case bituminous membranes. Adhesive can be applied by roller, squeegee, trowel, brush or spray.

Latex water-based adhesive such as water-based neoprene is cold applied to the roof deck and the membrane is rolled out over it. The amount of the required adhesive will depend on the porosity of the substrate; however, 1 liter will typically cover 3 m² [28]. The adhesive should be spread sufficiently widely to receive the membrane for more than 7 meters in length and then the membrane is immediately rolled out over the adhesive while
it is in its live state. The membrane is then pressed over the adhesive with squeegee to remove all trapped air. Seam is achieved by hot air or solvent welding. Subsequent rolls are laid in the same manner and each roll should overlap the previous roll.

In case solvent-based adhesive is used, it should be spread, as thin as possible with full coverage, first to the substrate and then to the backing of the membrane. It should be left to dry, for 10 to 45 minutes depending on the climate and adhesive, before the two surfaces are brought together.

4.4.3.4.1.1.4 Loose Laid Installation Method

In the case of loose laid system, only a few attachments to the substrate are made. The membrane is not welded to the concrete structure except on a few locations such as perimeter of the roof, lap joints, upstands, pipes, the terminating ends and at other critical locations. Spot or partial bonding is used to minimize the transmission of stresses and thermal movements from the concrete structure to the membrane. Primer or adhesive should be applied to the locations where the membrane will be fully welded and should be allowed to dry thoroughly. The substrate should be in good condition or a protective under layer should be installed to prevent any damage to roofing membrane. The membrane sheets are welded to each other where they overlap.

The most important benefit of loose laying is that movements of other roofing components are not transferred to the waterproofing membrane. Therefore, loose laid will not be affected by local stresses caused by cracking that may occur in the roof screed. With loose laid system, the waterproofing sheets are totally isolated from all the
movements happening underneath so that any stresses resulting could be accommodated on large areas and not localized [5]. Loose laid also prevents blistering that can be caused by the moisture content that remains in a fully cured screed or light weight concrete [85]. The increase in moisture temperature causes pockets of compressed moisture vapor to be formed under the membrane.

A typical loose laid procedure is as follows:

1. Start at the low side of the roof near the drainage outlets.
2. Unroll the first sheet so that its side edge follows the line of the bottom edge of the cant strip.
3. The membrane should be adjusted so that the end of the roll covers the face of the cant strip and extends 15 cm up the face of the parapet.
4. Re-roll the membranes to expose the primed areas at parapet and apply the gas torch to the membrane to fully weld it to primed areas at parapet and the cant strip.
5. The second row of membranes should overlap with the first by about 10 cm.
6. After the side and end laps have been formed, they should be reworked by smoothing with a heated round nosed trowel [48].
7. If a second layer is to be installed, it should be positioned so that its lap joints occur midway between those of the first layer [48].
4.4.3.4.1.4.1 Advantages of Loose Laid System

Loose laid roofing membrane has many advantages over other types of installations and that is why it is popular, specially in single-ply systems. The following are some of its advantages:

1. It will not be affected by local stresses of roof screed that happen as a result of cracks.

2. Air bubbles resulting from humidity will not exist between the membrane and the roof deck.

3. If light weight concrete is used as a sloping screed, air bubbles that resulted from humidity would be formed between the roofing membrane and light weight concrete. Using loose laid system will lessen bubble formation.

In spite of all advantages, loosely laid membrane has its shortcomings. For example, it is conceivable to have a leak occur in the membrane with the possibility that the building interior would experience water penetration several feet away from where it actually occurred in the membrane.

4.4.3.4.1.5 Mechanically Bonded

In this system, the membranes are attached to the roof deck with fasteners and reinforcement plates or battens that pass through the membrane, the thermal insulation materials and any other roof components to hold the membrane to the deck [52, 86]. Therefore, no bonding agents are used to adhere the membrane to the roof deck. Seams and flashing rely on adhesives, some using solvent welding method and some using heat
welding [86]. Mechanically fastened systems are considered partially adhered systems which are light weight with some freedom of movement [52].

Mechanical fixing is needed when light roofing is needed or when a fully adhered system (by adhesive or any other way) is not considered suitable. Mechanically adhered systems are normally more expensive than ballasted system and less expensive than fully adhered systems [86].

To mechanically fix single-ply membrane, the membrane is rolled out and anchored directly to the deck along one edge using appropriate fasteners. The adjacent sheet is then lapped over the fasteners and homogeneously seamed to the first sheet. This is repeated across the roof surface. Penetrations must be sealed by the membrane. The membrane should be mechanically fixed and sealed along the roof perimeter.

4.4.3.4.1.1.6 Self Adhering (Sticking)

Membranes that are self sticking are like other membranes except that the bottom surface is made with adhesive and a release paper. This is especially important where torching poses a hazard and the use of hot mop asphalt becomes difficult, time consuming or impractical [42]. Self adhering membranes should be applied over either a bituminous base sheet or a cold applied primer base, which should be left to dry before installing the membrane, corresponding to ASTM. D-41. To be applied on roofs, self adhering membranes should be applied starting at the low point of the roof. Unroll the membrane in the prescribed direction and align it to the roof edge or base sheet [42]. Carefully re-roll the membrane without altering the alignment. Then unroll the membrane again slowly
pulling and removing the release paper and press the surface uniformly to prevent the formation of air pockets. Lap joints of 10 cm should be maintained between the rolls. Figure 55 shows the installation of self-adhesive membrane. Some examples of available self-adhering products are given:

![Figure 55: The installation of self-adhesive membrane [Dermabit, 42]](image)

A. Bituseal 1000, 1200 & AL

These are self-adhesive membranes manufactured by Bitumat Company Limited. Bituseal 1000 has 60 grams/m² glass fiber mat reinforcement while Bituseal 1200 has 130 grams/m² non-woven polyester fabric. The thickness for these membranes is 1.5 mm.
They are covered on their top surface with polyethylene foil and on the bottom with a siliconized release paper. They can be used under shingles and roof tiles.

B. BITU-THENE 1200X HC

This product is technically advanced cold applied self-adhesive flexible waterproofing membrane which has been developed specially for inverted or protected membrane roofs in the Middle East. It is manufactured in Dammam 2nd Industrial City by Bitumat-Servicised Systems. It is a combination of an elastic rubber/bitumen compound with a solar reflective four layer cross laminated high density polyethylene carrier film. Its thickness is 1.5 mm. Horizontal and vertical surfaces should be primed with one coat of Servicised B Primer HC using brush or roller. The primer should be allowed to dry. Bituthene 1200X HC should be laid by peeling back the protective silicone release paper and applying the self-adhesive face on the prepared surface [40]. Use roller to ensure complete adhesion specially at lap joints.

4.4.3.4.1.2 Lap Joints

Lap joints must be carefully made because they are potential areas for problems. There are many ways of making lap joints depending upon the roofing membrane’s material that is to be used. Lap joints can be welded by: torching, hot bitumen, adhesive, solvent, hot air or by mechanical fixing.
4.4.3.4.1.2.1 Lap Joints For Bituminous Membranes

For bituminous membranes, lap joints are treated as the membrane itself. That is by torch welding or hot mopping.

4.4.3.4.1.2.2 Lap Joints For Non-Bituminous Single-Ply Membranes

Lap joints for non-bituminous single-ply membranes such as PVC, EPDM and Hypalon are performed by adhesive welding, splice tape, solvent welding or hot air.

4.4.3.4.1.2.2.1 Adhesive Welding

Adhesive seams employ contact adhesive applied to the two membrane surfaces after they have been cleaned with a solvent or special slice wash [87]. Adhesive seams cannot be made during periods of precipitation or high wind because moisture, foreign objects and dirt will prevent proper bonding and curing of contact adhesive [87]. Figure 56 shows the installation of single-ply lap joint using adhesive.
Figure 56a: Positioning the membrane [Firestone, 41].

Figure 56b: Folding the membrane back [Firestone, 41].

Figure 56c: Cleaning joint area [Firestone, 41].
Figure 56d: Applying the adhesive on both sheets [Firestone, 41].

Figure 56e: Providing extra adhesive at cross seams [Firestone, 41].

Figure 56f: Testing the adhesive for readiness [Firestone, 41].
Figure 56g: Closing the lap [Firestone, 41].

Figure 56h: Assembling the lap [Firestone, 41].

Figure 56i: Rolling the assembled lap [Firestone, 41].
Figure 56j: Preparing the edge [Firestone, 41].

Figure 56k: Sealing the lap [Firestone, 41].

Figure 56l: Feathering the lap sealant [Firestone, 41].
4.4.3.4.1.2.2.2 Using Splice Tape

Another method of making lap joints for single-ply membrane is by using splice tape. Figure 4.33 shows the steps required to make splice tape seams.

Figure 57a: Preparation [Firestone, 41].
Figure 57b: Marking the edge line [Firestone, 41].

Figure 57c: Positioning the tape [Firestone, 41].

Figure 57d: Checking tape alignment [Firestone, 41].
Figure 57c: Removing paper backing [Firestone, 41].

Figure 57f: Applying pressure [Firestone, 41].

Figure 57: Lap joints made by using splice tape [Firestone, 41].
4.4.3.4.1.2.2.3 Solvent Welding

Solvent welding is used for lap joints, and for welding the membrane to metal sheets and to other accessories.

Solvent welded seams are made by applying solvent to two sides of a clean, dry membrane. Both surfaces of the membrane should simultaneously be brushed with solvent thoroughly and evenly. Top sheet is pressed into the bottom layer using hand, ball or sand bags. The solvent break down the molecular-bonded polymer chain causing the membrane to soften and then the membrane edges are pressed together and linked with the molecular chains in both sides as the solvent evaporates [87].

The lap joint should not be less than 5 cm and the solvent weld should not be less than 3 cm [82]. Flat brush or roller is used to apply it. Solvent seams are used for PVC, CPE and CSPE membranes.

4.4.3.4.1.2.2.4 Hot Air Welding

Hot air welding is another technique that is commonly used for performing lap joints. Hot air welded seams are made by fusing two membrane edges with a temperature controlled stream of hot air [87]. The two surfaces of clean membrane are melted by hot air and then pressed together by a roller and allowed to cool. Care should be observed to avoid overheating and underheating.

The lap joints should not be less than 5 cm and the welding area should not be less than 3 cm. This method is used to seam CSPE, CPE and PVC.
4.4.3.4.2 Installation of Liquid Applied Materials

Liquid applied materials are applied to the substrate by squeegee, trowel, roller or spray gun. Their application is simple and does not require very skilled labor. They are applied in two or more coats making a thin membrane after they cure. Usually the first coat is just like the primer in bituminous membranes in terms of dust absorption and crack filling. Usually the first coat is very light and it should be left for 24 hours in order for entrapped air to escape. Figures 58, 59 and 60 show the installation of liquid applied membranes.

Figure 58: Installation of liquid-applied membrane using squeegee [88].
Figure 59: Installation of liquid-applied membrane using roller.

Figure 60: Installation of liquid-applied membrane using spray gun.
4.4.3.5 Installation Procedures

Installation procedure differs with different type of membrane materials weather bituminous or single-ply elastomeric or liquid applied materials

4.4.3.5.1 Bituminous Membranes

Bituminous membranes are used as single layer, double layer or multi-layer systems.

4.4.3.5.1.1 Single Layer System

1. Make the necessary surface preparation work.

2. Make sloping screed and leave it to dry.


4. Apply the right primer and leave it to dry.

5. Unroll the first sheet to cover the cant strip and make it at least 10 cm higher than the top angle of the cant strip. The membrane should be stretched to remove any wrinkles.

6. The membrane roll shall be run perpendicular to the slope of the roof deck starting at the low point [32]. All laps in the sheet shall be installed so as to avoid water blockage.

7. Start installing roofing membrane starting from the low areas of the roof. That is, the corners where drainage outlets are located.

8. By the gas torch, heat the bottom side of the membrane to about 200 °C and bond it to the parapet, the cant strip and the roof deck. Unroll half of the length of the sheet each
time until the whole sheet is bonded; press on it to ensure complete bonding. The second sheet should overlap with the first for at least 15 cm and welded to it.

9. The torch flame should be approximately 10 cm away from the membrane.

10. The second row of sheets should be parallel to the first. Each time you start with a roll, the roll should be unrolled, then stress the roll to remove any unevenness. Then roll it to half of its length and start heating until half of the roll is bonded. Then start heating the other half in the same way.

11. The second row of sheets should overlap with the first by 10 cm.

12. Seams at overlaps shall be checked for proper weld by running a heated trowel along the edge of the seam to reseal all voids in the lap by slightly melting the membrane evenly creating a fully welded seam.

13. After the whole roof is covered by the membrane and after the flashing work is completed, close all drains and perform the flood test.

4.4.3.5.1.2 Double Layer System

1. See the previous section for the installation of the first layer and flood test and leave it to dry.

2. The second layer should be installed fully bonded onto the first layer by applying the butane gas torch flame to the whole width of the roll in order to completely burn off the polyethylene foil and melt the bitumen [32].

3. Installation of the second layer starts at the lowest point. The first roll of the second layer should cover half of the width of first roll of the first layer to make side laps. This
way, the side edges of both layers will be staggered. The second row of membranes should be installed in a position and aligned so that its edges overlap with sides of the first row by 10 cm [85]. In critical locations such as roof corners and pipes penetrating the roof, the second membrane rolls should be 10 cm higher than the first.

4. When unrolling a membrane roll, it should be pulled forward so that it becomes completely horizontal with no high sections and then roll it to its half and start the welding. When the first half is bonded completely, roll the second half and start torch welding until it is completely welded.

5. The second rolls should fully adhere to the first rolls by melting their sides together with gas torch.

6. The first layer can be fully bonded by melting the polyethylene layer and the bitumen.

7. If the first layer is nailed to the roof deck, the nails should be distributed at each 30 cm [27].

8. If the first layer is spot bonded, the roof shall be primed and the spot shall be 30 cm a part [27].

4.4.3.5.1.3 Built-up Roofing System

In this system, asphalted jute or commercial paper are used with bituminous perforated felts to constitute the roofing system. Hot asphalt is used as a bonding agent between the bitumen felts. After the sloped concrete screed is completely dry and the cant strip is made, the roof surface is cleaned and prepared to receive the roofing system as follows:

1. Prime 50 cm around all critical locations and cant strip with primer.
2. Cut strips of non-perforated felts and bond them by hot bitumen to the already primed critical locations and cant strip.

3. Base sheets of perforated bitumen felts should be laid loose on the rest of the roof without bonding. Overlapping of neighboring felts should be 10 cm.

4. After one layer of perforated felts has been laid, the second layer should start with unperforated felts by pour and roll method. Hot bitumen is poured in front of the unrolled felt which is then unrolled into the bitumen and distributed equally under the full width of the roll.

5. After that the third layer of felts without perforations is laid with hot bitumen.

6. After all layers are made, hot bitumen is poured on the roof.

Exposed built-up roofing should have a fully bonded layer of mineral finished membrane.

4.4.3.5.2 Non-Bituminous Single-Ply Membranes

Single-ply membrane application is similar to that of bitumen except that adhesive is used instead of primer and most of the time they are loose laid. Many of these materials are non-compatible with bitumen.

4.4.3.5.3 Liquid Applied Membranes

Most of the time, liquid applied products are ready for use as they are brought to the job site. Squeegee, roller and spray gun are the most widely used methods of applying these materials to the roof deck. (See installation of liquid-applied materials section).
4.4.4 **ROOFING SYSTEMS' DRAWINGS**

The following few pages shows drawings of the most commonly used roofing systems.

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Figure 61: Inverted roof with single layer [27].
1. Cant strip
2. Primer
3. Felt
4. Felt
5. Thermal Insulation
6. Separation layer
7. Tiles or Gravel
8. Metal flashing
9. Sealant

Figure 62: Protected single layer membrane [Awazel, 85].
Figure 63: Non-accessible single layer covered system, front view [Bitumat, 32].
Figure 64: Accessible single layer system [Bitumat, 32].
Figure 65: Single layer system covered with fixed tiles [Bitumat 32].
Figure 66: Double layer system with first layer loose laid [27].
Figure 67: Exposed double layer system [27].
1. Cant strip
2. Primer
3. Felt
4. Felt
5. Thermal Insulation
6. Separation Layer
7. Tiles or Gravel
8. Felt
9. Metal Flashing
10. Sealant

Figure 68: Protected double layer system [Awazel, 85].
Figure 69: Non-accessible protected/covered double layer system [Bitumat 32].
Figure 70: Accessible protected/covered double layer system [Bitumat, 32].
Figure 71: Accessible protected/covered double layer system [Bitumat, 32].
Figure 72: Protected/covered built-up roofing system [27].
Figure 73: Built-up roof with gravel finish [27].
Figure 74: Exposed built-up roofing system [27].
4.5 CRITICAL LOCATIONS OF WATERPROOFING

In making waterproofing, attention should be paid to critical locations on the roof. Anything that makes a joint with the roof should be classified as a critical location. Care should be given to those locations when making the waterproofing. Such locations include: openings, pipes projecting through the slab, walls, chimneys, vents, skylights, parapet or other projections which penetrate up. All of these locations should be flashed so that they are watertight and can withstand bad weather conditions such as wind, hot sun, freezing and structural movement. Figure 75 shows the treatment of a few critical locations.

Figure 75: Treatment of critical locations [26].
4.5.1 Exterior Openings On The Roof

On a roof, it is sometimes unavoidable to make openings to serve a certain purpose and to utilize a normally unusable roof. Some examples are: AC ducting, PVC pipes for split AC units and PVC pipes for central TV antenna wires. These openings become sources of problems to the roof because of weak bonds between two different materials: the concrete of the roof and the PVC pipe for example. Therefore, careful detailing is required to minimize the effect of movement. Duct and pipe works should be kept at least 30 cm above the sloping roof surface. This allows the formation of satisfactory flashing and gives room for maintenance.

4.5.1.1 AC Duct Openings

A central AC machine can be put on the ground or on the roof. They are usually put on the roof for the purpose of space utilization. Putting them on the roof requires making duct openings. For the duct opening, there are two places that are critical: the top(s) and the bottom(s) of the openings. For the top(s), aluminum flashing is used. For the bottom(s), waterproofing materials should be concentrated.

AC ducts should be surrounded by a concrete curb or a metallic curb; a counter flashing should be installed onto the duct to cover the curbs and prevent water from leaking along the duct. Figures 76 and 77 show duct openings.
Figure 76: Flashing of duct opening.

Figure 77: Flashing of duct opening.
4.5.1.2 Waterproofing of Pipes Penetrating the Roof

First of all, it should be known that pipes penetrating the roof will most likely be a source of trouble; therefore, penetration of the roof should be avoided if possible. Attention that is given during design to plumbing aspects of the roof will save time and money after construction. As a good engineering practice, it is recommended that lateral entry be used for installing pipes and conduits. Vertical entry is much more vulnerable to problems. Pipes should not be installed in such a way as to make successful roofing impossible, such as making them crowded in one location, as can be seen in Figure 78 and 79. Penetrations should be spaced at least 18 inches apart to accommodate proper flashing installation; they should be kept out of waterways [88]. See Figures 80 and 81.
Figure 79: Crowded pipe penetrations.

Figure 80: Properly planned pipe penetration helps in making successful roofing.
Figure 81: NRCA clearance for multiple pipes [79].
The following few steps should be followed to make successful waterproofing and flashing for pipes penetrating the roof:

1. The pipe circumference should be measured and an opening in a piece of the membrane should be made suitable to the particular pipe.

2. The pipe should penetrate this piece of membrane and it should be bonded to the pipe by a gas torch or other method depending on the roofing system used.

3. Then a piece of ultra-violet resistant membrane is bonded and clamped to the pipe or it can be capped by metal capping.

Detailed procedure can be referred to the specified roofing system.

See Figures 82, 83, 84, 85, 86 and 87 for some pipe penetration flashing designs.
1. MARK CIRCUMFERENCE OF CIRCLE
   MAKE DIAGONAL CUTS.

2. PLACE MEMBRANE.
   TORCH EDGES.

3. PREPARE COLLAR OF MEMBRANE.
   OBTAIN PIPE CLIP.

4. TORCH APPLY COLLAR
   FIT PIPE CLIP
   RE WORK SEAMS
   WITH HEATED TROWEL.

Figure 82: Typical flashing of pipe penetration [Awazel, 85].
Figure 83: Upstands to pipe penetrations [Awazel, 85].

1. Primer
2. First layer cut around the pipe
3. Collar
4. Second layer upstand
5. Mineral Granule Surfaced Membrane
6. Pipe clip
Figure 84: Pipe penetration with metal capping [27].
Figure 85: Pipe penetration for tile-finished inverted roof [Dermabit, 47].
Figure 86: NRCA pipe flashing for PVC using prefabricated cover [79].
Figure 87: NRCA pipe flashing for EPDM using prefabricated cover [79].
4.5.1.2.1 PVC Pipes For Split AC Units

For split AC units, the AC unit is split in two machines, the compressor and the air handling unit. The air handling unit is installed inside to blow air and the compressor is installed outside the building. Compressors can be installed on the ground, on the roof or they can be hung on the exterior walls. But for easy maintenance and space utilization, the roof is used for split AC compressors, as can be seen in Figures 88 and 89. On the roof, the link between the compressors and air handling units is done by PVC pipes and the bond between the PVC pipes and the concrete roof is weak, and so should be given special attention. Watertight stack sleeves should be provided and extended a minimum of 6 inches above the slab level [89]. See Figure 90.

4.5.1.2.2 PVC Pipes For TV Antenna

To get good signal reception, TV antenna should be installed on high ground. Being the highest ground, house roof is the usual candidate for antenna installation. PVC pipe is also used to hold the antenna's wires that link the antennas to the amplifiers. This makes another source of leaking problem which increases the burden on the waterproofing system.
Figure 88: AC Compressors installed on the roof.

Figure 89: AC Compressor is hung on the roof parapet to avoid foundation on the roof.
Figure 90: PVC pipes for AC units penetrating the roof.
4.5.1.3 Skylights

Skylights are installed on the roof to provide light to the interior of the house. They must be detailed properly or else they are a potential source of roofing problems. See Figures 91 and 92.

1. Waterproofing membrane
2. Base Sheet
3. Cant strip
4. Insulation boards
5. Roof deck

Figure 91: Skylight flashing-1 [Dermabit, 42].

Figure 92: Skylight flashing-2 [28].
4.5.2 Other Weak Joints On The Roof

Beside the roof openings, some other critical locations are the joints between two different concrete structures including AC and antenna tower foundations, and the parapet joint with the roof.

4.5.2.1 AC Foundations On The Roof

Central AC machines and split AC compressors and antenna tower need concrete foundations. The bottoms of the foundations and the top of the roof usually have a weak bond that should be improved to avoid leakage problem. Putting AC foundations directly on the waterproofing membrane is a bad practice that can create bonds which will make the drainage difficult. See Figure 88 for AC foundations. Also a satellite dish needs foundation, as in Figure 93.
Figure 93: Satellite dish on the roof needs foundation.
4.5.2.2 The Joint Between The Roof And The Parapet

Some other joints are the joints between the concrete roof and the parapet which if not designed carefully could be a major source of leakage. A heavy cant of the waterproofing membrane should be applied with flashing extending over the cant 6 inches on the slab and 6 inches up the vertical surface.

The vertical termination of the waterproofing membrane at the parapet should be protected by a counter flashing system such as metal strip, reglet, groove or drip in concrete [30]. Base flashing at the parapet should be self protected against UV radiation with aluminum foil or granule. Figures 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, and 106 show the joints between the roof and the parapet and detailing of the termination on vertical walls.
Figure 94: Roof/Parapet joint and terminating end for single-ply roofing membrane [ACC, 36].
Figure 95: Roof/Parapet joint and terminating end for mastic asphalt membrane [ACC, 36].
Figure 96: Dermabit parapet details for tile finish inverted roof system [47].
Figure 97: Dermabit parapet details for exposed roofing system [47].
Figure 98: Wall / Parapet termination [Firestone, 41].
1. Flashing cement.
2. Waterproofing membrane
3. Concrete wall
4. Cant strip
5. Sand/Cement screed to slope
6. Concrete deck

Figure 99: Cement flashing of low parapet [Dermabit, 42].

Figure 100: Treatment of wall or curb [69].
Figure 101: Typical edge details using tiles to cover the junction [27].
Figure 102: Dunstable membrane terminations [28].
Figure 103: Examples of termination techniques [90].

Figure 104: Hypalon cap flashing termination [28].

Figure 105: Hypalon reglet termination [28].
Figure 106a: Reglet.

Figure 106b: Counterflashing.

Figure 106c: Mechanical termination.

Figure 106d: Coping stone.

Figure 106e: Cap flashing.

Figure 106: HyChoice vertical terminations [91].
4.5.2.3 Upstands

Upstands are vertical walls in the roof such as stair houses. They can be any protruding bodies such as chimneys, ducts, AC foundations, skylights, etc. There should be a cant strip between the roof deck and upstands. The cant strip should be covered by 1 meter wide strip of roofing membrane extending to the vertical upstand and the horizontal roof. The membrane should be fully bonded to the cant strip and the roof. The exposed membrane should have ultra-violet protection such as granule or aluminum paint. Metal strip flashing should be installed on the upstands. Another way is by surrounding the protruding body by at least 20 cm thick wall reaching a height of at least 15 cm above the top roofing layer [47]. All membrane work to upstands must be protected from attack by ultra-violet radiation. This is done by using membrane with a top surface finish of mineral granule or aluminum paint.

4.5.2.4 Drains

Drainage outlets should be carefully made so that they won’t be sources of roofing problems. Apply adhesive or primer, whichever is applicable around the outlet. Cut a piece of the membrane and fix it with adhesive or primer over the whole area of the outlet and heat weld the edges. Cut a small circle in the material directly over the center of the drainage outlet and fold the material and fix it into the bowl [92]. See drainage section for detailed drawings.
4.5.2.5 Corners

Corners of the roof must be detailed properly so that they won’t be sources of roofing problems. Corners can be inside corners or outside corners. Inside corners are usually at the parapet while outside corners are on locations on the roof other than the parapet such as corners of AC foundations. The membrane should be trimmed in such a way that the two edges butt each other neatly at the angle [28]. The cut edges should be covered by a sufficiently wide piece of membrane. Figures 107 and 108 show examples of a roof’s internal and external corners. Figures 109 and 110 show typical treatment of corners.

Figure 107: Internal / External corners on the roof.
Figure 108: External corner on the roof.
Figure 109: DRC treatment of roofs' internal and external corners [28].
Figure 110a: Internal corner

Figure 110b: External corner

Figure 110: Dermabit treatment of internal and external corners [47].
4.5.2.6 Expansion Joints

The top covering must be sectioned every 4 meters in both directions by a 1 cm wide joint and must be stopped at the parapets and all openings with a 3-cm wide joint filled with a plastic material [22]. They should be cut and shaped using a reinforcing membrane piece at the central joint. They should be fully heat welded with resealed edges and seams as the rest of the flashing [22]. Expansion joints should be sealed completely with a good sealant because they have the potential to be sources of water accumulation.

There are two main methods of making expansion joints so that they won’t be a source of leakage problems. The first method is to make at each expansion joint a small wall and install the waterproofing membrane on this small wall just like short parapet details. In the second method, the expansion joints are filled with compressible material over which a solid compressible rod is installed. The sealant fills the rest of the joint. Roofing membrane over expansion joints should not be loose laid. Figure 111 shows gaps that are left for expansion joints. Figures 112, 113 and 114 show typical treatment of expansion joints.
Figure 111; Gaps between fixed tiles left for expansion joints.
Expansion Joints Greater than 1/2"

Expansion Joints up to 1/2"

Figure 112: Typical expansion joint treatment-1 [69].
Figure 113: Typical expansion joint treatment-2 [27].
Figure 114; Typical expansion joint treatment-3 [Firestone, 41].
5. CHAPTER FIVE

5.0 ROOFING PROBLEMS

Before discussing the problems that might be encountered in a roof, it would be beneficial to discuss the weather effect and the areas that are more vulnerable to problems than other areas in a particular roof.

5.1 EFFECT OF WEATHER

Weather is the primary factor that we are guarding against in having a roofing system to protect the roof. Our problems with the weather do not stop there; the roofing system itself needs protection from weather.

5.1.1 Ultra-Violet Light

Waterproofing materials should be protected against weather conditions, especially materials that are exposed.

5.1.2 Thermal Effect

Thermal effect will cause expansion and contraction of the roof and roofing. Movements will overstress, stretch, bend and twist the roofing membrane.
5.1.3 Moisture and Humidity

One of the primary factors in premature roofing failure is moisture entering the roof system as a vapor from the underside and condensing within the system [81]. Moisture is a hidden enemy; penetration or accumulation of water can go undetected for years. Long-term presence of trapped moisture within the roofing leads to roofing problems. When heated, moisture turns to vapor. Vapor can lead to rapid deterioration of the entire roofing system.

In high humidity areas, penetration of moisture to reinforcing bars can cause corrosion of steel by an electrochemical process. Iron in the presence of a liquid has a tendency to revert to its original state, iron oxide. In the presence of oxygen and water, the reaction produces hydroxyl ions which, with the ferrous ions, form a precipitate consisting of ferrous hydroxide. If exposed to oxygen, this is converted to ferric hydroxide, the familiar reddish brown rust. Cracks in the concrete may form because the iron oxide corrosion products occupy a larger volume than the original metal [14].

Moisture in flat roofs is a major cause of their premature failure; it aggravates blistering, splitting, wrinkling and ridging in built-up membranes and seams in single-ply membranes [93]. Moisture may delaminate components, decrease their strength, cause corrosion and rot and make some components susceptible to deterioration [93]. Moisture causes new paint to peel within a year. Moisture between plies, or within the insulation, will result in delamination because of expansion-contraction or vaporization-condensation effects caused by daily and long-term temperature cycles [8]. The resulting blisters, ridges
and splits will allow further moisture penetration and membrane damage [8]. Trapped moisture causes ballooning of roofs. Vents can be used to relieve pressure build-up and to remove moisture from roofing system and in turn prevent ballooning; however, recent research has indicated that it is not possible to dry out wet insulation by venting [93]. Also, the presence of too much moisture in thermal insulation decreases the insulation’s performance. Therefore, a moisture survey is necessary before recovering.

Eaton [75] gave three non-destructive methods which are currently being used to survey moisture content: infrared thermography, nuclear backscatter and capacitance (Impedance). These methods detect changes in the roofing system’s properties due to moisture and do not directly detect water [93]. Any of these methods can be used to identify wet roofing location(s).

There are many factors that promote the presence of moisture in the roofing system among which are included:

- The moisture that comes from the roof deck or sloping screed if they are covered before they are completely cured.
- Moisture that exists in the membrane due to improper or long storage.
- Moisture that results from installing the roofing in poor weather such as rain or humidity.
- Improperly installed flashing or flashing damage.
- Cracks in the roof which can be passages for moisture.

Moisture in the roof can be minimized by doing the following:

- Providing ventilation in closed area.
• Adequate insulation should be used to prevent interior surfaces from dropping below the due point temperature [41].

• Vapor retarder may be required, if the inside humidity is high, to reduce moisture migration into the roofing system which can be treated paper, vinyl, bitumen, etc. [81].

### 5.1.4 Sand Storm and Wind

A problem common to BUR and single-ply membranes is the removing of gravel by wind. High wind and hurricanes can blow large loose gravel off the roof damaging properties and causing a devastating effect on windows and cars in the neighborhood and leaving the roof membrane unprotected [50]. To minimize the chance of this happening, large stones can be used because they are heavy and, therefore, harder for the wind to remove. Another solution to this problem is to use mechanical or adhesive attachments. In mechanical attachment systems, corrosion of the fastener can be a problem which may lead to premature failure; therefore, corrosion resistant fasteners should be used.

Storm and wind are not so serious in Saudi Arabia because there is no strong wind and because gravel is not usually used in residential buildings. If it is used, the parapet is often high enough to reduce the wind effect. Therefore, wind effect is often ignored. Parapets have a generally beneficial effect; they reduce the high suction on the interior areas of the roof, so they are recommended [94].
5.2 AREAS OF POTENTIAL PROBLEMS

On the roof and when installing the roof, there are many areas that are susceptible to roofing problems. These areas need particular attention in application and post-construction periodic inspection. They include: material attachment, joints, flashing, material defects and labor errors and all critical locations which were discussed in chapter 4.

Waterproofing in roofs is generally fully bonded to the roof deck and it is a fact that building movements do not spread themselves evenly, but express themselves at convenient points, such as dry work joints, change of plain, horizontal/vertical junctions, change of materials, etc. Consequently the stress imposed on the waterproofing becomes highly localized and with repeated cyclic action quickly exceeds its ability to resist and leads to inevitable early failure in many cases [5].

5.2.1 MATERIAL ATTACHMENT

A problem of single-ply membranes is that adhesive gluing of a membrane strip to its neighbor does not hold in some cases [95]. A good attachment method should be used.

5.2.1.1 Joints

Successful performance of the roofing membrane depends to a large extent on strong and watertight lap joints. In almost all cases when we talk about joints, we mean
lap joints; however, butt joints are used, especially with single-ply membranes such as EPDM, but on a low scale.

Leaks happen in joints of uneven areas. A common problem for bitumen sheets and single-ply systems is the failure of lap joints between sheets. Open laps are sources of moisture infiltration which can cause roofing problems.

In lap joints, watertight seams are made by heat welding or adhesive. Field studies of single-ply membranes have shown that unsatisfactory adhesion in seams is the most common problem causing leakage [57]. Lap joints may suffer from a void in the seam which can cause local separation between the sheets at the overlapping area. Bond strength of the joint is determined by the bond between adhesive molecules. Quality control of heat-welded seams is mainly undertaken visually or by cutting out and peeling seam pieces apart [57]. Non-destructive examination (NDE) is a testing method which does not involve damaging the test samples during the evaluation of the quality of lap joints.

In bituminous membrane, lap joints should be made carefully, ensuring proper melting of both membranes and allowing a proper bleed out at the seam [47]. When welding bituminous sheets, it is important to heat the sheets to a high enough temperature for a sufficient time for the melted surfaces to obtain sufficient cohesion [57]. However, overheating must be avoided or else the viscosity of the bitumen can reach the point where displacement of bitumen from its reinforcement occurs [57].
5.2.1.2 Flashing

Failure of flashing at critical locations is a common roofing problem. These locations include: parapets, pipe penetrations, vents, other penetrations such as stacks and AC ducts, drains, skylights, roof mounted equipment, expansion joints, etc.

Grittin [39] mentioned the following flashing failure modes:

- Sagging when a vertical flashing tends to slide downward which may result from omitting flashing nails or using low quality primer or adhesive.
- Ponding leakage.
- Leakage around poorly designed flashing.
- Leakage directly through the flashing as a result of improper application.
- Separation of flashing materials as a result of flashing design that does not account for the fact that different flashing materials have different coefficients of expansion and contraction.
- Diagonal wrinkling which may occur as a result of membrane shrinkage both parallel to and away from the parapet.
- Post-construction damage resulting from careless maintenance workers or roof visitors.

5.2.2 Material Defects

Failure rarely occurs solely due to faults in waterproofing membrane itself.
5.2.3 Labor Error

Labor error is always possible in the application of the roofing system. Therefore, a knowledgeable foreman should always be available for watching the labor work and for directing the workers in the proper application methods.
5.3 PROBLEMS

"Anyone who hasn't had major roofing problems is either lying or lucky," said George F. Rubin [96]. The roof represents about 5% of the cost of a typical building, but accounts for more litigation than any other building element [95]. Roofing is involved in 11% of all claims against architects and engineers as reported by the Washington DC-based insurer Victor O. Schinnerer & Co. [96]. Mistakes by the contractor can include everything from allowing materials to become wet during the project execution to poor execution of flashing details [96]. The designer might fail to provide enough drains or fail to design the roof with at least a minimal amount of slope [96]. There is often more than one guilty party and that includes owners who squeeze bids and ignore maintenance [96]. Most roofing problems lie not with membrane materials but with installation and maintenance.

Just like anywhere else, in Saudi Arabia roofing problems are very common. If you drive around in the cities, you will see many wood plenums and/or channels for removing debris from roofs of houses, as can be seen in Figure 115.
Rabiah, Saad [97] in his research "Quality Assessment Of The Saudi Arabian Buildings" has said that 68% of the houses surveyed had leakage problems. This shows that leakage is a serious problem which should be faced. The most shocking thing is that 52% of these houses had waterproofing material. That means, more than half of the waterproofing systems are not doing their job.

Madaghah, M. [98] in his senior thesis "Building Maintenance Problems in Saudi Arabia" listed leakage of roofs as one of the major building maintenance problems. He
discussed many problems that might appear during the life-time of a building including roof problems. He indicated that the major problems that could happen to roofs and waterproofing are: crazing of the asphalted surface which could be caused by ponding of rain water or melting snow on the roof; minor cracking of asphalt or built-up bitumen felt which could be caused by shrinkage of the asphalt or heat aging of bitumen felt; major cracking of asphalt or built-up bitumen felt which could be caused by differential movement between the waterproofing membrane and substrate; and ridging of built-up bitumen felt which could be caused by uneven laying of insulation boards or by thermal or moisture movement of the substrate. The ridging always occurs over or near the joints between the boards. Vaporization of entrapped moisture usually inflates the ridges. Leakage usually happens at weak points such as cracks in the slab or electrical conduit outlets. Leakage can be caused by the entrapment of water during construction or from rainfall. Rippling, tearing and blistering are the chief forms of leakage. Mr. Madaghah reported that close to 80% of the surveyed houses had roof problems. He summarized the problems by severity ranking as: leakage 79%, cracking 50%, crazing 25%, rippling 25%, and ridging 21%. He concluded that the most severe roof problems are leakage and cracking.

Flemban, G. [99] in his senior thesis "A Survey of Flat Roofs with particular Reference to their Performance in Saudi Arabia" discussed flat roofs as an extension to the enclosed living area where they are used as places to sleep at night. He discussed that when concrete is used in house roofs, it brought its own problems as it is a dense material which stores heat and expands and contracts. These properties make it vulnerable to
cracking. Cracks make paths for water to flow in and consequently cause leakage. It can only be stopped by using waterproofing. He indicated that asphaltic bituminous materials are the most commonly used in Saudi Arabia. Flemban mentioned three main types of waterproofing materials: built-up roofing using organic and inorganic felts and hot asphalt; sheet materials such as polyethylene, polyisobutylene and neoprene; fluid-applied epoxide vinyl polymers, neoprene and rubber-asphalt compound. However, waterproofing membranes for flat roofs in Saudi Arabia are at present based mainly on bituminous roofing felts. Flemban mentioned some situations to which special attention must be given. These are the various junctions existing on the roof, with parapet, pipe work, drains and upstand wall within the roof.

Goergerson [100] summarizes the roofing membrane problems for different roofing materials in the following table (Table III):
### TABLE III

**ROOFING PROBLEMS AND THEIR OCCURRENCE [100]**

<table>
<thead>
<tr>
<th>Problem</th>
<th>PMBM</th>
<th>Percentage of Occurrence</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EPDM</td>
<td>PVC</td>
</tr>
<tr>
<td>Lap/seam</td>
<td>43%</td>
<td>37%</td>
<td>8%</td>
</tr>
<tr>
<td>Flashing</td>
<td>18%</td>
<td>21%</td>
<td>15%</td>
</tr>
<tr>
<td>Shrinkage</td>
<td>16%</td>
<td>8%</td>
<td>33%</td>
</tr>
<tr>
<td>Puncture/tear</td>
<td>7%</td>
<td>14%</td>
<td>14%</td>
</tr>
<tr>
<td>Embrittlement</td>
<td>6%</td>
<td>2%</td>
<td>22%</td>
</tr>
<tr>
<td>Wind uplift</td>
<td>4%</td>
<td>8%</td>
<td>3%</td>
</tr>
<tr>
<td>Fastener</td>
<td>%</td>
<td>3%</td>
<td>-</td>
</tr>
<tr>
<td>Blistering</td>
<td>%</td>
<td>3%</td>
<td>-</td>
</tr>
<tr>
<td>Ridging/buckling</td>
<td>%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Splitting</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slippage</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other</td>
<td>7%</td>
<td>3%</td>
<td>5%</td>
</tr>
</tbody>
</table>
5.3.1 Primary Problems

Primary problems are the central problems that will lead to roofing failure. They include leakage and cracking.

5.3.1.1 Leakage

Leaks can start from the day the roofer leaves the job, compromising the design and construction of the roof. Leakage of roofs leads the list of all construction problems [96].

Poor workmanship is blamed for the vast majority of roof leaks. More than 60% of building owners blamed poor workmanship for the leaks and over half mentioned poor building design [96]. A quarter of the owners with leaks also blamed poor materials [96].

Leakage is by far the most common problem of flat roofs. It is the basic thing that waterproofing systems are designed to face. Therefore, other problems are leading to this central problem. All efforts are made to guard against roof leakage. It is the most critical problem that roofs of residential buildings in Saudi Arabia are suffering from. So, this is the main reason for which this research is proposed. Figure 116 shows a roof that was leaking; the owner of this house made many unsuccessful attempts to stop the leak but was successful only after covering the whole roof with a separate sheet metal roof.
Figure 116: A separate sheet metal roof was used to protect the original roof in a house in Doha.

5.3.1.1.1 Leakage Sources

When leakage occurs, the point of leakage and the source of water must be investigated. To identify the location of the leak is very difficult as defects in the waterproofing materials very seldom coincide with the place where the water enters the building on the underside of the slab[101].

Morrison [8] gave some hints that may lead to the source of a leak. It is not easy to find the leak location because in many instances the leak can show up at some distance from its original penetration by channeling within the roof. If the leak begins with the
falling of rain and stops soon after the rain stops, then the leak is probably close to where the water appears inside and it is probably resulting from a large crack or hole. If the leak appears during rain but only when the wind is strong or blowing in a certain direction, the source is likely to be a wall or flashing leak. If the leak continues long after the rain has stopped, it is probably coming from a pond or saturated insulation. If the leak is only on a wall, then it is likely to be from a failing flashing of wall or parapet. If the leak appears on cold days, it may be the result of condensation.

Interior inspection can be performed to detect problems by looking for signs of leakage such as stains, discolored ceiling tiles, peeling paint or wall covering.

5.3.1.2 Cracking

Built-up roofs will usually suffer from cracks. Built-up roofs deteriorate due to thermal stresses involving expansion and contraction.

Since the coefficient of thermal expansion of normal dense concrete is 6 x 10^6 per degree Fahrenheit, a temperature change of 80°F will expand concrete 0.05 percent or 0.06 inch in ten feet or 0.6 inch in 100 feet [14].

There are many causes of cracks other than thermal stresses, such as building settlement, deterioration of concrete integrity and high vibration caused by new neighboring constructions, especially those constructions that involve digging and rock breaking. Figures 117, 118, 119, 120, and 121 show some of the roof cracking mechanisms.
Figure 117: Cracks on the roof deck which should be treated before roofing commences.

Figure 118: Inside junction between the roof and the parapet is always a potential crack area.
Figure 119: Cracks can be seen from the outside at the junction between the roof and the parapet.

Figure 120: Cracks at the parapet and at the junction between the roof and the parapet.
5.3.2 Secondary Problems

Secondary problems are the problems that will lead to the primary problems. These usually happen first. They will not cause roofing failure unless they are left without remedy for a long time. If they are left with no correction, they may be converted to primary problems which are more likely to lead to roofing failure. These problems include blistering, ponding, ridging & splitting and crazing in addition to other problems as explained below.
5.3.2.1 Blistering

The main concrete pouring deck and the sloping concrete screed contain quite a large quantity of water. Trapped air and moisture vapor under the waterproofing membrane will form pressures which may lead to blistering of the waterproofing unless a form of pressure release is provided [26], specially in fully bonded application. The mechanism of blistering arises from pockets of trapped air and moisture which expand in the sudden heat of the sun and displace the membrane to form blisters [26]. The moisture often enters the system due to lack of adhesion between plies or between the membrane and the subsurface [100].

All blisters originate with the formation of a void or non-adhered membrane area. Voids may be caused by: moisture in the system, use of rolls crushed into oval, failure to broom out entrapped air, distorted insulation boards, trapping of foreign material and unfilled edges on cants [39]. Blisters probably grow from the evaporation of moisture and the expansion of the resulting water vapor contained within the void [39]. An 80°F (for example from 70 to 150°F) temperature rise expands water about 1500 times its original liquid volume [39].

Blisters drastically increase the membrane's vulnerability to degradation [39]. Precaution must be taken to prevent excessive moisture from being trapped during construction and also to allow for the release of vapor pressures which may build up under the waterproofing material. Failure to allow for the release of trapped moisture may lead to blistering of the waterproofing [26].
Blisters happen in almost all types of roofing systems such as built-up roofing, elastomeric and modified bitumen and polyurethane foam and coating.

In built-up roofing systems, blistering usually happens between plies, which leads to splitting. It occurs when moisture trapped between plies vaporizes, creating bubbles in the membrane [100]. In BUR, blistering takes three basic forms: full blistering, inter-layer blistering and top pitting [26]. See Figures 122 and 123.

Figure 122: Full membrane blistering [26].

Figure 123: Modes of built-up roofing blistering [39].
5.3.2.2 Ponding

The ponding of rainwater is frequently observed on flat roofs which increases the dead load and results in failure of waterproofing material. Therefore, sloping screed must be done carefully to clear the roof surface of water as rapidly as possible [26]. Dead load deflection should be taken into account so that it won't cause adverse effects on drainage flow, especially for decks that have the slope inherent in the roof deck and roofs that carry water tanks. The sloping screed usually negates the deflection consideration [26].

Ponding of water can cause cracking around the areas of the ponds. This happens because the wet membrane where the water stands is at a different temperature from the dry membrane sections [15]. A pond of water on part of a roof makes that area much cooler than the dry area; at the interface of the dry and wet areas stresses are induced within the roofing membrane [102]. Cracks develop around the edge of the pond due to different rates of expansion and contraction [15].

When water is allowed to stand on a flat roof, it can cause devastating effects. Watson [46] mentioned the following consequences of water ponding:

- If a minor defect or accidental puncture exists in the roofing system, water can flow into the system.
- The slow evaporation of ponded water can leave concentrated solutions of chemical pollutant from the atmosphere.
- Degradation of flashing.
- Growth of vegetation, grass and small trees with roots growing through the roofing membrane.

Figure 124 shows the effect of bonding on the roofing membrane.

![Figure 124](image)

**Figure 124**: Effect of ponding on the roofing membrane.

### 5.3.2.3 Blowing

Trapped moisture and air can cause lots of problems during the initial application of hot asphalt. The high asphalt temperature raises the temperature of moisture droplets above boiling point and causes air expansion which increases steam temperature. Bubbles and blows are formed as a result of the gas forcing its way through the waterproofing
material. This is caused by lack of securement to the substrate due to the use of insufficient fasteners, inappropriate adhesive or poor application of adhesive.

5.3.2.4 Ridging and Splitting

Splits are long cracks in the roofing membrane. Splitting usually occurs in cold weather on bituminous membranes [103].

If there is no allowance for movement, splitting problems are likely to occur. The design should take account of structural movement to reduce the likelihood of movement being transmitted to waterproofing material [26]. Cycles of movement can cause a slip of the adhesive stitch of the membrane which in turn creates loose materials in certain locations forming ridges [26]. Splitting resulting from movement mechanisms affects the skirting more than other locations.

Splitting has many causes acting singly or in combination. They include: stress from differential movement or cracking of the structural deck, ponding on the membrane, stress that occurs when a poorly attached membrane contracts, high wind, rolling loads moving across the roof, static loads that cause deflection, thermal contraction, insulation movement, water absorption in felts, shrinkage cracking of poured decks, deck deflection and stress concentration [39].

Ridges are narrow elongated wrinkles. Ridging or wrinkles normally occur over the joints of dimensionally unstable insulation boards or roof deck [39]. Common causes for ridging are [103]: felt expansion when it absorbs moisture, expansion and contraction
of poorly attached membrane or insulation during seasonal changes and slippage of insulation or deck.

5.3.2.5 Crazing

Crazing is caused by thermal expansion and contraction. It occurs usually on exposed roofing. It is a surface effect only and should not be a cause for concern. It is a function of surface temperature. The thicker the membrane, the better crazing resistance it holds. Figure 125 shows an example of crazing effect.

![Figure 125: Crazing](image)

5.3.2.6 Delamination

Delamination is not a very common membrane failure. Usually it is caused by: application of inadequately heated bitumen, insufficient bitumen between felts (in case of built-up roofing), mixing of incompatible materials, and absorption and evaporation of water. This problem mostly happens in polyurethane foam and coating systems.
5.3.2.7 Flashing Defects

Flashing defects happen in almost all types of roofing systems such as BUR, elastomeric systems and modified bitumen. Flashing problems are commonly caused by lack of securement, movement of the metal counter flashing with respect to the parapet or wall and/or disintegration of the supporting mortar.

5.3.2.8 Fishmouthing

Fishmouthing is the lifting of laps or openings at felt edges or unbonded edges that allows water into the system. It resembles the open mouth of a fish. Common causes of fishmouthing are [103]: pulling of felts during installation, wrinkles formed during installation, excess solvent in PVC systems and inadequate welding of the seams. This is usually a bitumen and elastomeric membrane problem.

5.3.2.9 Slippage

Slippage is the felt movement of one ply relative to another. Common causes of slippage include: excessive use of interply bitumen, improper selection of bitumen types, overheating of bitumen and combination of the above. This is usually a bitumen membrane problem.
5.3.2.10 Puncturing

Punctures or breaks in the roofing membranes are usually caused by [103]: broken blisters, nails backing out of the deck, dropped objects, hails and mechanical abuse. Puncturing results in flashing leaks that are difficult to locate.

5.3.2.11 Falling of Plaster

Falling of plaster is caused by seepage of water into the roof deck and the corrosion of its concrete reinforcement.

5.3.2.12 Others

Some other roofing problems are as follows:

1. Decay of non-durable waterproofing materials [1]; See Figures 126 and 127.

2. Lamination and breakage of small roofing units e.g. tiles cased by exposure to sun and temperature changes[1].

3. The disturbance or stripping of loading layer by wind pressure or when fixings are inadequate or have corroded.

4. The splitting of a continuous membrane following bubbling due to water vapor pressure produced by solar heating of water contained within the roof structure such as [1]:
   - Residual water used in casting concrete or in mixing wet screeds.
   - Rain falling and being absorbed by the structure prior to the application of waterproofing.
5. Condensation within the roof structure of water vapor coming from the air beneath it.

Figure 126: Brittleness of liquid applied membrane after 3 years of exposure.

Figure 127: Brittleness of liquid applied membrane after 3 years of exposure.
5.3.3 Concrete Mix

Lots of problems are encountered because of bad concrete mix. Some of the chemicals used can cause problems. Sweet water and good quality aggregate must be used to avoid concrete deterioration. The water content should be controlled to avoid unneeded water.

Al-Bahii in his research [104] indicated that 45% of ready mix concrete factories in Saudi Arabia have low characteristic strength, less than the nominal design strength and 45% also have bad production practices in terms of uniformity and production because of faulty control systems. This indicates that low quality ready mixed concrete used in roofing, whether the main roofing deck or the sloping concrete screeds could be the main cause of roofing failure.

Al-Idi et al [105] indicated three causes of concrete deterioration:

1. Deformation and cracks in the concrete mix which allow gases and chemical contaminants along with oxygen and moisture to penetrate the concrete.

2. Low quality aggregates of relatively soft limestone.

3. Brackish ground water used in mixing and curing.

For good durability, it is recommended to use good dense low w/c ratio concrete with proper concrete cover over reinforcement [106].
5.4 CAUSES OF ROOFING/WATERPROOFING PROBLEMS AND FAILURE

There are lots of causes that will lead to leakage and roofing failure if not corrected. Premature roofing failures are caused by both economical and technical factors [39]. Al-Diyab [27] listed 5 causes of roofing problems: poor workmanship, faulty detailing and design, incorrect evaluation of local conditions, damage and abuse of the material and choosing cheap systems. R. Aston [107] indicated that over 50% of roof failure was due to faulty design and about 35% to faulty workmanship. He stated that the principle causes of failure were condensation within the roof structure and thermal movement between its separate elements. Bill Russo of Denver, Co, a roofing consultant, stated that the major contributing factors to roof problems and failures are lack of proper design input, improper application and, on occasion, material failure [108]. Chissick [4] mentioned that of 500 defects, 42% were due to design, 47% were due to workmanship and 11% were due to unexpected use.

Sidny Slade of Awazel said that 60% of Awazel contracts are for re-roofing projects of buildings which were designed without adequate slopes, too few drainage outlets and parapets as low as 5 cm above roof deck. It is estimated that more than two thirds of roofing activity in the US involves re-roofing [75]. These projects involve approximately 2 billion square feet of roofing per year [109]. Some of the roofing problem causes are discussed below:
5.4.1 Faulty Design

Roofing design is the most important factor in making successful roofing. More than half of all roofing problems are caused by failing design principles. Marsh [78] indicated that most failures of flat roofs are not inherent failures of the roof covering but are design failures.

The efficient removal of water from the roof area should be given careful attention. The roof should have adequate slope. Ponding should be avoided. Standing water increases the risk not only of leakage through defective roof covering, but also by itself causing defects due to differential temperature build-up of the top layer of the roofing [78]. Even minor defects in the roof covering can lead to disastrous results.

Sidny Slade of Awazel indicated that recently an architect came to Awazel with a design in which 6000 m² roof had one rainwater outlet. The water was expected to travel 52 meters to reach the outlet.

AE typically select materials and assembly instructions from literature furnished by materials makers which may or may not apply to the specific job [95].

The most common bad design practice is the use of inadequate or poor detailing in design and construction leading to cracking at joints and rupture by differential movements between the roof covering and the substrate [110].

Poor design can result in: movement of the deck below the roof membrane, build-up of water vapor below the membrane and solar radiation damage to the membrane.

Marsh [78] gives five basic principles which should be considered in the design of any flat roof:

1. **Drainage:** Ensure that water is directed away from the roof to prevent pooling and runoff.
2. **Slope:** Ensure that the roof has a sufficient slope to facilitate drainage.
3. **Seamless Completion:** Ensure that all edges and seams are properly designed and constructed to prevent water infiltration.
4. **Material:** Use appropriate materials that are compatible with the environment and the intended use of the roof.
5. **Maintenance:** Establish a regular maintenance schedule to ensure the roof remains in good working order.
1. Roof drainage

2. Protection of roof covering from structural, thermal and moisture movement of the deck.

3. Protection against solar radiation.

4. Entrapped construction water must be allowed to escape.

5. Condensation must be prevented from forming below the roofing membrane.

An example of bad design is the use of a small size drainage outlet as shown in Figure 128.

Figure 128: Newly installed roofing with 2-inch drainage outlets which is small and should not be used.
5.4.2 Poor Workmanship

Poor workmanship is one of the main causes of roofing problems, especially at the lap welds between sheets and the roofing detailing at critical locations. We can say that regardless of the quality of the component materials, the roof's integrity depends totally on good field work [39].

5.4.3 Saudi Arabia's Weather

Saudi Arabia has very harsh weather conditions on the waterproofing materials because of large difference of temperature in daylight and at night. Humidity in coastal areas and dust are among the characteristics of Saudi Arabia’s weather. Materials that will be used in Saudi Arabia should be carefully evaluated for suitability. Severe environment coupled with bad construction practices are the causes for the deterioration of concrete structures [106]. In addition, condensation is one of the main causes of failure.

5.4.4 Storage and Handling

Bad handling and storage of waterproofing materials can seriously affect their integrity. Each roll has to be carried individually to the site, either by hand or mechanical load lifters [47]. Bad handling includes throwing the rolls and pulling them on the ground.

Bad storage includes storing the rolls over each other, storing in a hot location and storing them exposed to the sun. Waterproofing membranes, whether palletized or loose, should be stored in a covered area. The rolls should be stored in a vertical position on a smooth floor so that edges won’t be damaged.
5.4.5 Selection of Cheap Systems

Some roofing contractors use cheap materials and systems and give long warranty periods hoping for a quick profit or that the he will change his work or will leave the country later. Aggressive bidding will lead to short cuts in specifications.

5.4.6 Faulty Use

It was said before that any design can be made to fail if it is used in a way for which it was never designed [4].

5.4.7 Other Causes

There are some other causes of roofing problems such as:

1. The job is fast tracked.
2. Everything on the job is cut to the bone.
3. To use little or the wrong bitumen or adhesive.
4. Edges that are structurally independent from perimeter wall [111].
5. Dead-level roofs that pond with water.
6. Roof decks containing excessive moisture, causing blisters.
7. Improperly designed flashing.
8. Roof drains of insufficient size, number, style and placement to drain a roof quickly [14].
9. Lack of required maintenance by owner. See Figure 129.
10. Usage of incompatible materials in the same roofing system.

11. Damage by other trades.

12. Poor detailing.

13. Lack of expansion joints.

14. A common problem is the carelessness of maintenance workers on the roof who damage the roofing with their tools.

Figure 129: Electrical conduit box was neglected and left open on the roof.
5.5 PROBLEMS REMEDY

5.5.1 REDUCTION OF WATER CONTENTS IN ROOFS

Residual construction water or water accumulated from rainfalls on an exposed slab can be drained through weepholes formed at low points. Entrapped moisture should be continuously ventilated through outlets in the roof covering. Structural integrity may be threatened if water seeps to the roof deck and then to the house columns and foundations. The penetration of water into dense reinforced concrete roofs is not likely to cause deterioration as the dense material excludes the oxygen and carbon dioxide necessary for reinforcement corrosion [1].

5.5.2 INSPECTION AND PREVENTIVE MAINTENANCE

Roof inspection should be carried out each six months. Defects will most likely be found at the bottom of skirting, over joints in insulation or other roof boards, alongside gutters or at rain water outlets [85].
5.6 PROBLEMS FREE ROOFING

John McDermond, Manager, BondCote Roofing Systems, LaGrange, GA, stated that roof warranty does not keep the water out, rather a properly designed and detailed system and quality workmanship create a successful roof system [108].

A roof membrane is expected to last 20 years; only BUR has this kind of proven lasting performance [95]. The secret to trouble-free, 20-year BUR roofs lies in a trouble prevention approach; that is, appropriate design, highest quality materials and retaining a roofing contractor who understands the value of building [95]. Increasing the thickness of the plies of bitumen and reinforcement in built-up roofing can increase the tensile strength and in turn prevent the cracking problem.

To make successful roofing without problems, the following should be done:
1. The flat roof must be designed so that condensation cannot occur between the ceiling and the outer surface.
2. The waterproofing material used should be strong enough to withstand movement of the substrate and temperature changes.
3. The critical locations must be such that weak spots are not formed at corners, joints, parapets, upstands, pipes and drainage outlets.
4. Inspection and maintenance should be carried out regularly.
5. A good attachment method should be used.
6. Choose compatible insulation. Thermal insulation materials must be compatible with the roofing membrane. Adhesives or solvents used to seam certain membranes dissolve polystyrene insulation [82].

7. Be sure flashing is correct. Most roofing problems are flashing problems. Proper detailing and installation require more money but it is money well spent [50].

8. Minimize equipment on the roof. Equipment on the roof requires flashing and flashing is the source of most roofing problems.

9. Inspect the roof after bad weather and at least once a year.

10. Develop detailed specifications that are proper for the selected system.

11. Select quality contractor.

12. Practice a quality controlling during installation.

13. Perform a flood test upon completion of installation of the roofing membrane. See Figure 130.
5.6.1 Safety and Quality

Safety and quality are the two keys for successful roofing. Quality control should begin with the employee. Management of the contractor should have a quality control program.
5.6.2 Roof Design

It must be known that there is no one roofing system which will suit all conditions. Each roofing should be designed individually taking into account all relevant factors pertaining to the particular house roof.

Ref. [112] lists some of the main design factors to be considered:

1. Adequate depth of roof zone and slope.

2. Selection of roof deck.

3. Falls and outlets.


5. Appropriate insulation materials.

6. Wind loading.

7. Form of attachment: full or partial bonding.

8. Waterproofing material.


10. Design details such as skirting of upstands.

5.6.3 Owner’s Involvement

In order to have successful roofing and to assure long satisfactory roofing performance, the owner should be involved in all stages of the roofing project from specification to installation. Only roofing systems that have long-proven in-service track records should be specified; new systems may prove unreliable [113].
5.6.4 Selection of the Roofing Contractor

Lots of owners spend a lot of time trying to find the best roofing material in the market, thinking that this approach is the key to successful roofing. Having the best roofing material is good; however, materials alone cannot guarantee roofing success. A few owners look for the best roofing contractor.

The selection of the roofing contractor is the key to a satisfactory installation. A reputable roofing contractor should be selected. This contractor should be experienced in the specified roofing system and financially stable [113]. The owner should not be tempted to award the installation contract on the basis of an unreasonably low price [113]. A good contractor performs the work in a professional and timely manner. To know who will meet these specifications, contractors should be prequalified by supplying information that includes a list of experienced personnel with their credentials, previous job references, audited financial statements; in addition, the owner should inspect current roofing work and previous roofing work and check previous customers' satisfaction [114]. Also work to be accomplished should be described in detail including the quantity of materials, the type of roofing system, type of installation, start and completion dates, warranty, etc.
6. CHAPTER SIX

RESEARCH DESIGN

6.1 METHODOLOGY

The initial phase of this research was to search in the literature to find out the waterproofing systems available and the problems that are associated with them. This will include the identification of roofing components and the construction methods that are used to assemble these components. Greatest emphasis was put on the waterproofing membrane. The second phase involved surveying the local market to see what is available. This included meeting the suppliers to ask them about what they have. The last phase involved gathering data through questionnaires. In general, the questionnaires told us about three things: materials used, application methods and problems faced.

6.1.1 MARKET SURVEY

A market survey was conducted to see what is available in the market with respect to materials and services. This told us about materials and services that an owner might not otherwise take advantage of.
6.1.2 MEETINGS WITH SUPPLIERS

Meetings with different suppliers were held to see what concerns they have about their materials and to see if some of the problems faced by owners were misuses that suppliers had cautioned against. The aim was also to ask suppliers about the real problems they have encountered.

6.1.3 QUESTIONNAIRE TO HOUSE OWNERS

A questionnaire to house owners was distributed. A total of 109 questionnaires were distributed; only 101 were accepted. The respondents included owners from Eastern Province cities, Jeddah, Riyadh and Tabuk. Houses are the real life laboratories for roofing materials; therefore, the responses of house owners to the questions are the most valuable material of this study. To support the questionnaire, meetings were held with owners as needed.

The questionnaire consisted mainly of six groups. Each group contained several questions. These groups of questions were: house information, roof insulation, thermal insulation, waterproofing, roof assembly and problems encountered.

6.1.4 QUESTIONNAIRE TO ROOFING CONTRACTORS

This study sought included the opinion of the roofing contractors through a separate questionnaire. Roofing contractors are the main players in the roofing works. They make the difference between good roofing and bad roofing; therefore, their input could not be overlooked. All Eastern Province Roofing Contractors were contacted to fill
the questionnaire. A total of 24 contractors/respondents filled in the contractors’ questionnaire. Most of these contractors are either branches from main offices in Jeddah, Riyadh and Al-Ahsa or have branches in these locations in addition to other locations in different Provinces in the Kingdom. Therefore, we can say without any hesitation that these roofing contractors responded on behalf of all roofing contractors in Saudi Arabia. In other words, this study covered roofing contractors in the Kingdom.
6.2 DATA COLLECTION

The data was collected through literature of books, articles, theses, dissertations and manufacturer's literature. Also data was collected through the questionnaires that were distributed to house owners and roofing contractors. A quite extensive literature was collected and reviewed even the questionnaires had been analyzed.

6.3 POPULATION UNDER STUDY

The survey included houses in the Eastern Province. Investigating 100 houses was adequate in fulfilling our objectives. The selection of the houses was random with the consideration that houses of different ages be included in order that we could get an indication of how early problems occur.

6.4 DATA ANALYSIS

After questionnaires were received, they were analyzed. The results are in chapter 7.
6.5 RESEARCH STEPS

6.5.1 INFORMATION GATHERING

1. Part of the literature was reviewed.
2. A market survey was made to see what is available in the market.
3. Meetings were held with suppliers, manufacturers, contractors and owners to ask about problems encountered from installations as well as from products.

6.5.2 QUESTIONNAIRE DISTRIBUTION

Questionnaires were prepared and distributed to owners and roofing contractors.

6.5.3 PERSONNEL INTERVIEWS

1. Personal interviews with house owners and roofing contractors were made.
2. Personal interviews with waterproofing suppliers and manufacturers were also made.

6.5.4 CONCLUSION AND RECOMMENDATIONS

After the literature was reviewed and questionnaires were analyzed, conclusions summarizing the findings were drawn. From these findings, recommendations are given in the last chapter.
CHAPTER 7

7.0 QUESTIONNAIRE ANALYSIS AND RESULTS

7.1 CONTRACTORS' QUESTIONNAIRE

This questionnaire was distributed to all known roofing contractors in the Eastern Province. Most of these contractors have branches in other Saudi Arabia’s provinces or they are branches for contractors in other province. A total of 24 contractors were met and filled this questionnaire.

7.1.1 ROOFER INFORMATION

This part of the questionnaire deals with some background about the roofing contractor
Question No. 1  
**How long have you been in roofing business?**

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Less than 3 years</td>
<td>3</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>2. Between 3 and 7 years</td>
<td>6</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>3. Between 7 and 12 years</td>
<td>3</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>4. More than 12 years</td>
<td>12</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>5. Additional Remarks</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

The above table shows that half (50%) of roofing contractors in the Eastern Province are experienced contractors with more than 12 years, experience. Also 62.5% of roofing contractors have more than 7 years of experience. This basically tells us two things: we should not have so many roofing problems as we are having today, and these contractors are successful contractors or else they would not have stayed in business for so many years. Another factor is how large a percentage of roofing jobs those 62.5% are getting? 87.5% of roofing contractors have been in business for more than 3 years. These 87.5% are assumed to be successful contractors. Successful contractors are assumed to be doing a good job. Only 12.5% of the contractors are assumed to be inexperienced contractors with less than 3 years in business. See Figure 131.
Figure 131; Contractors Years of Experience. Half of them have more than 12 years.
Among roofing contractors in the Eastern Province, there are only three large contractors. More than half (54%, with less than 50 workers) are relatively small contractors with respect to the number of employees. This indicates that either roofing work is not labor dependent work (i.e. few workers can do a big job) or that the roofing market is not so big as to require large number of workers. This also indicates that a contractor with few workers can survive and shows that roofing work can be done successfully with few workers, making roofing an easy business. See Figure 132.
Figure 132: Roofers' size with respect to number of workers.
Question No. 3  Approximately, how many square meters do you perform annually?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Less than 10,000 m²</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>2. Between 10,000 and 20,000 m²</td>
<td>6</td>
<td>25</td>
</tr>
<tr>
<td>3. Between 20,000 and 50,000 m²</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>4. More than 50,000 m²</td>
<td>11</td>
<td>46</td>
</tr>
</tbody>
</table>

Forty six percent (46%) of the respondents are large contractors who perform more than 50,000 m² a year. A total of more than half a million (550,000) m² is performed by 11 contractors, which is less than half of the respondents. This shows how large the roofing business in Saudi Arabia is and if a large business has problems then lots of money is wasted. Therefore, problems have to be identified and corrective recommendations need to be executed. See Figure 133.
Figure 133: Roofers' size with respect to the amount of square meters performed annually.
Chapter 7: Questionnaire Analysis And Results

Question No. 4. It is appreciated if you kindly list 10 residential villas you have worked on?

There are two purposes for this question. The first is to see how successful is the work of a particular contractor by asking his clients about his work. The second purpose is to support the second questionnaire by having available information about owners so that they can be called to fill the second questionnaire. More than 120 villa projects were provided. Other projects such as hospitals, mosques and schools were also provided but they were ignored since they were not included in the scope of this research.

Question No. 5. In Saudi Riyals, what is the average roofing cost of an average roofing system for an average size villa (300 m²)?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Less than 10,000 SR</td>
<td>7</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>2. Between 10,000 and 20,000 SR</td>
<td>11</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>3. Between 20,000 and 35,000 SR</td>
<td>4</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>4. More than 35,000 SR</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

From the results above, it can be seen that the average cost of roofing is not too expensive. 29% of the respondents indicated that roofing cost was less than SR 10,000 and 46% indicated that roofing cost was between SR 10,000 and SR 20,000, say SR 15,000. That is, 75% of the respondents were in the low cost range. This shows that roofing cost is not too expensive according to roofing contractors. See Figure 134.
Figure 134: Average roofing cost for 300 sq. meters.
Question No. 6. When a roofing work is completed, how do you check that you have done a good functionally working roofing system?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. By doing a flood test</td>
<td>23</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>2. By satisfying a customer’s desire</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>3. I have good materials and trained labor so I trust that all my work is good</td>
<td>5</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>4. Other methods/remarks</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

Almost all respondents (96%) indicate that they do a flood test after completing roofing jobs to insure that the roofing work is effective and has no defects. Doing flood tests is a good practice, because even if good quality materials were used and even if the best trained workers did the roofing, mistakes may happen. This reveals that roofing works should not have problems. See Figure 135.
Figure 135: Methods of checking how good is the roofing system.
## Question No. 7.
How many years is your warranty for the roofing system you are doing?

<table>
<thead>
<tr>
<th>No.</th>
<th>Roofing System</th>
<th>Warranty in Years</th>
<th>No. of Contractors Giving This Warranty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inverted Roof System</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Exposed Asphalt</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Exposed EPDM</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Covered EPDM</td>
<td>&gt;10</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Small Jobs</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Medium Jobs</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Big Jobs</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Under Sloped Concrete</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Bituminous Membrane with Polyester</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Bituminous Membrane</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>Bituminous Membrane</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>12</td>
<td>Double Layer System 4 mm each layer</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>Built-up Roofing</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Bituminous Membrane (Single &amp; Multiple Layer)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>Polyurethane</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>Sprayed Polyurethane</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>Acrylic Based Materials</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>Acrylic Liquid-applied</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>Hypalon (Single Play)</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>PVC</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>
Warranty of 1 Year

Most contractors give one year warranty for acrylic based liquid applied waterproofing materials. Some give up to 3 years for this system. Also small jobs are given one year warranty.

Warranty of 5 Years

Five years’ warranty is given for the following waterproofing systems:

- Exposed Bituminous Membranes
- Waterproofing system where the membrane is covered by sloped concrete screed
- Medium size jobs
- Sprayed Polyurethane

Warranty of 10 Years

Ten years’ warranty is granted for the following systems:

- Inverted roofing system regardless of the material
- Exposed EPDM
- Polyurethane (at least one contractor)
- Modified Bitumen with Polyester enforcement
- PVC
- Hypalon
Chapter 7; Questionnaire Analysis And Results

Warranty of more than 10 Years

Covered EPDM is given more than 10 years’ warranty. Multi-layer bituminous membrane system is given 15 years’ warranty. Also built-up roofing is given 15 years’ warranty.

No system is given more than 15 years’ warranty. Most systems are given 5 years’ warranty. It can be concluded that the normal warranty period is 5 years.

<table>
<thead>
<tr>
<th>Question No. 8</th>
<th>What are the limitations on your roofing warranty?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANSWERS:</strong></td>
<td><strong>No. of Answers</strong></td>
</tr>
<tr>
<td>1. Workmanship only</td>
<td>1</td>
</tr>
<tr>
<td>2. Materials only</td>
<td>1</td>
</tr>
<tr>
<td>3. Comprehensive materials and workmanship</td>
<td>19</td>
</tr>
<tr>
<td>4. Comprehensive materials, workmanship and all other damages to the house</td>
<td>4</td>
</tr>
<tr>
<td>5. Other remarks</td>
<td>0</td>
</tr>
</tbody>
</table>

Almost all respondents give warranty for their work; 79% of the respondents guarantee both their materials and workmanship. 17% of the respondents insure all damages to the house that are caused by poor workmanship and material, see Figure 136. This shows the high level of awareness and confidence among all roofing contractors, which promises problem-free roofing in future because contractors will make every effort
to do a high quality job. But the problem is that some owners, who are looking for cheap prices, hire unqualified contractors who do poor jobs. It can be concluded that there are two problems: irresponsible contractors who give a warranty but do not abide by it and owners who hire unqualified and/or non-specialized contractors.

Figure 136: Limitations in roofing warranty versus the percentage of roofing contractors using these limitations.
### Question No. 9. On what basis do you give your warranty?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I trust my labor</td>
<td>5</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>2. I trust that my materials are the best</td>
<td>6</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>3. My experience with materials and application methods</td>
<td>23</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>4. Others, Specify</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Depends on the building</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>-- Depends on the warranty of the manufacturer of the material</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

All respondents except one (96%) indicated that experience with materials and application methods are the main bases for their warranty. This indicates that an (if not the most) important factor in roofing work is the application method of good material. 21% indicated that their trust in their labor is their base for warranty. Also 25% indicated that their trust in their materials is the basis for the warranty. These percentages show that roofing contractors know what they are doing. See Figure 137.
Figure 137: Basis for warranty versus the percentage of contractors.
**Question No. 10**  Is there any roofers' pre qualifications?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes (Elaborate)</td>
<td>14</td>
<td>58</td>
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<tr>
<td>2. No</td>
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<td>21</td>
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<td>3. No answer</td>
<td>4</td>
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<td>4. Depends on Commercial License</td>
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</table>

There are many different answers for this question. 58% of the contractors indicated that there are pre-qualifications asked specially by large customers such as Saudi Aramco, Sabic, and some government agencies. Such pre-qualifications include number of workers and number of projects performed. Four contractors did not answer this question. One contractor said that roofing work should only be performed by a contractor who is registered as a roofer at the chamber of commerce. Obviously, not all roofers are registered as roofers because usually customers do not ask for a roofer's certificate. Customers are concerned only about the price and how the contractor presented himself to them as a roofer. It is recommended that customers ask for valid roofer's registration.
7.1.2 Roofing Components

Question No. 11. What are the roofing components you use?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
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<tbody>
<tr>
<td>1. Flashing</td>
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<td>2. Gravel</td>
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<td>3. Fixed tiles</td>
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<td>4. Loose tiles</td>
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<td>5. Expansion joints</td>
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<td>7. Thermal insulation</td>
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<td>8. Roofing membrane (Waterproofing)</td>
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<td>9. Screed concrete</td>
<td>15</td>
<td>58</td>
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<tr>
<td>10. Sealant in the screed concrete</td>
<td>9</td>
<td>37.5</td>
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<td>11. Others (specify)</td>
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<td>Light Weight Concrete</td>
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<tr>
<td>Cant Strip</td>
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<td>4</td>
<td></td>
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<tr>
<td>Rock Wool</td>
<td>1</td>
<td>4</td>
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</table>

Looking at the number of contractors using different roofing components, we can see that most contractors used most of the roofing components mentioned. Therefore, most of the contractors have enough experience in using roofing components such as flashing which is used to seal critical locations, expansion joints, waterproofing membrane, and thermal insulation. This shows that we have experienced contractors in the market. See Figure 138.
Figure 138: Usage of different roofing components versus percentage of contractors.
### TABLE IV

table: roofing systems offered by roofing contractors

<table>
<thead>
<tr>
<th>NO</th>
<th>Roofing System</th>
<th>Remarks</th>
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<tr>
<td>1</td>
<td>1 Roof Deck (Main Concrete Pouring)</td>
<td>This is an inverted, covered, accessible</td>
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<tr>
<td></td>
<td>2 Sloped Screed Concrete</td>
<td>roofing system using bituminous roofing</td>
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<tr>
<td></td>
<td>3 Cant Strip</td>
<td>membrane and fixed tiles as the loading</td>
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<tr>
<td></td>
<td>4 Roofing Bituminous Membrane</td>
<td>layer.</td>
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<td></td>
<td>5 Polyethylene Protection Layer</td>
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<tr>
<td></td>
<td>6 Thermal Insulation</td>
<td></td>
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<tr>
<td></td>
<td>7 Separation Layer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 Sand &amp; Cement</td>
<td></td>
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<tr>
<td></td>
<td>9 Fixed Tiles</td>
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<td>10 Flashing</td>
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<td>2</td>
<td>1 Roof Deck (Main Concrete Pouring)</td>
<td>This is an inverted, covered, non-</td>
</tr>
<tr>
<td></td>
<td>2 Sloped Screed Concrete</td>
<td>accessible roofing system using gravel as</td>
</tr>
<tr>
<td></td>
<td>3 Waterproofing</td>
<td>a loading layer with loose tiles as</td>
</tr>
<tr>
<td></td>
<td>4 Thermal Insulation</td>
<td>walkways.</td>
</tr>
<tr>
<td></td>
<td>5 Separation Layer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Gravel with Loose Tiles as Walkways</td>
<td></td>
</tr>
</tbody>
</table>
### Chapter 7: Questionnaire Analysis and Results

| 3 | 1. Roof Deck (Main Concrete Pouring)  
2. Waterproofing  
3. Thermal Insulation  
4. Separation Layer  
5. Sloped Screed Concrete | This is an inverted, covered, accessible roofing system using sloped concrete screed as a loading layer. This is not recommended system since the waterproofing is installed on a non-sloped deck. This is recommended only if the roof deck is sloped. |
|---|---|---|
| 4 | 1. Roof Deck (Main Concrete Pouring)  
2. Thermal Insulation  
3. Sloped Screed Concrete  
4. Waterproofing | This is a conventional, exposed, non-accessible roofing system using sloped concrete screed as a loading layer installed on the top of the thermal insulation material. In order to prevent its cracking, the screed had to be enforced. |
| 5 | 1. Roof Deck (Main Concrete Pouring)  
2. Waterproofing  
3. Thermal Insulation  
4. Sloped Screed Concrete | This is an up-side down; covered, accessible roofing system which resembles system #3 except it has no protection layer over the thermal insulation material. |
| 6 | 1. Roof Deck (Main Concrete Pouring)  
2. Thermal Insulation  
3. Sloped Screed Concrete  
4. Waterproofing  
5. Gravel | This is a conventional, covered, non-accessible roofing system just like system #4 but the waterproofing is covered by gravel. |
| 7 | 1. Roof Deck (Main Concrete Pouring)  
2. Thermal Insulation  
3. Sloped Screed Concrete  
4. Expansion Joints  
5. Waterproofing | This is a conventional, exposed, non-accessible roofing system which resembles system #4 except that the sloped concrete screed has expansion joints. |
| 8 | 1. Roof Deck (Main Concrete Pouring)  
2. Sloped Screed Concrete  
3. Waterproofing  
4. Thermal Insulation  
5. Protection/ Separation Layer  
6. Gravel  
7. Flashing | This is an inverted, covered, non-accessible roofing system which resembles system #2 except that flashing is added.  
Six contractors indicated that they make this system. |
| 9 | 1 Roof Deck (Main Concrete Pouring) | This is an inverted, covered, accessible roofing system which resembles system #8 except that it has non-removable loading layer. |
|   | 2 Sloped Screed Concrete |   |
|   | 3 Waterproofing |   |
|   | 4 Thermal Insulation |   |
|   | 5 Protection Layer |   |
|   | 6 Fixed Tiles |   |
|   | 7 Expansion Joints |   |
|   | 8 Flashing |   |
| 10 | 1 Roof Deck (Main Concrete Pouring) | This is an inverted, covered, non-accessible roofing system (RS) which resembles system #2 but without walkways. It also resembles RS no. 8 but without flashing. |
|    | 2 Sloped Screed Concrete |   |
|    | 3 Waterproofing |   |
|    | 4 Thermal Insulation |   |
|    | 5 Protection Layer |   |
|    | 6 Gravel |   |
| 11 | 1 Roof Deck (Main Concrete Pouring) | This is a conventional, covered, non-accessible roofing system which resembles system #6 but with protection layer installed on the waterproofing. |
|    | 2 Thermal Insulation |   |
|    | 3 Sloped Screed Concrete |   |
|    | 4 Waterproofing |   |
|    | 5 Protection Layer |   |
|    | 6 Gravel |   |
| 12 | 1 Roof Deck (Main Concrete Pouring) | This is a conventional, covered, accessible roofing system. Cement protection layer is added to protect the waterproofing membrane against ultraviolet radiation. |
|    | 2 Thermal Insulation |   |
|    | 3 Sloped Screed Concrete |   |
|    | 4 Waterproofing |   |
|    | 5 Cement Protection Layer |   |
| 13 | 1 Roof Deck (Main Concrete Pouring) | This is an inverted, covered, non-accessible roofing system (RS) which resembles RS #2 and RS #10 but with loose tiles used as the loading layer. |
|    | 2 Sloped Screed Concrete |   |
|    | 3 Waterproofing |   |
|    | 4 Thermal Insulation |   |
|    | 5 Protection Layer |   |
|    | 6 Loose Tiles |   |
| 14 | 1 Roof Deck (Main Concrete Pouring) | This is a simple exposed non-accessible system with no thermal insulation. |
|    | 2 Bituminous Rolls with Granule |   |
|    | 3 Flashing |   |
| 15 | 1 Roof Deck (Main Concrete Pouring)  
2 Thermal Insulation (Sprayed Polyurethane)  
3 Polyurethane Waterproofing  
4 Sloped Screed Concrete | This is a conventional, covered, accessible roofing system that uses sloped concrete screed and polyurethane waterproofing material. |
|---|---|---|
| 16 | 1 Roof Deck (Main Concrete Pouring)  
2 Thermal Insulation (Sprayed Polyurethane)  
3 Acrylic Waterproofing  
4 Sloped Screed Concrete | This is a conventional, covered, accessible roofing system that uses sloped concrete screed just like RS #15 except that the waterproofing material is acrylic based material. |
| 17 | 1 Roof Deck (Main Concrete Pouring)  
2 Bituminous Rolls  
3 Thermal Insulation (Boards)  
4 Protection Layer  
5 Sloped Screed Concrete  
6 Flashing | This is an inverted, covered, accessible roofing system which uses bituminous rolls as waterproofing and sloped concrete as a loading layer. |
| 18 | 1 Roof Deck (Main Concrete Pouring)  
2 Bitumen Double Faced Covered Polyurethane Thermal Insulation Boards  
3 Waterproofing  
4 Polyethylene Sheets Protection Layer  
5 Sloped Screed Concrete  
6 Flashing | This is a conventional, covered, accessible roofing system that uses polyurethane boards as a thermal insulation material. |
| 19 | 1 Roof Deck (Main Concrete Pouring)  
2 Waterproofing  
3 Thermal Insulation  
4 Protection Layer  
5 Sloped Screed Concrete  
6 Expansion Joints  
7 Flashing | This is an inverted, covered, accessible roofing system which uses sloped concrete screed with expansion joints as a loading layer. |
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</table>

- **Layer 20**: This is an inverted, covered, accessible roofing system which resembles RS #9 except that fixed tiles do not have expansion joints.
- **Layer 21**: This is an inverted, covered, accessible roofing system which uses PVC waterproofing material, and fixed tiles as a loading layer.
- **Layer 22**: This is an inverted, covered, accessible roofing system which resembles RS #23 except that the loading layer used is loose laid tiles.
- **Layer 23**: This is an inverted, covered, accessible roofing system which resembles RS #23 except that the loading layer used is gravel.
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
</table>
| 24 | 1. Roof Deck (Main Concrete Pouring)  
2. Sloped Screed Concrete  
3. EPDM Membrane Waterproofing  
4. Thermal Insulation  
5. Protection Layer  
6. Fixed Tiles | This is an inverted, covered, accessible roofing system which resembles RS # 23 except that the waterproofing material is EPDM. |
| 25 | 1. Roof Deck (Main Concrete Pouring)  
2. Sloped Screed Concrete  
3. EPDM Membrane Waterproofing  
4. Thermal Insulation  
5. Protection Layer  
6. Loose Laid Tiles | This is an inverted, covered, accessible roofing system which resembles RS # 24 except that the waterproofing material is EPDM. |
| 26 | 1. Roof Deck (Main Concrete Pouring)  
2. Sloped Screed Concrete  
3. EPDM Membrane Waterproofing  
4. Thermal Insulation  
5. Protection Layer  
6. Gravel | This is an inverted, covered, accessible roofing system which resembles RS # 25 except that the waterproofing material is EPDM. |
| 27 | 1. Roof Deck (Main Concrete Pouring)  
2. Sloped Screed Concrete with  
3. Waterproofing sealant  
4. Expansion Joints  
5. Waterproofing Membrane  
6. Thermal Insulation  
7. Protection Layer  
8. Gravel  
9. Flashing | This is an inverted, covered, non-accessible roofing system. |
<table>
<thead>
<tr>
<th>Chapter 7: Questionnaire Analysis and Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>28</strong></td>
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<tr>
<td>1. Roof Deck (Main Concrete Pouring)</td>
</tr>
<tr>
<td>2. Sloped Screed Concrete</td>
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<td>3. waterproofing sealant</td>
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<td>4. Expansion Joints</td>
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<tr>
<td>5. Waterproofing Membrane</td>
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<tr>
<td>6. Thermal Insulation</td>
</tr>
<tr>
<td>7. Protection Layer</td>
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<tr>
<td>8. Tiles</td>
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<tr>
<td>9. Flashing</td>
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<tr>
<td><strong>This is an inverted, covered roofing system with tiles used as a loading layer.</strong></td>
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<tr>
<td><strong>29</strong></td>
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<tr>
<td>1. Roof Deck (Main Concrete Pouring)</td>
</tr>
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<td>2. Thermal Insulation</td>
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<tr>
<td>3. Sloped Screed Concrete</td>
</tr>
<tr>
<td>4. Waterproofing Membrane</td>
</tr>
<tr>
<td>5. Protection Layer</td>
</tr>
<tr>
<td>6. Tiles</td>
</tr>
<tr>
<td>7. Flashing</td>
</tr>
<tr>
<td><strong>This is a conventional, covered roofing system which resembles RS #30 except that the sloped concrete screed does not contain waterproofing sealant or expansion joints.</strong></td>
</tr>
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</tr>
<tr>
<td>1. Roof Deck (Main Concrete Pouring)</td>
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<td>2. Thermal Insulation</td>
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<td>3. Sloped Screed Concrete</td>
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<tr>
<td>4. Waterproofing Membrane</td>
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<td>5. Protection Layer</td>
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<td>6. Gravel</td>
</tr>
<tr>
<td>7. Flashing</td>
</tr>
<tr>
<td><strong>This is a conventional, covered non-accessible roofing system which resembles RS #31 except that gravel is used as the loading layer.</strong></td>
</tr>
<tr>
<td><strong>31</strong></td>
</tr>
<tr>
<td>1. Roof Deck (Main Concrete Pouring)</td>
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<tr>
<td>2. Waterproofing Membrane</td>
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<td>4. Protection Layer</td>
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<td>5. Sloped Screed Concrete with</td>
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<td>6. Waterproofing sealant</td>
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<td>7. Flashing</td>
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<td><strong>This is an inverted, covered, non-accessible roofing system which resembles RS #19 except that the sloped concrete screed has waterproofing sealant and does not have expansion joints.</strong></td>
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This table shows that roofing business in Saudi Arabia is inconsistent where 24 contractors offer 52 different roofing systems. The commonness of each system is shown in the next table.
**TABLE V**

**ROOFING COMPONENTS THAT ARE BEING USED BY ROOFING CONTRACTORS**

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X# The roofing component and its location within the roofing system  
#X The roofing component and how many times it was applied  
BS Bituminous Sheets  
LAC Liquid Applied Acrylic  
LAPU Liquid Applied Polyurethane  
PUF Polyurethane Foam  
PUB Polyurethane Boards  
PWM Plastic Wire Mesh/Fiber Mesh (FM)  
CCS Cement Cant Strip  
CPL Concrete Plastering Layer/Cement Protection Layer  
PE Polyethylene Sheeting  
CP Commercial Paper  

Note: In the above systems, X1 is the roof deck. It was not included because it is the same for all systems.
From the above table it can be seen that the most commonly used roofing system is roofing system No. 8. This system is used by 6 contractors (25% of roofing contractors). Other systems were used by 1 or 2 contractors only. This shows how diverse and disorganize the roofing business is. Each contractor make his own roofing system.
Question No. 13. What types of waterproofing membrane are you using on roofs?

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</tbody>
</table>

This question asked contractors about the waterproofing materials they are using. Almost all of them (92%) used bituminous based materials. The second most commonly used waterproofing material is polyurethane based materials which are used by two thirds of the contractors. Forty two percent (42%) used acrylic based materials. EPDM and PVC were only used by 21% of the contractors. See Figure 139.
Figure 139: Types of waterproofing materials used by roofing contractors.
**Question No. 14. In your judgment, what is the best roofing membrane?**

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Asphalt-based bitumen sheets</td>
<td>12</td>
<td>50</td>
<td>Under sloped concrete</td>
</tr>
<tr>
<td>2. Acrylic-based material</td>
<td>2</td>
<td>8</td>
<td>Above sloped concrete</td>
</tr>
<tr>
<td>3. Polyurethane-based material</td>
<td>10</td>
<td>42</td>
<td>Withstand harsh environment; easy to maintain; one layer w/o welds; elastic and sticks to the concrete</td>
</tr>
<tr>
<td>4. Built-up roofing</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5. Single ply membrane such as EPDM &amp; PVC</td>
<td>7</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>6. Others; Specify</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>EPDM</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>CSPE(Hypalon)</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

In this question, we wanted to get roofers’ opinions with regard to the best roofing materials according to their experience. Bituminous based materials were thought to be the best by 50% of contractors while 42% thought that polyurethane based materials were the best. Single-ply membrane such as EPDM and PVC were thought to be very good by 29% of roofers. See Figure 140.
Figure 140: Best waterproofing materials according to roofing contractors.
**Chapter 7: Questionnaire Analysis and Results**

**Question No. 15.** Regarding the pervious question, why do you prefer that roofing membrane?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Because it resists aging and lasts for long time</td>
<td>18</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>2. We have historical record that it resists aggressive environment</td>
<td>8</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>3. The factory give the warranty</td>
<td>9</td>
<td>37.5</td>
<td></td>
</tr>
<tr>
<td>4. Our experience with it</td>
<td>13</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>5. Others; Specify</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Elastomeric properties</td>
<td>3</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>- Does not need additives to increase its boiling point</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- Does not need other materials in order to install</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- Easy installation</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- Does not break with substrate</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- Goes with substrate condition</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- Good with different environmental conditions</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

This question asked about the performance criteria for the preferred materials. Most contractors (75%) indicated that the fact that waterproofing lasts for a long time gives them the confidence to give warranties that they can afford and which may be accepted by owners. The second criterion is the roofer’s experience with the materials.
### Question No. 16  What is/are the most popular roofing membrane(s)?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Asphalt-based bitumen sheets</td>
<td>19</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>2. Acrylic-based material</td>
<td>4</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>3. Polyurethane-based material</td>
<td>6</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>4. Built-up roofing</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>5. Single ply membrane such as</td>
<td>6</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>EPDM &amp; PVC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Others; Specify</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>No Answer</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

The most popular roofing materials are bituminous-based materials according to 79% of roofing contractors. The second most popular materials are polyurethane based and single-ply membranes. The least popular roofing system is built-up roofing. See Figure 141.
Figure 141: Most popular waterproofing materials according to roofing contractors.
### Question No. 17. What is/are the most economical roofing membrane(s)?

<table>
<thead>
<tr>
<th>Answers</th>
<th>No. of Answers</th>
<th>% ofAnswers</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Asphalt-based bitumen sheets; Why?</td>
<td>14</td>
<td>58</td>
<td>-Low cost with good results and warranty period; in Kingdom manufacturers; raw materials locally available</td>
</tr>
<tr>
<td>2. Acrylic-based material; Why?</td>
<td>4</td>
<td>17</td>
<td>Cheap but not good</td>
</tr>
<tr>
<td>3. Polyurethane-based material; Why?</td>
<td>4</td>
<td>17</td>
<td>Easy installation; workers with no experience can install it; not too expensive in the long run</td>
</tr>
<tr>
<td>4. Built-up roofing; Why?</td>
<td>3</td>
<td>12.5</td>
<td>Cheap (Low cost); easy to install; long run cost</td>
</tr>
<tr>
<td>5. Single-ply membrane such as EPDM &amp; PVC; Why?</td>
<td>3</td>
<td>12.5</td>
<td>Lasting for long time</td>
</tr>
<tr>
<td>6. Others; Specify Hypalon</td>
<td>1</td>
<td>4</td>
<td>Easy to install; less complication; low material cost</td>
</tr>
<tr>
<td>6. Others; Specify Hypalon</td>
<td>1</td>
<td>4</td>
<td>Easy to install; less complication; low material cost</td>
</tr>
<tr>
<td>No Answer</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

According to 58% of roofing contractors, the most economical materials for roofing are bituminous based materials. See Figure 142.
Figure 142: Most economical roofing membrane.
### Question No. 18. What type of thermal insulation are you using?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Expanded polystyrene</td>
<td>7</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>2. Extruded polystyrene</td>
<td>15</td>
<td>62.5</td>
<td>Costs less, efficient, easy to install</td>
</tr>
<tr>
<td>3. Polyurethane boards</td>
<td>10</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>4. Polyurethane foam</td>
<td>8</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>5. Light weight concrete</td>
<td>11</td>
<td>46</td>
<td>As screed to falls + Insulation</td>
</tr>
<tr>
<td>6. Others, Specify</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyisocyanurate</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Fiberglass</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Saudi Perlite</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Rock Wool</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Most contractors indicated that they use thermal insulation material that is requested by owners. Extruded polystyrene is used by 62.5% of contractors. Light weight concrete and polyurethane boards are used by 46% and 42% respectively. Other thermal insulation materials are only used by less than third of roofers. See Figure 143.
Figure 143: Usage of thermal insulation materials versus percentage of roofing contractors using them.
Question No. 19. In your judgment, what is the best thermal insulation material and why?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Expanded polystyrene</td>
<td>1</td>
<td>4</td>
<td>Doesn’t absorb water; low cost; long lasting life; easy to install</td>
</tr>
<tr>
<td>2. Extruded polystyrene</td>
<td>11</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>3. Polyurethane boards</td>
<td>9</td>
<td>37.5</td>
<td>Compatible to the roofing system; more resistant to chemicals; low thermal conductivity; low cost</td>
</tr>
<tr>
<td>4. Polyurethane foam</td>
<td>4</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>5. Light weight concrete</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>6. Others, Specify Saudi Perlite</td>
<td>2</td>
<td>8</td>
<td>Doesn’t change with time; long lasting life; not a chemical material; multi-purpose material</td>
</tr>
<tr>
<td>7. Rock wool</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>7. Others Answers</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Contractors indicated that the best thermal insulation material is extruded polystyrene (46%) and polyurethane boards (37%). Few contractors voted for other materials. See Figure 144.
Figure 144: Best thermal insulation materials according to roofing contractors.
Question No. 20. How detailed are the engineering drawings that you usually get from house designer for roofing insulation?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No mention</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>2. No details</td>
<td>8</td>
<td>33</td>
</tr>
<tr>
<td>3. Detailed</td>
<td>9</td>
<td>37.5</td>
</tr>
<tr>
<td>4. Other remarks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lacking some details</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>- Roof plan only</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>- Contradiction between</td>
<td></td>
<td></td>
</tr>
<tr>
<td>drawings and specifications</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>- Different systems are mixed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>together</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>- Engineering offices have no</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>experience; only ready made</td>
<td></td>
<td></td>
</tr>
<tr>
<td>specs. which the A/E put w/o</td>
<td></td>
<td></td>
</tr>
<tr>
<td>knowledge if they are suitable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or not.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks:
- Engineering offices should have insulation / waterproofing engineer in their staff just like other disciplines

This question asked contractors if they got detailed drawings from the designer. Surprisingly, 37.5% thought they got detailed drawings showing how the roofing should be done. However, the rest thought the designer either doesn’t mention roofing or gives very few and useless details. So, the roofer usually makes these drawings.
### 7.1.3 Roofing Construction Methods

#### Question No. 21. Where do you locate the drainage outlets?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Through the parapets</td>
<td>20</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>2. In the middle of roofing area</td>
<td>5</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>3. Others; Specify</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- At about 40 to 50 cm from the parapet so that water will not accumulate near to it</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>- Grill beside the parapet</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- At corners of the roof</td>
<td>3</td>
<td>12.5</td>
<td></td>
</tr>
</tbody>
</table>

There are many locations on the roof that the drainage outlet can be installed. They can be put in the middle of the roof, through the parapet, or close to the parapet. Eighty three percent (83%) of the contractors indicated that they install drainage outlets through the parapet. See Figure 145.
Figure 145: Roofing contractors' practices with regard to locations of drainage outlets.
Question No. 22. At what level you design the drain outlets

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Just below the top layer of roofing system</td>
<td>10</td>
<td>42</td>
</tr>
<tr>
<td>2. Just below the thermal insulation layer</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3. Just below the roofing membrane level</td>
<td>11</td>
<td>46</td>
</tr>
<tr>
<td>4. Other levels (specify)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-The same level as the waterproofing</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>-Just above the roofing membrane (so that it becomes insulated against any leakage to the roof from it)</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>-The same level as the top layer</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>-At zero point of roofing slope</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

It is very important to install the drainage outlets at the right level so that they can get rid of water as soon as it reaches them. Water should not accumulate in many locations. Different drainage designs have different leveling designs. For example, if the drain is at the parapet its bottom is the critical level while if it is somewhere else its top is the needed level which has to be lower than the waterproofing membrane or the top roofing layer. In any case, the drainage outlet level should be lower than the roofing membrane. Unfortunately, only 46% of roofing contractors follow this practice. See Figure 146.
Figure 146: Drainage outlet levels with respect to roofing components.
## Question No. 23. What slope percentage do you use?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 1%</td>
<td>21</td>
<td>87.5</td>
<td></td>
</tr>
<tr>
<td>2. Up to 3%</td>
<td>3</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>3. More than 3%</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4. Other remarks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5%</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>1% to 2%</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>2%</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>At what A/E decide</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

SASO requires a minimum roofing slope of 1%. Most roofing contractors (87.5%) are making 1% slope. Only 8% of contractors do not meet this requirement. See Figure 147.
Figure 147: Roofing slope used by roofing contractors.
**Question No. 24. How do you adjust non-smooth, non-sloped roof deck?**

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No adjustment, just lay the roofing membrane on the roof deck</td>
<td>4</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>2. Plaster the roof and lay the membrane on the plastered roof</td>
<td>6</td>
<td>25</td>
<td>With bonding agent to adhere to the roof deck</td>
</tr>
<tr>
<td>3. Use light weight concrete for smoothing and sloping</td>
<td>15</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>4. Use sloping concrete screed</td>
<td>8</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>5. Others; Specify - Plaster only non-smooth areas</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>- According to engineering drawings</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- Depends on how bad is it.</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

This question was asked in order to know the methods (if any) that contractors use to prepare the roof for installation of roofing. For this purpose, 58% use light weight concrete. Unfortunately, 17% do not make any adjustment. See Figure 148.
Figure 148: Roof deck preparation methods used by roofing contractors.
### Question No. 25. How do you evaluate your customer satisfaction?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No complaint; therefore very satisfied</td>
<td>29</td>
<td>87.5</td>
<td></td>
</tr>
<tr>
<td>2. Few complaints</td>
<td>5</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>3. Lots of complaints</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4. Other remarks</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Roofing contractors claimed that 87.5% of their customers are satisfied, without complaints.

### Question No. 26. What are your customers' complaints?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No complaints</td>
<td>10</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>2. Minor problems</td>
<td>14</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>3. Other remarks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Some owners make modifications on the roof w/o the knowledge of the roofer until the rain falls</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>- Some complaints on the leakage near drainage outlets</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Contractors claimed that customers either have no complaints (42%) or only minor complaints.
Question No. 27. How knowledgeable are most of your customers on roofing?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Excellent</td>
<td>1</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>2. Very Good</td>
<td>4</td>
<td>14.8</td>
<td></td>
</tr>
<tr>
<td>3. Good</td>
<td>8</td>
<td>29.6</td>
<td></td>
</tr>
<tr>
<td>4. Fair</td>
<td>10</td>
<td>37.1</td>
<td></td>
</tr>
<tr>
<td>5. Poor</td>
<td>4</td>
<td>14.8</td>
<td></td>
</tr>
<tr>
<td>6. Other remarks</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

The purpose of this question was to ask roofers their feeling about the knowledge of their customers about roofing. Most contractors indicated that their customers have a fair knowledge of roofing. About 15% of contractors have customers with poor knowledge. See Figure 149.
Figure 149: Knowledge of owners about roofing according to roofing contractors.
### 7.1.5 Roofing Problems

#### Question No. 28. What are the roofing problems in Saudi Arabia including those associated with roofing membrane?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Leakage</td>
<td>20</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>2. Ridging</td>
<td>7</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>3. Crazing</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4. Cracking</td>
<td>5</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>5. Blistering</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6. Breaking of welding</td>
<td>6</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>7. Mechanical damage</td>
<td>8</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>8. Dust on the roof when applying liquid membrane</td>
<td>5</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>9. Others, Specify</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Lots of welds</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- Cracks of blisters of the roofing deck</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>- Bad quality materials</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>- Cuts on the roofing membranes because of bad workmanship</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- People doing other works or repair damage to the membrane and do not report the damage for repair</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

The purpose of this question was to ask roofers about the roofing problems they have experienced. Leakage is the number one problem for 83% of roofers, who said that leakage is the problem they always face. Other main problems are mechanical damage (33%), ridging (29%), breaking of welds (25%), and cracking. See Figure 150.
Figure 150: Roofing problems in Saudi Arabia as reported by roofing contractors.
Question No. 29. What percentage of the following roofing problems have you encountered?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>% Mentioned</th>
<th>Average %</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Leakage-----%</td>
<td>2,5,10,20,30,30,35,50,50,70,90,100</td>
<td>41=&gt;26.6</td>
<td></td>
</tr>
<tr>
<td>2. Ridging------%</td>
<td>10,25,25,60</td>
<td>30=&gt;19.5</td>
<td></td>
</tr>
<tr>
<td>3. Crazing------%</td>
<td>10,10</td>
<td>10=&gt;6.5</td>
<td></td>
</tr>
<tr>
<td>4. Cracking of (membrane, blistering under the membrane, etc.)------%</td>
<td>5,10,20,90,100</td>
<td>45=&gt;29.2</td>
<td></td>
</tr>
<tr>
<td>5. Bad Design--------%</td>
<td>5,10,10,10,10,10,25</td>
<td>12=&gt;7.8</td>
<td></td>
</tr>
<tr>
<td>6. Others, Specify------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bad Workmanship</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plumbers and Electricians damage the waterproofing membrane while doing their work w/o informing the roofer before pouring concrete</td>
<td>15</td>
<td>15=&gt;9.7</td>
<td></td>
</tr>
</tbody>
</table>

This question asked about the size of each problem that a roofer encountered.

Twelve contractors indicated that they faced leakage. The percentage of leakage problems varies between 2% with one contractor and 100% with another. An average of 41% of leakage problems were faced by those twelve contractors. Among other problems, leakage share is only 26.6%. Ridging was a problem for four contractors with frequency percentages between 10% and 60%, an average of 30% of problems facing these four
contractors and an average of 19.5% among other problems. Five contractors were faced by cracking with frequency percentages between 5% and 100%, an average of 45% of problems facing these five contractors and an average of 29.2% among other problems. Crazing was a problem for two contractors with frequency percentages of 10%, an average of 6.5% among other problems. Bad design was a problem for five contractors with frequency percentages between 5% and 25%. An average of 12% of problems facing these five contractors and an average of 7.8% among other problems. Bad workmanship was a problem for one contractor with 15% of problems facing this contractor and an average of 9.7% among other problems facing other contractors. See Figure 151.
Figure 151: Percentage of roofing problems encountered by roofing contractors.
**Question No. 30. How do you make problem-free roofing?**

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Using skilled labors</td>
<td>23</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>2. Using good quality materials</td>
<td>22</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>3. Good selection of roofing assembly</td>
<td>14</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>4. Installation at the right time and right weather</td>
<td>14</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>5. Make good slope on the roof</td>
<td>11</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>6. Make enough drainage outlets</td>
<td>11</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>7. Others, Specify</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Good design</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- Co-operation between general contractor and the roofer in doing the plumbing, electrical and piping installation in a way that does not weaken the roofing</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

This question was asking about making roofing without problems, which is what every owner is looking for. In the opinion of 96% and 92% of contractors, the most important factors were using skilled labor and good quality materials when installing the roofing. See Figure 152.
Figure 152: Ways of making roofing without problems.
**Question No. 31.** How do you tackle the roofing problems when they happen?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Making a new roofing above the old one</td>
<td>9</td>
<td>37.5</td>
<td></td>
</tr>
<tr>
<td>2. Removing the old roofing completely and re-roofing</td>
<td>5</td>
<td>21</td>
<td>only if the problem is major</td>
</tr>
<tr>
<td>3. Trace the source of the problem and spot roofing</td>
<td>18</td>
<td>75</td>
<td>No guarantee for other spots</td>
</tr>
<tr>
<td>4. Others, Specify</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- By installing curved piping in different locations so that vapor can evaporate; otherwise, it will force the membrane to go up or it will penetrate through the roof deck down to the inside of the house deteriorating the paint inside the house</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>- Depends on the particular case</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

This question asked the contractors about the approach they take when they are hired to fix a roofing with problems. Tracing the source of the problem and spot roofing was the approach that 75% of roofers usually take. The second and third most popular approaches of tackling problems were making a new roof above the old roof (37.5%) and removing the old roofing completely and re-roofing. In any case, it depends on the condition of the particular roof. See Figure 153.
Figure 153: Tackling roofing problems.
# Question No. 32. How do we know that we have roofing problem?

<table>
<thead>
<tr>
<th>ANSWERS:</th>
<th>No. of Answers</th>
<th>% of Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. By yearly physical inspection</td>
<td>7</td>
<td>29</td>
</tr>
<tr>
<td>2. By wet ceiling</td>
<td>18</td>
<td>75</td>
</tr>
<tr>
<td>3. Leakage drops</td>
<td>18</td>
<td>75</td>
</tr>
<tr>
<td>4. Removing the loading layer</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5. Others, Specify</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- By cracks on the concrete</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>- By seeing high tiles</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question intended to ask about the ways of knowing if we have a defective roof or not. Most contractors did not give a good answer because we want to know if the roof is having problems before it becomes obvious by dripping or wetting of the ceiling. Among roofers, 29% recommended yearly physical inspection.

# Question No. 33. Any further comments; include any suggested solutions to roofing problems.

1. It is recommended to use inverted roof systems with insulation on top of the membrane. In this case, the waterproofing membrane will be protected from mechanical impact and weather conditions.

2. Use extruded polystyrene thermal insulation. It does not absorb water; so, its thermal resistance remains good and almost unchanged for a long period of time.
3. Spread gravel or loose laid tiles on non-accessible roofs or roofs with light foot use like A/C maintenance. This makes the accessibility to the waterproofing membrane easy for repair in the future.

4. There are a lot of unprofessional roofing contractors in the market and they spoil the market (prices & quality). There should be some restrictions on people working in the roofing business.

5. Use good quality materials and skilled workers.

6. Eliminate sharp points when doing surface preparation. Sharp points may cause damage to the roofing membranes.

7. Install the roofing membrane properly in its standard overlap of 10 cm.

8. Install cant strip to avoid future cracking at the corners.

9. Install aluminum strip flashing with sealant.

10. Municipality should insist on A/E giving the waterproofing works in detail. That is with respect to drawings and specifications and this should cover roof, kitchens and bathrooms because the cost of repairing deteriorated concrete is very expensive.

11. A/E should differentiate in his design between dry climate locations and humid locations. He should also make instructions and guidelines to contractors to use the best available construction chemicals to prevent corrosion and hence extend the life span of buildings in humid locations and coastal areas.

12. Select a good roofing system.

13. Have as many drainage outlets as possible.

15. Hire a specialized roofer.

16. Have a water test before covering the roofing membrane for at least two days.

17. Cover the roofing system with proper covering.

18. Roofing should be done in a proper way, with proper material at the right time.

19. Install the roofing membrane above the sloping concrete screed.

20. The sloping concrete screed should have expansion joints.

21. Install curved pipes on different roof locations to allow water vapor to get out of the roof.

22. Roofing insulation is very important for it protects the roofing deck from corrosion and in turn the building will live longer.

23. Owners have to be educated about waterproofing and roofing.

24. A/E should be knowledgeable about roofing materials and their prices. For any particular material, there is a minimum price. This material cannot be cheaper than the minimum price.

25. It is recommended that each meter of the roofing roll has the name and the specifications so that other low quality material won't be sold as a good quality materials.

26. It is recommended that plumbers and electricians co-ordinate their work with the roofer work so that no one will negatively affect the work of the other.
7.2 HOUSE OWNERS QUESTIONNAIRE

From the beginning, at the thesis proposal stage of this thesis, we decided to limit the population under study to 100 owners. In order to achieve this 100-owners target that will be suitable for the research objectives, we have asked for information from more than one thousand owners. To get good, credible information, we have excluded the following types of houses from this research:

1. Similar houses; for example, if a compound contains a number of houses that have similar roofing systems, these houses are considered as one house only.

2. Houses that do not contain waterproofing materials.

3. Houses that are not built by the owner. If somebody bought a house, it is assumed that he doesn’t know how the roofing was assembled. Therefore, no questionnaire was filled by an owner who bought a ready-made house.

4. Houses that are not occupied by owners. The resident who lives in a rented house doesn’t know how the roofing was built.

5. Some other unique houses whose inclusion would not help in obtaining our objectives.

We received a total of 109 completed questionnaires; however, only 102 questionnaires were accepted. Seven of the questionnaires were rejected because they were incomplete. Among the 102 acceptable questionnaires there are 36 that reported problems in roofs. The following table shows the locations of the surveyed houses including the houses with problems.
<table>
<thead>
<tr>
<th>Location of the house</th>
<th>Number of houses</th>
<th>Houses with Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeddah</td>
<td>45</td>
<td>6</td>
</tr>
<tr>
<td>Dammam</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>Riyadh</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>Doha</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Danah</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Kharj</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Rahmah</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Qatif</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Sayhah</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Tarout</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Tabuk</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 154 shows the houses' locations graphically. See also Figure 155 which shows the houses with problems.
Figure 154: Houses' Locations. Jeddah, Western Province, has the largest share.
Figure 155: Comparison between total number of houses with the number of houses that have problems in each location.
Chapter 7: Questionnaires' Analysis and Results

The following is a question-by-question explanation and analysis. The respondents' answers for each question are tabulated as follows:

Column # 1: **ANSWERS**; shows a list of answers that the respondents give.

Column # 2: **Tot. No. of Houses**; shows the total number of houses for each answer.

Column # 3: **% of Houses**; shows the percentage of houses for each answer. \(\{(\text{column 2} \times 100)/102\}\); 102 is the total number of houses.

Column # 4: **Houses with Problems**; shows the number of houses that were reported to have problems.

Column # 5: **% of Houses with problems**; % of Houses with problems for this answer to the total number of houses of this answer. \(\{(\text{column 4} \times 100)/\text{column 2}\}\)

Column # 6: **% of this type**; % of this type to the total number of houses with problems. \(\{(\text{column 4} \times 100)/36\}\); 36 is the total number of houses with problems.

### 7.2.1 Household Information

#### Question No. 1. How old is your house?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 1 month to 2.5 years</td>
<td>35</td>
<td>34</td>
<td>10</td>
<td>29</td>
<td>28</td>
</tr>
<tr>
<td>2. 2.5 years to 5 years</td>
<td>19</td>
<td>19</td>
<td>7</td>
<td>37</td>
<td>19</td>
</tr>
<tr>
<td>3. 5 years to 7.5 years</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td>33</td>
<td>11</td>
</tr>
<tr>
<td>4. 7.5 years to 10 years</td>
<td>21</td>
<td>21</td>
<td>7</td>
<td>33</td>
<td>19</td>
</tr>
<tr>
<td>5. more than 10 years</td>
<td>15</td>
<td>15</td>
<td>8</td>
<td>53</td>
<td>22</td>
</tr>
</tbody>
</table>

The purpose of this question was to ascertain of the age of the house in order to know how long the waterproofing lasted, so that we can see if the failure is due to aging or not. Almost half of the houses surveyed are more than five years old. See Figure 156 and Figure 157.
Figure 156: Ranges of houses’ age. Almost half of the houses age are more than five years old.
Figure 157: Comparison between houses of different categories with and without problems.
Chapter 7: Questionnaires’ Analysis and Results

Question No. 2. What type of roof does your house have?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flat roof</td>
<td>81</td>
<td>79</td>
<td>26</td>
<td>32</td>
<td>72</td>
</tr>
<tr>
<td>2. Slanted roof</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>6</td>
</tr>
<tr>
<td>3. Both slanted and flat</td>
<td>19</td>
<td>19</td>
<td>8</td>
<td>42</td>
<td>22</td>
</tr>
<tr>
<td>4. Corrugated sheet metal</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Other type (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Because a flat type roof is by far the most common used in Saudi Arabia and it is the type that is more vulnerable to leaks than other types of roofs, this survey was limited to flat roofs. Therefore, all houses surveyed should have a flat roof either wholly or partially. As indicated in the results, more than 80% of the roofs are totally flat.

Question No. 3. What is the total roofing area?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 100 m² or less</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>6</td>
</tr>
<tr>
<td>2. Between 100 m² and 200 m²</td>
<td>12</td>
<td>12</td>
<td>5</td>
<td>42</td>
<td>14</td>
</tr>
<tr>
<td>3. Between 200 m² and 300 m²</td>
<td>47</td>
<td>46</td>
<td>19</td>
<td>40</td>
<td>53</td>
</tr>
<tr>
<td>4. Between 300 m² and 400 m²</td>
<td>34</td>
<td>33</td>
<td>8</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>5. More than 400 m²</td>
<td>7</td>
<td>7</td>
<td>2</td>
<td>29</td>
<td>6</td>
</tr>
</tbody>
</table>

The total roofing area was asked about to see if the drainage outlets are less than required for the roofing area and to see if the number or size of drainage outlets can be considered as a cause of roofing problems. See Figure 158 and Figure 159.
Figure 158: Ranges of the total roofing areas. Almost 50% of the houses are between 200 and 300 square meters.
Figure 159: Comparison between houses with and without problems with different roofing areas.
### 7.2.2 Roofing Insulation Assembly

**Question No. 4. Is there roof insulation on your house?**

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes</td>
<td>98</td>
<td>96</td>
<td>36 houses with problems</td>
</tr>
<tr>
<td>2. No</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3. I don't know</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Insulation in this question means both thermal and waterproofing. The purpose of asking this question was to see if the house was suitable for this survey. If the roof is not insulated, then the survey should be stopped and the questionnaire should not be completed after question 5 has been answered. If the roof is insulated, the owner should proceed answering the rest of the questionnaire.

**Question No. 5. If the answer to question 4 is no, Why?**

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I don't think it is worth it or it is effective</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2. It costs too much</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3. My roof has large slope</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4. My roof has concrete sealant</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5. No body I know has it</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6. My roof has light weight concrete</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>7. Other reasons (specify)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- There is no need for thermal insulation</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>- I had no idea about thermal insulation.</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>- No one I know used thermal insulation.</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>- There is a false ceiling; therefore, no need to have an additional thermal insulation material.</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>- I did not have enough background about insulation and its effectiveness.</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

The purpose of this question was to know the reason(s) that made owners hesitate in having thermal insulation and waterproofing for their houses.
### Question No. 6. If the answer to question 4 is yes, Why?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I see that my neighbor or my relative has insulation</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>2. I think it is effective</td>
<td>67</td>
<td>66</td>
<td>26</td>
<td>39</td>
<td>72</td>
</tr>
<tr>
<td>3. I heard that it is effective</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>63</td>
<td>14</td>
</tr>
<tr>
<td>4. It comes with the contract</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>5. Other reasons (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--To protect the house against harsh environment</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>--Perhaps it will be effective</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>--Its cost was low to me</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>--The agent convinced me</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>--The contractor convinced me</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>--I noticed a wet spot on the ceiling in the rainy season</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>--Because of leakage problems that happened in the first year</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>20</td>
<td>3</td>
</tr>
</tbody>
</table>

Answers to this question help us understand what made owners pay the cost of thermal insulation and waterproofing.

### Question No. 7. Did you have any knowledge about roof insulation systems before you start building your house?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes</td>
<td>41</td>
<td>40</td>
<td>14</td>
<td>34</td>
<td>39</td>
</tr>
<tr>
<td>2. No</td>
<td>33</td>
<td>32</td>
<td>12</td>
<td>36</td>
<td>33</td>
</tr>
<tr>
<td>3. A little</td>
<td>28</td>
<td>27</td>
<td>10</td>
<td>36</td>
<td>28</td>
</tr>
</tbody>
</table>

The purpose of this question was to know about the knowledge of owners with regard to roofing systems before they built their houses. See Figure 160 and Figure 161.
Figure 160: Owners' Level of Knowledge about Roofing. Two third of owners had some knowledge.
Figure 161: Houses with problems against owners' level of roofing knowledge.
Chapter 7; Questionnaires' Analysis and Results

Question No. 8. Do you think you had enough knowledge about roof insulation when you decided to make roof insulation and to select the type of insulation you have selected?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes</td>
<td>50</td>
<td>49</td>
<td>19</td>
<td>38</td>
<td>53</td>
</tr>
<tr>
<td>2. No</td>
<td>51</td>
<td>50</td>
<td>17</td>
<td>33</td>
<td>47</td>
</tr>
</tbody>
</table>

The purpose of this question was to see how confident owners were in their roofing system selection. As can be seen the result is 50/50.

Question No. 9. When did you install roof insulation, i.e. what is the age of your house roof insulation?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. During the construction of the house</td>
<td>88</td>
<td>86</td>
<td>29</td>
<td>33</td>
<td>81</td>
</tr>
<tr>
<td>2. After I had problems in the roof</td>
<td>13</td>
<td>13</td>
<td>9</td>
<td>69</td>
<td>25</td>
</tr>
<tr>
<td>3. Other Remarks (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--When I heard about it</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--After one year of house completion</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--After five years of house completion</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>--After 18 months of house completion</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

This question was asked in order to know if the roofing systems was installed during the construction of houses or after problems had been encountered. That is, to see how aging affects the performance of a particular roofing system. Looking at the results, it can be seen that 86% had the roofing made during the construction of the house, which is good practice. See Figure 162 and Figure 163.
Figure 162: Roofing Installation. Most owners installed their roofing during house construction.
Figure 163: Houses with and without problems shown against roofing installation time.
Question No. 10. What are the components of the roof assembly of your house? (mark more than one if applicable).

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flashing</td>
<td>11</td>
<td>11</td>
<td>4</td>
<td>36</td>
<td>11</td>
</tr>
<tr>
<td>2. Gravel</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>3. Fixed tiles*</td>
<td>63</td>
<td>62</td>
<td>18</td>
<td>29</td>
<td>14</td>
</tr>
<tr>
<td>4. Loose tiles</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5. Expansion joints</td>
<td>18</td>
<td>18</td>
<td>10</td>
<td>56</td>
<td>28</td>
</tr>
<tr>
<td>6. Protection layer</td>
<td>9</td>
<td>9</td>
<td>5</td>
<td>56</td>
<td>14</td>
</tr>
<tr>
<td>7. Thermal insulation</td>
<td>23</td>
<td>23</td>
<td>8</td>
<td>35</td>
<td>22</td>
</tr>
<tr>
<td>8. Roofing membrane (Waterproofing)</td>
<td>62</td>
<td>61</td>
<td>25</td>
<td>40</td>
<td>69</td>
</tr>
<tr>
<td>9. Screed concrete</td>
<td>49</td>
<td>48</td>
<td>19</td>
<td>39</td>
<td>53</td>
</tr>
<tr>
<td>10. Sealant in the screed concrete</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>57</td>
<td>11</td>
</tr>
<tr>
<td>11. Others (specify)</td>
<td>144</td>
<td>144</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Marble</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Enforcement for the sloped concrete</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>--Enforcement for the sloped concrete</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Jute</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>--Slopes in the main concrete deck</td>
<td>23</td>
<td>23</td>
<td>10</td>
<td>56</td>
<td>28</td>
</tr>
<tr>
<td>--Plastic enforcement wire mesh</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Plastic enforcement wire mesh</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Sand and cement</td>
<td>64</td>
<td>63</td>
<td>19</td>
<td>30</td>
<td>53</td>
</tr>
<tr>
<td>--Hot asphalt</td>
<td>39</td>
<td>38</td>
<td>14</td>
<td>36</td>
<td>39</td>
</tr>
<tr>
<td>--Commercial paper</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>67</td>
<td>6</td>
</tr>
<tr>
<td>--Plaster layer</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>6</td>
</tr>
<tr>
<td>--Concrete protection layer</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Cant strip</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>67</td>
<td>6</td>
</tr>
<tr>
<td>--Chinko</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>--Very smooth screed concrete</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>--Broken blocks</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>--Plastic wire mesh</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Steel Wire mesh</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Most of the fixed tiles are made with slope to falls. One owner indicated that his fixed tiles were without slope.

This question asked about the roofing components regardless of their orders. The roofing components, which were used by house owners along with their percentages of use are listed in the table above. Also, see Figure 164 and Figure 165.
Figure 164: Frequency of Using Different Roofing Components. Fixed tiles is the most used component.
Figure 165: Roofing components on total number of houses and houses with problems.
### Question No. 11. Who installed the roof assembly?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The general contractor</td>
<td>51</td>
<td>50</td>
<td>17</td>
<td>33</td>
<td>47</td>
</tr>
<tr>
<td>2. The supplier (Manufacturer)</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Specialized contractor</td>
<td>39</td>
<td>38</td>
<td>16</td>
<td>41</td>
<td>44</td>
</tr>
<tr>
<td>4. Others (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Workers from the streets (unskilled)</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Owner himself with workers</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>50</td>
<td>8</td>
</tr>
<tr>
<td>--A contractor with low experience</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
</tbody>
</table>

This question queried about the applicator of the roofing to check how good a system is which was installed by the general contractor or by a specialized contractor. That is, to see how the applicator affects the performance of the roofing system and how much a specialized contractor contributes to the quality of a roofing system. See Figure 166 and Figure 167.
Figure 166: Roofing Installer. Most roofing was installed by the general contractor.
Figure 167: Total number of houses and houses with problems as related to the applicator.
Question No. 12. How was the roof assembled? Put in order starting from the top** component, assign numbers starting from 1, 2, 3,...etc.

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flashing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Gravel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Fixed tiles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. loose tiles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Expansion joints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Protection layer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Thermal insulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Roofing membrane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Waterproofing)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Screed concrete</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Sealant in the screed concrete</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Others (specify)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**The systems below were made in order starting from bottom up. That is from the roof deck to the loading layer.

The purpose of asking this question was to find out what roofing systems are being used by owners in Saudi Arabia, how many are being used, and how good and how common each system is. The owners' roofing systems are tabulated below in Table VII. It worths noting that similar systems are grouped together as a one system. For example, roofing system No. 15 is used by one owner in Riyadh, one owner in Tabuk and one owner in Khobar. Roofing system No. 19 is used by nine owners in Jeddah and one owner in Riyadh.
<table>
<thead>
<tr>
<th>NO</th>
<th>ROOFING SYSTEM</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Description:</strong> Inverted, covered, accessible</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Merits:</strong> Good quality materials, use of expansion joints.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Drawbacks:</strong> 1) Waterproofing was installed on a non-sloped surface. 2) The sloped concrete screed was not enforced. 3) The sloped concrete screed was installed on a non-firm surface.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Problems:</strong> Leakage and cracks</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Usage:</strong> This roofing system was used by one owner only.</td>
</tr>
<tr>
<td>1</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>2 Waterproofing; Elastomeric Polyurethane: SPECTRACORE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Thermal Insulation; Polyurethane Boards</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Sloped Concrete Screed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Expansion Joints Drainage Outlets: 4--3-inches</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td></td>
</tr>
<tr>
<td>KH</td>
<td>2 Sloped Concrete Screed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Waterproofing; Bituminous Sheets Flashing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 3--2-inch</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td></td>
</tr>
<tr>
<td>JD</td>
<td>2 Bituminous Sheets (Waterproofing)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Sand &amp; Cement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Fixed Tiles with Slope 3JD Drainage Outlets: 2--4-inch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18JD Drainage Outlets: 3--4-inch; NP 40JD Drainage Outlets: 2--4-inch; NP</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Description:</strong> Exposed, non-accessible</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Merits:</strong> The waterproofing was installed on a sloped surface. Use of flashing.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Drawbacks:</strong> No thermal insulation, small size of drainage outlets.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Problems:</strong> None</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Usage:</strong> This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Description:</strong> Covered, accessible</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Merits:</strong> Good size of drainage outlets</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Drawbacks:</strong> Waterproofing was installed on a non-sloped surface. Only 2 drainage outlets.</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Problems:</strong> Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Usage:</strong> This roofing system was used by three owners. 18JD, 40JD</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1 Roof Deck (Main Concrete Pouring) with polystyrene hordi</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Sloped Concrete Screed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Thermal Insulation; Extruded Polystyrene</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Waterproofing; Self Adhesive Membrane</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Flashing</td>
<td></td>
</tr>
<tr>
<td><strong>Drainage Outlets:</strong> 5--3-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Description:</strong> Conventional, exposed, non-accessible.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Merits:</strong> Good quality materials, Good number of drainage outlets.</td>
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<td><strong>Drawbacks:</strong> It is a bad practice to have the waterproofing materials on the thermal insulation in this way.</td>
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<tr>
<td><strong>Problems:</strong> No</td>
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<tr>
<td><strong>Usage:</strong> This roofing system was used by one owner only.</td>
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</tbody>
</table>

| 5 | 1 Roof Deck (Main Concrete Pouring) |
|   | 2 Waterproofing; Liquid Applied Acrylic |
|   | 3 Thermal Insulation; Expanded Polystyrene |
|   | 4 Sloped Concrete Screed |
|   | 5 Waterproofing; Liquid Applied Acrylic |
| **Drainage Outlets:** 9--2-inch |
| **Description:** Conventional, exposed and accessible. |
| **Merits:** Good number of drainage outlets. The waterproofing was installed on a sloped surface. |
| **Drawbacks:** The sloped concrete screed was not enforced; The sloped concrete screed was installed on a non-firm surface; Drainage outlet size was too small. |
| **Problems:** No |
| **Usage:** This roofing system was used by one owner only. |

| 6 | 1 Roof Deck (Main Concrete Pouring) |
|   | 2 Sloped Concrete Screed |
|   | 3 Sealant in the Screed Concrete |
|   | 4 Waterproofing; Liquid Applied |
|   | 5 Polyurethane, 2 coats |
|   | 6 Thermal Insulation; Extruded Polystyrene, ESCOFOAM |
|   | 7 Protection Layer |
|   | 8 Gravel |
| **Drainage Outlets:** 3--2-inch |
| **Description:** Inverted, covered and non-accessible. |
| **Merits:** Good quality materials, The waterproofing was installed on a sloped surface. |
| **Drawbacks:** Drainage outlet size was too small. |
| **Problems:** Leakage |
| **Usage:** This an inverted covered system using loose gravel as a loading layer. This system was used by one owner only. |
|   | 7 | 1 Roof Deck (Main Concrete Pouring) | **Description**: Inverted, covered and accessible.  
**Merits**: Good size of drainage outlets  
**Drawbacks**: The sloped concrete screed was not enforced; The sloped concrete screed was not installed on a firm base.  
**Problems**: No  
**Usage**: This roofing system was used by one owner only. |
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<tbody>
<tr>
<td></td>
<td>DN</td>
<td>2 Asphalt</td>
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<td>3 Jute</td>
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<td>4 Asphalt</td>
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<tr>
<td>5 Jute</td>
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<tr>
<td>6 Asphalt</td>
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<tr>
<td>7 Thermal Insulation; Extruded Polystyrene</td>
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<tr>
<td>8 Sloped Concrete Screed</td>
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<tr>
<td>Drainage Outlets: 4--4-inch</td>
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</table>

|   | 8 | 1 Roof Deck (Main Concrete Pouring) | **Description**: This a conventional roofing system if we consider light weight concrete as the thermal insulation material. It is a covered system with a fixed loading layer.  
**Merits**: Use of steel enforcement and expansion joints.  
**Drawbacks**: Light Weight Concrete is not a good thermal insulation materials.  
**Problems**: Yes  
**Usage**: This roofing system was used by one owner only. |
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<tr>
<td></td>
<td>DM</td>
<td>2 Light Weight Concrete</td>
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<td>3 Bituminous Sheets (Waterproofing)</td>
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<tr>
<td>4 6-mm Steel Enforcement</td>
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<td>5 Sloped Concrete Screed</td>
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<td></td>
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<tr>
<td>6 Expansion Joints</td>
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<td>7 Flashing</td>
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<tr>
<td>Drainage Outlets: 3--3-inch</td>
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</table>

|   | 9 | 1 Roof Deck (Main Concrete Pouring) | **Description**: This is an inverted, covered roofing system. It seems to be a good system, but the loading layer should have been enforced by steel bars to prevent it from cracking.  
**Merits**: Has double thermal insulation protection  
**Drawbacks**: The top concrete layer is expected to crack because it was not enforced plus it was installed on a non-firm base.  
**Problems**: No  
**Usage**: This system was used by one owner only. |
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<tbody>
<tr>
<td></td>
<td>DN</td>
<td>2 Light Weight Concrete</td>
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<tr>
<td>3 Bituminous Sheets (Waterproofing)</td>
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<tr>
<td>4 Thermal Insulation; Extruded Polystyrene</td>
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<tr>
<td>5 Polyethylene Sheeting</td>
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<tr>
<td>6 5-cm thick screed concrete</td>
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<td>7 Flashing</td>
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<td>Drainage Outlets: 4--4-inch</td>
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</table>
| 10 | 1 | Roof Deck (Main Concrete Pouring) | **Description:** This is a covered waterproofing system using liquid applied material.  
**Merits:** Use of waterproofing in the screed concrete.  
**Drawbacks:** No expansion joint, drainage outlet size was too small.  
**Problems:** Yes  
**Usage:** This roofing system was used by one owner only. |
|   | 2 | Waterproofing 1\textsuperscript{st} Coat; Black |
|   | 3 | Waterproofing 2\textsuperscript{nd} Coat; White |
|   | 4 | Sloped Concrete Screed |
|   | 5 | Waterproofing in the screed concrete |
|   |   | Drainage Outlets: 3--2-inch |

| 11 | 1 | Roof Deck (Main Concrete Pouring) | **Description:** This has two coats of roofing membrane; therefore, it can be conventional and inverted, exposed and covered. However, the first coat is useless.  
**Merits:** Double waterproofing protection  
**Drawbacks:** The sloped concrete screed layer is expected to crack because it was not enforced plus it was installed on a non-firm base. It does not contain expansion joints. Drainage outlet size was too small and their number is too little.  
**Problems:** Leakage and cracks  
**Usage:** This system was used by one owner only. |
|   | 2 | Waterproofing 1\textsuperscript{st} Coat Acrylic |
|   | 3 | Thermal Insulation; Extruded Polystyrene |
|   | 4 | Sloped Concrete Screed |
|   | 5 | Waterproofing; Polyurethane, Vulkem 350/351 2 Coats |
|   |   | Drainage Outlets: 2--2-inches |

| 12 | 1 | Roof Deck (Main Concrete Pouring) | **Description:** This is an inverted covered roofing system using bituminous sheets as a waterproofing material and marble as a loading layer.  
**Merits:** No comments  
**Drawbacks:** The waterproofing was put on a non-sloped surface.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
<p>|   | 2 | Waterproofing; Bituminous sheets |
|   | 3 | Sloped Concrete Screed |
|   | 4 | Thermal Insulation; Extruded Polystyrene |
|   | 5 | Sand &amp; Cement |
|   | 6 | Marble |
|   |   | Drainage Outlets: 3--3-inch |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th>1 Roof Deck (Main Concrete Pouring)</th>
<th>2 Waterproofing, Bituminous Sheets</th>
<th>3 Polyethylene Protection Layer</th>
<th>4 Sand &amp; Cement</th>
<th>5 Fixed Tiles with Slope</th>
<th>Drainage Outlets: 2--4-inch</th>
<th>31JD Drainage Outlets: 2--4-inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>JD</td>
<td>Description: This is a covered waterproofing system using bituminous sheets.</td>
<td>Merits: Good drainage outlet size.</td>
<td>Drawbacks: The waterproofing was put on a non-sloped surface; Drainage outlets were too few.</td>
<td>Problems: No</td>
<td>Usage: This roofing system was used by two owners; 31JD</td>
<td></td>
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<tr>
<td>14</td>
<td>RD</td>
<td>Description: This is a waterproofing system using asphalt and jute that used sloped concrete screed as a loading layer.</td>
<td>Merits: Usage of steel reinforcement; Good drainage outlets size.</td>
<td>Drawbacks: The waterproofing was put on a non-sloped surface; Drainage outlets were too few.</td>
<td>Problems: Leakage and cracks</td>
<td>Usage: This roofing system was used by one owner only.</td>
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<tr>
<td>15</td>
<td>RD</td>
<td>Description: This is a waterproofing system using asphalt and jute that used fixed tiles as a loading layer.</td>
<td>Merits: Good number and size of drainage outlets.</td>
<td>Drawbacks: The waterproofing was put on a non-sloped surface.</td>
<td>Problems: No</td>
<td>Usage: This roofing system was used by three owners. 72TB, 85KH</td>
<td></td>
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<tr>
<td>16</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td>Description: This is a covered system using asphalt and jute.</td>
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<tr>
<td>RD</td>
<td>1. Asphalt</td>
<td>Merits: No comments</td>
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<td></td>
<td>2. Jute</td>
<td>Drawbacks: The waterproofing was put on a non-sloped surface; Drainage outlets were too few.</td>
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<td></td>
<td>3. Asphalt</td>
<td>Problems: Yes</td>
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<td></td>
<td>4. Sand &amp; Cement</td>
<td>Usage: This roofing system was used by six owners; 77RD, 78RD, 86RD, 87RD, 89RD</td>
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<td>5. Fixed Tiles with Slope</td>
<td>NP: No Problems</td>
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<tr>
<td></td>
<td>Drainage Outlets: 2--3-inch, Leakage</td>
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<td>77RD Drainage Outlets: 2--3-inch, Leakage</td>
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<td>78RD Drainage Outlets: 2--4-inch (NP)</td>
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<td>86RD Drainage Outlets: 2--3-inch, Leakage</td>
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<td>87RD Drainage Outlets: 2--4-inch (NP)</td>
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<td>89RD Drainage Outlets: 2--4-inch, Cracks</td>
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<td>17</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td>Description: Covered and accessible</td>
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<tr>
<td>JD</td>
<td>1. with Red Block Hordi</td>
<td>Merits: No comments</td>
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<td></td>
<td>2. Hot Asphalt</td>
<td>Drawbacks: The waterproofing was put on a non-sloped surface; Drainage outlets were too few.</td>
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<td></td>
<td>3. Jute</td>
<td>Problems: Yes</td>
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<td>4. Commercial Paper</td>
<td>Usage: This roofing system was used by one owner only.</td>
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<td></td>
<td>5. Sand &amp; Cement</td>
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<td>6. Fixed Tiles with Slope</td>
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<td></td>
<td>Drainage Outlets: 1--3-inch</td>
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<tr>
<td>19 JD</td>
<td>1</td>
<td>Roof Deck with Red Clay Hordi</td>
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<td>Hot Liquefied Asphalt</td>
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<td>3</td>
<td>Sand &amp; Cement</td>
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<td>4</td>
<td>Fixed Tiles with Slope</td>
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<td></td>
<td>19JD Drainage Outlets: 4--4-inch</td>
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<td></td>
<td>28JD Drainage Outlets: 2--4-inch</td>
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<td>42JD Drainage Outlets: 4--4-inch</td>
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<td>43JD Drainage Outlets: 4--4-inch</td>
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<td>44JD Drainage Outlets: 4--4-inch</td>
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<td>46JD Drainage Outlets: 2--4-inch</td>
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<td>49JD Drainage Outlets: 4--3-inch</td>
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<td></td>
<td>67JD Drainage Outlets: 2--4-inch</td>
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<td>68JD Drainage Outlets: 2--4-inch</td>
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<td></td>
<td>88RD Drainage Outlets: 2--3-inch</td>
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<tr>
<td><strong>Description:</strong> This system used asphalt as the waterproofing materials and fixed tiles as the loading layer.</td>
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<tr>
<td><strong>Merits:</strong> Good size of drainage outlets.</td>
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<td><strong>Drawbacks:</strong> The waterproofing was put on a non-sloped surface.</td>
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<td><strong>Problems:</strong> No</td>
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<tr>
<td><strong>Usage:</strong> This roofing system was used by ten owners; 28JD, 42JD, 43JD, 44JD, 46JD, 49JD, 67JD, 68JD, 88RD</td>
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| 20 JD | 1 | Roof Deck (Main Concrete Pouring) |
| | 2 | Waterproofing; Liquid Applied Polyurethane 2 coats |
| | 3 | Thermal Insulation (Polyurethane Boards) |
| | 4 | Sand & Cement |
| | 5 | Fixed Tiles with/out Slope |
| | 6 | Expansion Joints |
| | Drainage Outlets: 5--2-inch |
| **Description:** This is a covered roofing system with fixed tiles. |
| **Merits:** Good number of drainage outlets |
| **Drawbacks:** The waterproofing was put on a non-sloped surface |
| **Problems:** No |
| **Usage:** This roofing system was used by one owner only. |

| 21 JD | 1 | Roof Deck (Main Concrete Pouring) with red block hordi |
| | 2 | Bituminous Sheets (Waterproofing) |
| | 3 | Sand & Cement |
| | 4 | Fixed Tiles with/out Slope |
| | 21JD Drainage Outlets: 2--4-inch |
| | 38JD Drainage Outlets: 1--4-inch (NP) |
| | 56JD Drainage Outlets: 4--4-inch (NP) |
| | 57JD Drainage Outlets: 2--2-inch (NP) |
| | 70JD Drainage Outlets: 2--4-inch (NP) |
| **Description:** This is a covered waterproofing system. |
| **Merits:** Good size of drainage outlets. |
| **Drawbacks:** The waterproofing was put on a non-sloped surface; Drainage outlets were too few. |
| **Problems:** Leakage |
| **Usage:** This roofing system was used by five owners; 38JD, 56JD, 57JD, 70JD |
| 22 | 1. Roof Deck with red clay hordi | **Description:** This system used two layers of asphalt as waterproofing and fixed tiles as a loading layer.  
**Merits:** No comments  
**Drawbacks:** The waterproofing was put on a non-sloped surface  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
| JD | 2. Asphalt first layer | |
|    | 3. Asphalt second layer | |
|    | 4. Sand & Cement | |
|    | 5. Fixed Tiles with Slope | |
|    | **Drainage Outlets:** 3--3-inch | |
| 23 | 1. Roof Deck (Main Concrete Pouring) | **Description:** This system differs from some roofing systems by the usage of rough sand on the asphalt.  
**Merits:** Good number of drainage outlets  
**Drawbacks:** The waterproofing was put on a non-sloped surface  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
| JD | 2. Asphalt | |
|    | 3. Rough Sand | |
|    | 4. Bituminous Rolls Waterproofing | |
|    | 5. Asphalt | |
|    | 6. Sand & Cement | |
|    | 7. Fixed Tiles with Slope | |
|    | **Drainage Outlets:** 4--3-inch | |
| 24 | 1. Roof Deck (Main Concrete Pouring) with red block hordi | **Description:** Covered and accessible  
**Merits:** Good size of drainage outlets.  
**Drawbacks:** The waterproofing was put on a non-sloped surface; Drainage outlets were too few.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
<p>| DO | 2. Waterproofing; Liquid Applied Polyurethane 2 coats | |
|    | 3. Sloped Concrete Screed | |
|    | <strong>Drainage Outlets:</strong> 1--4-inches | |</p>
<table>
<thead>
<tr>
<th>25</th>
<th>DM</th>
<th>Description: This is an exposed non-accessible waterproofing system.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td><strong>Merits:</strong> Double waterproofing protection; waterproofing was put on a sloped surface; Good number of drainage outlets.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Drawbacks:</strong> The concrete protection layer is too weak with no enforcement; the size of drainage outlets was too small.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Problems:</strong> Leakage</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Usage:</strong> This roofing system was used by one owner only.</td>
</tr>
<tr>
<td></td>
<td>1.</td>
<td>Roof Deck (Main Concrete Pouring) with Red Block Hordi</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>Sloped Concrete Screed</td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td>Waterproofing; Bituminous Sheets</td>
</tr>
<tr>
<td></td>
<td>4.</td>
<td>2-cm-thick Concrete Protection Layer</td>
</tr>
<tr>
<td></td>
<td>5.</td>
<td>Waterproofing; Granular surface Bitumen Sheets</td>
</tr>
<tr>
<td></td>
<td>6.</td>
<td>Flashing</td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 4–2-inch</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>DM</td>
<td>Description: This system has two types of waterproofing materials, one is covered and one is exposed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Merits:</strong> Double waterproofing protection; waterproofing was put on a sloped surface; Good size of drainage outlets.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Drawbacks:</strong> The 1st waterproofing was put on a non-sloped surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Problems:</strong> Yes</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Usage:</strong> This roofing system was used by two owners; 69JD</td>
</tr>
<tr>
<td></td>
<td>1.</td>
<td>Roof Deck (Main Concrete Pouring)</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>Waterproofing; Bituminous Sheets</td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td>Thermal Insulation (Extruded Polystyrene Boards; Escofoam)</td>
</tr>
<tr>
<td></td>
<td>4.</td>
<td>Sand &amp; Cement</td>
</tr>
<tr>
<td></td>
<td>5.</td>
<td>Fixed Tiles with Slope</td>
</tr>
<tr>
<td></td>
<td>6.</td>
<td>Expansion Joints</td>
</tr>
<tr>
<td></td>
<td>7.</td>
<td>Waterproofing; Paint-like Acrylic</td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 4–4-inch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>69JD Drainage Outlets: 3–4-inch</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>DN</td>
<td>Description: This is an exposed system which used the roof deck as the sloped concrete screed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Merits:</strong> Good, cheap system; Good size of drainage outlets; The waterproofing was put on a sloped surface.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Drawbacks:</strong> The size of drainage outlets was too small.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Problems:</strong> No</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Usage:</strong> This roofing system was used by one owner only.</td>
</tr>
<tr>
<td></td>
<td>1.</td>
<td>Roof Deck (Main Concrete Pouring) that includes Slope with Red Block Hordi</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>Waterproofing 1st Coat Acrylic</td>
</tr>
<tr>
<td></td>
<td>3.</td>
<td>Waterproofing 2nd Coat Acrylic</td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 10–2-inch</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>JD</td>
<td>1 Roof Deck (Main Concrete Pouring) with Red Block Hordi</td>
</tr>
<tr>
<td>----</td>
<td>----</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 Asphalt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Asphalted Jute</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Asphalt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Sand &amp; Cement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 Fixed Tiles with Slope</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drainage Outlets: 3--4-inch</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>30</th>
<th>JD</th>
<th>1 Roof Deck with red clay hordi</th>
<th><strong>Description:</strong> This system used bituminous sheets as a waterproofing material and fixed tiled as a loading layer. <strong>Merits:</strong> No comments <strong>Drawbacks:</strong> Few drainage outlets; The waterproofing was put on a non-sloped surface. The size of drainage outlets was too small. <strong>Problems:</strong> No <strong>Usage:</strong> This roofing system was used by one owner only.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2 Bituminous Sheets Waterproofing</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Sand &amp; Cement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Fixed Tiles with Slope</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Expansion Joints</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drainage Outlets: 2--2-inch</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>32</th>
<th>DN</th>
<th>1 Roof Deck (Main Concrete Pouring)</th>
<th><strong>Description:</strong> This is a conventional, covered roofing system using asphalt and jute as a waterproofing material. <strong>Merits:</strong> Good size of drainage outlets; <strong>Drawbacks:</strong> Sloped concrete screed was installed on a non-firm base without steel enforcement; The waterproofing was put on a non-sloped surface. <strong>Problems:</strong> No <strong>Usage:</strong> This roofing system was used by one owner only.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2 Thermal Insulation (Polyurethane foam) 10 cm thick</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 Hot asphalt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 Jute inserted in Asphalt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 Hot Asphalt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 Sloped Concrete Screed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drainage Outlets: 3--4-inch</td>
<td></td>
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<tr>
<td>---</td>
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<td>---</td>
<td></td>
</tr>
<tr>
<td>33 JD</td>
<td>1 Roof Deck (Main Concrete Pouring)</td>
<td><strong>Description:</strong> This is a covered inverted roofing system which used polyurethane boards as a thermal insulation material. <strong>Merits:</strong> Additional waterproofing protection on the thermal insulation materials. <strong>Drawbacks:</strong> The waterproofing was put on a non-sloped surface. <strong>Problems:</strong> No <strong>Usage:</strong> This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Bituminous Sheets Waterproofing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Thermal Insulation; Polyurethane Boards</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 A sprayed material on the thermal insulation (unknown)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Sand &amp; Cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Fixed Tiles with Slope</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 3--3-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34 JD</td>
<td>1 Roof Deck (Main Concrete Pouring)</td>
<td><strong>Description:</strong> This is a covered conventional roofing system. <strong>Merits:</strong> Good size of drainage outlets. <strong>Drawbacks:</strong> Few drainage outlets; The waterproofing was put on a non-sloped surface. <strong>Problems:</strong> No <strong>Usage:</strong> This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Thermal Insulation; Perlite</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Waterproofing; Bituminous Sheets</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Liquefied asphalt</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Sand and cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Fixed Tiles with Slope</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 2--4-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 JD</td>
<td>1 Roof Deck (Main Concrete Pouring) with Red Block Hordi</td>
<td><strong>Description:</strong> This is a covered waterproofing system which used asphalt and jute. <strong>Merits:</strong> No comments <strong>Drawbacks:</strong> Few drainage outlets; The waterproofing was put on a non-sloped surface. <strong>Problems:</strong> No <strong>Usage:</strong> This roofing system was used by three owners; 55JD, 100DM L/C: Leakage and cracks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Asphalt</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Jute</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Sand and cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Fixed Tiles with Slope</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 2--3-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>55JD Drainage Outlets: 2--4-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100DM Drainage Outlets: 2--4-inch, L/C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36 102 QT</td>
<td>1 Roof Deck (Main Concrete Pouring)</td>
<td><strong>Description:</strong> This system used asphalt only. <strong>Merits:</strong> Good number of drainage outlets <strong>Drawbacks:</strong> The waterproofing was put on a non-sloped surface. The size of drainage outlets was too small. <strong>Problems:</strong> Cracks <strong>Usage:</strong> This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 Asphalt</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Sand and cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Fixed Tiles with Slope</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 6--2-inch</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 37 | JD | 1 Roof Deck (Main Concrete Pouring) with Red Block Hordi  
2 Hot asphalt  
3 Sloped concrete screed  
Drainage Outlets: 4--3-inch | **Description:** This system used asphalt only.  
**Merits:** No comments  
**Drawbacks:** The waterproofing was put on a non-sloped surface.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
| 39 | DM | 1 Roof Deck (Main Concrete Pouring) with red block hordi  
2 Sloped Concrete Screed  
3 Plastic Wire Mesh Enforcement  
4 Waterproofing; Paint-like Acrylic Drainage Outlets: 6--2-inch | **Description:** This is an exposed, accessible system.  
**Merits:** Good number of drainage outlets; The waterproofing was put on a sloped surface; use of wire mesh enforcement.  
**Drawbacks:** The size of drainage outlets was too small.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
| 41 | JD | 1 Roof Deck (Main Concrete Pouring)  
2 Asphalt first layer  
3 Asphalt second layer  
4 Sand and cement  
5 Fixed tiles with slope  
Drainage Outlets: 5--4-inch | **Description:** This system used two layers of asphalt as a waterproofing material.  
**Merits:** Good number and size of drainage outlets.  
**Drawbacks:** The waterproofing was put on a non-sloped surface.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
| 45 | JD | 1 Roof Deck (Main Concrete Pouring)  
2 Waterproofing; Bituminous Sheets  
3 Thermal Insulation; Extruded Polystyrene  
4 Sand and cement  
5 Fixed tiles with slope  
Drainage Outlets: 3--3-inch | **Description:** Inverted, covered  
**Merits:** No comments.  
**Drawbacks:** The waterproofing was put on a non-sloped surface.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
<table>
<thead>
<tr>
<th>47</th>
<th>JD</th>
<th>1</th>
<th>Roof Deck (Main Concrete Pouring) with Red Block Hordi</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Waterproofing Bituminous Sheets</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Asphalt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>Sand and cement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>Fixed tiles with slope</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Drainage Outlets: 4--4-inch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Description: This roofing system used bituminous sheets as a waterproofing material.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Merits: Good number and size of drainage outlets.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drawbacks: The waterproofing was put on a non-sloped surface.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problems: Leakage</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usage: This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>JD</td>
<td>1</td>
<td>Roof Deck (Main Concrete Pouring) with red block hordi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Plastering layer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Bituminous Sheets Waterproofing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>Sand and cement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>Fixed tiles with slope</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Drainage Outlets: 1--4-inch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Description: This roofing system used bituminous sheets as a waterproofing material; in addition, plastering layer was used.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Merits: Good size of drainage outlets.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drawbacks: The waterproofing was put on a non-sloped surface.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problems: No</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usage: This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>JD</td>
<td>1</td>
<td>Roof Deck (Main Concrete Pouring)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Jute</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Hot asphalt</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>Jute</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>Hot asphalt</td>
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<tr>
<td></td>
<td></td>
<td>6</td>
<td>Sand and cement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>Fixed tiles with slope</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Drainage Outlets: 2--2-inch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Description: This roofing system used two layers of jute with two layers of asphalt as a waterproofing material.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Merits: No comments</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drawbacks: Few and small size of drainage outlets; The waterproofing was put on a non-sloped surface.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Problems: No</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usage: This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>JD</td>
<td>1</td>
<td>Roof Deck (Main Concrete Pouring)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Sand and cement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Fixed tiles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>Expansion joints</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>Bituminous Sheets Waterproofing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>Gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Drainage Outlets: 3--4-inch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Description: This is a strange roofing system that has the waterproofing covered by gravel and used the fixed tiles under the roofing membrane.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Merits: Good size of drainage outlets; The waterproofing was put on a sloped surface.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drawbacks: The waterproofing was installed on the fixed tiles</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Problems: No</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Usage: This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td>JD</td>
<td>52</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td>Description: This is a strange system that used two loading layers, fixed tiles and gravel. One should have been enough.</td>
</tr>
<tr>
<td>----</td>
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<td>----------------------------------</td>
<td>-------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Sloped screed concrete</td>
<td>Merits: Good size of drainage outlets; The waterproofing was put on a sloped surface.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Sand and cement</td>
<td>Drawbacks: The waterproofing was put on the fixed tiles.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Fixed tiles</td>
<td>Problems: No</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Bituminous Sheets Waterproofing</td>
<td>Usage: This roofing system was used by one owner only.</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Gravel</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drainage Outlets: 4–5-inch</td>
<td></td>
</tr>
<tr>
<td>JD</td>
<td>53</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td>Description: This system used a waterproofing materials that is applied on fixed tiles. Gravel was used as a loading layer.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Sand and cement</td>
<td>Merits: Good size of drainage outlets; The waterproofing was put on a sloped surface.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Fixed tiles</td>
<td>Drawbacks: Small number of drainage outlets; The waterproofing was put on the fixed tiles.</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Bituminous Sheets Waterproofing</td>
<td>Problems: No</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Gravel</td>
<td>Usage: This roofing system was used by one owner only.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drainage Outlets: 2–4-inch</td>
<td></td>
</tr>
<tr>
<td>JD</td>
<td>54</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td>Description: This is an inverted accessible covered roofing system.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Sloped screed concrete</td>
<td>Merits: The waterproofing was put on a sloped surface.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Waterproofing; Liquid applied</td>
<td>Drawbacks: Few drainage outlets.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Polyurethane</td>
<td>Problems: No</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Light Weight Concrete</td>
<td>Usage: This roofing system was used by one owner only.</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Sand and cement</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Fixed tiles</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Drainage Outlets: 2–3-inch</td>
<td></td>
</tr>
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<tr>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>58</td>
<td>1 Roof Deck (Main Concrete Pouring)</td>
<td><strong>Description:</strong> This is an inverted, accessible covered roofing system. <strong>Merits:</strong> The waterproofing was put on a sloped surface. <strong>Drawbacks:</strong> Few drainage outlets; The size of drainage outlets was too small. <strong>Problems:</strong> No <strong>Usage:</strong> This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td>103</td>
<td>2 Sloped screed concrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SY</td>
<td>3 Waterproofing; Commercial paper</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Thermal Insulation; Extruded Polystyrene</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Sand and cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Fixed Tiles with Slope</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 2--2-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>1 Roof Deck (Main Concrete Pouring)</td>
<td><strong>Description:</strong> This is a conventional, non-accessible, exposed roofing system. <strong>Merits:</strong> The waterproofing was put on a sloped surface. <strong>Drawbacks:</strong> Few drainage outlets; The size of drainage outlets was too small. <strong>Problems:</strong> No <strong>Usage:</strong> This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>2 Light Weight Concrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Sand and cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Fixed tiles with slope</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Waterproofing; Liquid Applied Polyurethane</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 2--2-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>1 Roof Deck (Main Concrete Pouring)</td>
<td><strong>Description:</strong> This is an exposed system. <strong>Merits:</strong> The waterproofing was put on a sloped surface. <strong>Drawbacks:</strong> Small number of drainage outlets; The size of drainage outlets was too small. <strong>Problems:</strong> Cracks <strong>Usage:</strong> This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>2 Sloped concrete screed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Waterproofing; Liquid Applied Acrylic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 2--2-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>1 Roof Deck (Main Concrete Pouring) with Red Block Hordi</td>
<td><strong>Description:</strong> This is exposed non-accessible roofing system. <strong>Merits:</strong> Good size of drainage outlets; The waterproofing was put on a sloped surface. <strong>Drawbacks:</strong> No comments <strong>Problems:</strong> Yes <strong>Usage:</strong> This roofing system was used by one owner only.</td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>2 Sloped concrete screed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Sealant in the sloped screed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Waterproofing Bituminous Sheets</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Waterproofing; Liquid Applied Acrylic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 3--4-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>1 Roof Deck (Main Concrete Pouring)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM</td>
<td>2 Sloped concrete screed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 Waterproofing Bituminous Sheets</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 Protection Layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 Sand and cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 Fixed tiles</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 Flashing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Drainage Outlets</strong>: 4--3-inch</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Description</strong>: Covered and accessible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Merits</strong>: The waterproofing was put on a sloped surface.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Drawbacks</strong>: No comments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Problems</strong>: Leakage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Usage</strong>: This roofing system was used by one owner only.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 63 | 1 Roof Deck (Main Concrete Pouring) |
| 104 | 2 Sloped concrete screed |
| DM | 3 Waterproofing; Liquid Applied Acrylic |
|    | 4 Sand and cement |
|    | 5 Fixed tiles with slope |
| 63/104DM | **Drainage Outlets**: 3--2&4 inch; 94/106 DM **Drainage Outlets**: 7--2-inch, Leakage and cracks |
| **Description**: Covered & accessible |
| **Merits**: The waterproofing was put on a sloped surface. |
| **Drawbacks**: No comments |
| **Problems**: No |
| **Usage**: This roofing system was used by two owners. |

| 64 | Thermal Insulation; Polyurethane Boards |
| DM | Waterproofing Bituminous Sheets |
|    | **Drainage Outlets**: 3--2-inch |
| **Description**: No comments |
| **Merits**: No comments |
| **Drawbacks**: The size of drainage outlets was too small. |
| **Problems**: No |
| **Usage**: This roofing system was used by one owner only. |

<p>| 65 | 1 Roof Deck (Main Concrete Pouring) |
| DM | 2 Asphalt layer |
|    | 3 Jute |
|    | 4 Asphalt layer |
|    | 5 Asphalt layer |
|    | 6 Sand and cement |
|    | 7 Fixed tiles with slope |
|    | <strong>Drainage Outlets</strong>: 4--2-inch |
| <strong>Description</strong>: Covered, accessible |
| <strong>Merits</strong>: No comments |
| <strong>Drawbacks</strong>: The waterproofing was put on a non-sloped surface. The size of drainage outlets was too small. |
| <strong>Problems</strong>: No |
| <strong>Usage</strong>: This roofing system was used by one owner only. |</p>
<table>
<thead>
<tr>
<th></th>
<th>66</th>
<th>71</th>
<th>73</th>
<th>74</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT</td>
<td>DM</td>
<td>TB</td>
<td>JD</td>
</tr>
<tr>
<td>1</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td>Roof Deck (Main Concrete Pouring)</td>
<td>Roof Deck (Main Concrete Pouring)</td>
</tr>
<tr>
<td>2</td>
<td>Plastering layer</td>
<td>Sloped screed concrete</td>
<td>Sloped screed concrete</td>
<td>with Red Block Hordi</td>
</tr>
<tr>
<td>3</td>
<td>Waterproofing; Acrylic-based</td>
<td>Expansion Joints</td>
<td>Thermal Insulation; Extruded</td>
<td>Waterproofing; Bituminous Sheets</td>
</tr>
<tr>
<td></td>
<td>waterproofing (3 coats)</td>
<td></td>
<td>Polystyrene</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Protection layer; Polyethylene</td>
<td></td>
<td>Sand and cement</td>
<td>Sand and cement</td>
</tr>
<tr>
<td>5</td>
<td>Extruded polystyrene thermal</td>
<td></td>
<td>6</td>
<td>Fixed tiles</td>
</tr>
<tr>
<td></td>
<td>insulation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Screed concrete with slope to falls</td>
<td></td>
<td>7</td>
<td>Expansion joints</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Expansion joints</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage Outlets:</td>
<td>6-3-inch</td>
<td>3-3/4 inch</td>
<td>4-3-inch</td>
<td>2-4-inch</td>
</tr>
</tbody>
</table>

<p>| Description: | Inverted, covered, accessible | Exposed, non-accessible | Covered, accessible | Covered, accessible. |
| Merits: | Good number of drainage outlets; use of expansion joints. | The waterproofing was put on a sloped surface. | Use of expansion joints. | Use of expansion joints. |
| Drawbacks: | The waterproofing was put on a non-sloped surface. | No comments | The waterproofing was put on a non-sloped surface. | Few drainage outlets; The waterproofing was put on a non-sloped surface. |
| Problems: | Leakage | Leakage | No | Leakage |
| Usage: | This roofing system was used by one owner only. | This roofing system was used by one owner only. | This roofing system was used by one owner only. | This roofing system was used by one owner only. |</p>
<table>
<thead>
<tr>
<th></th>
<th>Light Weight Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Waterproofing; Liquid Applied Polyurethane</td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 2--3-inch</td>
</tr>
</tbody>
</table>

**Description:** No components order was given.  
**Merits:** No comments.  
**Drawbacks:** Small number of drainage outlets.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only.

| 76 | Roof Deck (Main Concrete Pouring) | Covered, accessible  
|----|----------------------------------|
| RD | Waterproofing; Bituminous Sheets  
|    | Jute  
|    | Asphalt  
|    | Sand and cement  
|    | Fixed tiles  
|    | Drainage Outlets: 3--4-inch |

**Description:** Covered, accessible  
**Merits:** Good size of drainage outlets; The waterproofing protection was doubled.  
**Drawbacks:** The waterproofing was put on a non-sloped surface.  
**Problems:** Leakage  
**Usage:** This roofing system was used by one owner only.

| 79 | Roof Deck (Main Concrete Pouring)  
|    | Sleped Concrete Screed  
|    | Sealant in the Sleped Screed  
|    | Waterproofing; Self adhesive membrane  
|    | Sand and cement  
|    | Fixed tiles with slope  
|    | Drainage Outlets: 2--4-inch |

**Description:** Components' order was not given.  
**Merits:** Good size of drainage outlets.  
**Drawbacks:** Small number of drainage outlets.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only.

<table>
<thead>
<tr>
<th>80</th>
<th>Roof Deck (Main Concrete Pouring) with Red Block Hordi</th>
</tr>
</thead>
</table>
|    | Light Weight Concrete  
|    | Waterproofing; Bituminous Sheets  
|    | Sand and cement  
|    | Fixed tiles  
|    | Expansion joints  
|    | Flashing  
|    | Drainage Outlets: 3--4-inch |

**Description:** Conventional, covered and accessible.  
**Merits:** Good size of drainage outlets; The waterproofing was put on a sloped surface.  
**Drawbacks:** No comments.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only.
| 81 DN | 1 Roof Deck (Main Concrete Pouring) with red block hordi | **Description:**  
**Merits:** Good number of drainage outlets; The waterproofing was put on a sloped surface.  
**Drawbacks:** No comments.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Sloped Concrete Screed</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>3 Waterproofing; Paint-like Acrylic</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 10--3-inch</td>
<td>---</td>
</tr>
</tbody>
</table>

| 82 DO | 1 Roof Deck (Main Concrete Pouring)                        | **Description:**  
**Merits:** conventional, Exposed and non-accessible.  
**Drawbacks:** The sloped concrete screed was installed on a non-firm base with no steel enforcement and no expansion joints.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Thermal Insulation; Expanded Polystyrene</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>3 Sloped Concrete Screed</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>4 Waterproofing; Granular Bituminous Sheets</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 4--3-inch</td>
<td>---</td>
</tr>
</tbody>
</table>

| 83 DM | 1 Sloped Roof Deck (Main Concrete Pouring) with Sika          | **Description:**  
**Merits:** Covered, accessible  
**Drawbacks:** Usage of expansion joints.  
**Problems:** Yes  
**Usage:** This roofing system was used by one owner only. |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 Cement cant strip</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>3 Loose laid bituminous sheets</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>4 Sloped screed concrete</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>5 Expansion joints with sealant</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 4--3-inch</td>
<td>---</td>
</tr>
</tbody>
</table>

| 84 KH | 1 Roof Deck (Main Concrete Pouring)                          | **Description:**  
**Merits:** Covered, accessible  
**Drawbacks:** The waterproofing was put on a non-sloped surface. The size of drainage outlets was too small.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>2 Hot asphalt</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>3 Jute saturated with asphalt</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>4 Sand and cement</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>5 Fixed tiles with slope</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>6 Cant strip</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>Drainage Outlets: 4--2-inch</td>
<td>---</td>
</tr>
</tbody>
</table>
| 90 DO | 1 Roof Deck (Main Concrete Pouring) | **Description:** Covered, accessible.  
**Merits:** No comments.  
**Drawbacks:** The waterproofing was put on a non-sloped surface. The size of drainage outlets was too small.  
**Problems:** Leakage  
**Usage:** This roofing system was used by one owner only. |
| 91 DN | 1 Thermal Insulation; False Ceiling  
2 Roof Deck (Main Concrete Pouring)  
3 Sloped Concrete Screed  
4 Waterproofing; Sealant in the Sloped Screed  
Drainage Outlets: 4--2-inch | **Description:** Cheap system using false ceiling as a thermal insulation and sealant in the screed concrete as a waterproofing materials.  
**Merits:** No comments.  
**Drawbacks:** Materials might not be effective. The size of drainage outlets was too small.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only. |
| 92 KH | 1 Roof Deck (Main Concrete Pouring)  
2 Waterproofing; Liquid Applied Polyurethane  
3 Thermal Insulation; Extruded Polystyrene  
4 Wire mesh  
5 Sand and cement  
6 Broken blocks  
7 Very smooth sloped concrete screed  
Drainage Outlets: 6--4-inch | **Description:** Conventional, covered and accessible  
**Merits:** Good size and number of drainage outlets.  
**Drawbacks:** The waterproofing was put on a non-sloped surface.  
**Problems:** Leakage  
**Usage:** This roofing system was used by one owner only. |
| 93 DN | 1 Roof Deck (Main Concrete Pouring)  
2 Thermal insulation; Extruded Polystyrene  
3 Light weight concrete with slope  
4 Waterproofing; Bitumen Sheets, 1st layer (3 mm thick)  
5 Waterproofing; Bitumen Sheets, 2nd layer (3 mm thick)  
6 Protection layer (Polyethylene sheets)  
7 Sand and cement  
8 Fixed tiles  
9 Expansion joints  
10 Flashing  
Drainage Outlets: 4--3-inch | **Description**: Conventional, covered and accessible.  
**Merits**: Double thermal insulation and double waterproofing. The waterproofing was put on a sloped surface.  
**Drawbacks**: None.  
**Problems**: No  
**Usage**: This roofing system was used by one owner only. |
|---|---|
| 95 DO | 1 Roof Deck (Main Concrete Pouring)  
2 Hot asphalt  
3 Protection Layer  
4 Sand and cement  
5 Fixed tiles with slope  
Drainage Outlets: 4--2-inch | **Description**: covered and accessible  
**Merits**: No comments.  
**Drawbacks**: The waterproofing was put on a non-sloped surface. The size of drainage outlets was too small.  
**Problems**: Leakage  
**Usage**: This roofing system was used by one owner only. |
| 96 DO | 1 Roof Deck (Main Concrete Pouring)  
2 Waterproofing; Liquid Applied Acrylic  
3 Sloped screed concrete  
4 Sealant in the Sloped Screed  
5 Expansion Joints  
Drainage Outlets: 3--3-inch | **Description**: Covered and accessible.  
**Merits**: Use of expansion joints.  
**Drawbacks**: The waterproofing was put on a non-sloped surface.  
**Problems**: Leakage and cracks.  
**Usage**: This roofing system was used by one owner only. |
| DO  | 97 | Roof Deck (Main Concrete Pouring) | **Description:** Conventional, exposed and non-accessible.  
**Merits:** The waterproofing was put on a sloped surface.  
**Drawbacks:** Small number of drainage outlets; The sloped screed concrete was installed on a non-firm base with no steel enforcement or expansion joints.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only.  
|     |    | 1 | **Description:** Conventional, exposed and non-accessible.  
**Merits:** The waterproofing was put on a sloped surface.  
**Drawbacks:** Small number of drainage outlets; The sloped screed concrete was installed on a non-firm base with no steel enforcement or expansion joints.  
**Problems:** No  
**Usage:** This roofing system was used by one owner only.  |  | 2 | Thermal Insulation; Extruded Polystyrene  
3 | Sloped screed concrete  
4 | Sealant in the Sloped Screed  
5 | Waterproofing; Bituminous Sheets  
   | Drainage Outlets: 2--3-inch |  
|     |    | 98 | Roof Deck (Main Concrete Pouring) | **Description:** This is a reinforced exposed and accessible waterproofing system using liquid applied materials.  
**Merits:** The waterproofing was put on a sloped surface.  
**Drawbacks:** The size of drainage outlets was too small.  
**Problems:** Leakage and cracks.  
**Usage:** This roofing system was used by one owner only.  
|     |    | 1 | **Description:** This is a reinforced exposed and accessible waterproofing system using liquid applied materials.  
**Merits:** The waterproofing was put on a sloped surface.  
**Drawbacks:** The size of drainage outlets was too small.  
**Problems:** Leakage and cracks.  
**Usage:** This roofing system was used by one owner only.  |  | 2 | Sloped Concrete Screed  
3 | Waterproofing; Liquid Applied Acrylic, 2 coat  
4 | Plastic Reinforcement Mesh  
   | Drainage Outlets: 4--2-inch |  
|     |    | 99 | Roof Deck (Main Concrete Pouring) | **Description:** Inverted, covered and accessible.  
**Merits:** Good size and number of drainage outlets; use of reinforcement and expansion joints with the sloped concrete screed.  
**Drawbacks:** The waterproofing was put on a non-sloped surface; the sloped concrete screed was put on a non-firm base.  
**Problems:** Cracks.  
**Usage:** This roofing system was used by one owner only.  
|     | DM | 1 | **Description:** Inverted, covered and accessible.  
**Merits:** Good size and number of drainage outlets; use of reinforcement and expansion joints with the sloped concrete screed.  
**Drawbacks:** The waterproofing was put on a non-sloped surface; the sloped concrete screed was put on a non-firm base.  
**Problems:** Cracks.  
**Usage:** This roofing system was used by one owner only.  |  | 2 | Waterproofing; Liquid Applied Polyurethane  
3 | Thermal Insulation; Expanded polystyrene  
4 | Protection Layer; Polyethylene sheets  
5 | Steel Reinforcement  
6 | Sloped Concrete Screed  
7 | Expansion Joints  
<p>| Drainage Outlets: 6--4-inch |</p>
<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>Roof Deck (Main Concrete Pouring)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>Asphalt</td>
</tr>
<tr>
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Description: Covered and accessible.  
Merits: No comments.  
Drawbacks: The waterproofing was put on a non-sloped surface.  
Problems: No.  
Usage: This roofing system was used by one owner only.

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Description: Covered and accessible.  
Merits: Good size and number of drainage outlets; use cement cant strip.  
Drawbacks: The waterproofing was put on a non-sloped surface.  
Problems: Deterioration of the whole house with leakage and cracks; falling of roof plastering and corrosion of roof steel bars.  
Usage: This roofing system was used by one owner only.

This table shows that 75 different roofing systems were used by 102 owners. This diversity of systems shows that roofing business is far from standardization. The next table (Table VIII) summarizes these systems in a concise form and shows the commonness of these systems.
### TABLE VIII

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Chapter 7: Questionnaires' Analysis and Results

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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>X2</td>
<td>X3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X4</td>
<td>X5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>96</td>
<td>LAC2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>BS5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>EXRP2</td>
<td>X3</td>
<td></td>
<td>X4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>98</td>
<td>2LAC3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>LAPU2</td>
<td>PE4</td>
<td></td>
<td></td>
<td></td>
<td>EXNP3</td>
<td>X6</td>
<td></td>
<td>X7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>107</td>
<td>X2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>LAC6</td>
<td>X2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CM3,CCS5</td>
<td>IDM</td>
</tr>
</tbody>
</table>

X# The roofing component and its location within the roofing system
#X The roofing component and how many times it was applied
BS Bituminous Sheets
LAC Liquid Applied Acrylic
PUF Polyurethane Foam
PUB Polyurethane Boards
PWM Plastic Wire Mesh
RFD Roof Deck
RS Rough Sand
PE Polyethylene Sheeting
LAPU Liquid Applied Polyurethane
PSH Polystyrene Hordi
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BB</td>
<td>Broken Blocks</td>
<td>EXNP</td>
<td>Expanded Polystyrene</td>
</tr>
<tr>
<td>CCS</td>
<td>Cement Cant Strip</td>
<td>CP</td>
<td>Commercial Paper</td>
</tr>
<tr>
<td>EXRP</td>
<td>Extruded Polystyrene</td>
<td>PL</td>
<td>Plastering Layer</td>
</tr>
<tr>
<td>STE</td>
<td>Steel Enforcement</td>
<td>SAM</td>
<td>Self Adhesive Membrane</td>
</tr>
<tr>
<td>SUM</td>
<td>Sprayed Unknown Material</td>
<td>PRLT</td>
<td>Perlite</td>
</tr>
<tr>
<td>SWM</td>
<td>Steel Wire Mesh</td>
<td>CPL</td>
<td>Concrete Protection Layer</td>
</tr>
<tr>
<td>FC</td>
<td>False Ceiling</td>
<td>TB</td>
<td>The house is located at Tabuk</td>
</tr>
<tr>
<td>DM</td>
<td>The house is located at Dammam</td>
<td>RD</td>
<td>The house is located at Riyadh</td>
</tr>
<tr>
<td>JD</td>
<td>The house is located at Jeddah</td>
<td>KH</td>
<td>The house is located at Khobar</td>
</tr>
<tr>
<td>DO</td>
<td>The house is located at Doha</td>
<td>QT</td>
<td>The house is located at Qatif</td>
</tr>
<tr>
<td>DN</td>
<td>The house is located at Danah</td>
<td>SY</td>
<td>The house is located at Sayhat</td>
</tr>
<tr>
<td>TT</td>
<td>The house is located at Tarout</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>The house is located at Ras Tanura</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This table shows that the most commonly used system is system No. 19 which is used by 10 owners. System No. 16 is used by 6 owners. System No. 21 is used by 5 owners. These systems were used in Jeddah and Riyadh. Therefore, roofing business is more standardized in Jeddah and Riyadh than in the Eastern Province where almost each house has a separate roofing system.
**Question No. 13.** How do you know that you have got a functionally working good roofing system?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I trust that the roofing contractor had made a good job</td>
<td>30</td>
<td>29</td>
<td>13</td>
<td>43</td>
<td>36</td>
</tr>
<tr>
<td>2. I ask the contractor to make flood test and I witnessed that*</td>
<td>26</td>
<td>25</td>
<td>8</td>
<td>31</td>
<td>22</td>
</tr>
<tr>
<td>3. I was witnessing the roofer while he was making the roofing</td>
<td>51</td>
<td>51</td>
<td>17</td>
<td>33</td>
<td>47</td>
</tr>
<tr>
<td>4. Other ways of checking (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- I consulted experienced engineers</td>
<td>14</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- I never had problems for the last five years</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- I hired a consultant/engineer</td>
<td>10</td>
<td>10</td>
<td>2</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>-- I don't know (I am not sure)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
</tbody>
</table>

* One owner indicated that in spite of making a flood test, the roofing failed one year later.

This question was meant to ask owners whether they are confident in their roofing systems and, if they are, we would like to know the methods that owners used to check the effectiveness of their roofing systems. From the answers we got, less than half of the owners questioned witnessed the roofer while doing the roofing. About one third of the owners gave their trust to roofers; therefore, owners trusted that the contractor would make a good job. That means that owners only assumed that their roofing works well; they are not sure. Only one quarter of owners asked for a flood test. See Figures 168 and 169.
Figure 168: Ways of knowing how good the roofing is. More than 50% of owners witnessed their roofing made.
Figure 169: Houses with and without problems as related to the ways of knowing the roofing's effectiveness.
Question No. 14. How much was the cost of the roof assembly in Saudi Riyals?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Less than 10,000 SR</td>
<td>32</td>
<td>31</td>
<td>11</td>
<td>34</td>
</tr>
<tr>
<td>2. Between 10,000 and 20,000 SR</td>
<td>34</td>
<td>33</td>
<td>13</td>
<td>38</td>
</tr>
<tr>
<td>3. Between 20,000 and 30,000 SR</td>
<td>18</td>
<td>18</td>
<td>7</td>
<td>39</td>
</tr>
<tr>
<td>4. More than 30,000 SR</td>
<td>15</td>
<td>15</td>
<td>4</td>
<td>27</td>
</tr>
</tbody>
</table>

The purpose of asking this question was to get a feeling of the cost of roofing that owners are willing to pay. Two thirds of owners were in the low cost bracket. It seems that owners tend toward low cost roofing. See Figures 170 and 171.
Figure 171: Roofing cost as related to roofing problems.
Question No. 15. What was the percentage of the roof assembly cost to the total cost of the house?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>% of Total No. of Houses</th>
<th>% of Houses with Problems</th>
<th>% of Houses with Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Up to 5%</td>
<td>78</td>
<td>77</td>
<td>38</td>
</tr>
<tr>
<td>2. Between 5% and 10%</td>
<td>17</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>3. Between 10% and 15%</td>
<td>3</td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>4. Between 15% and 20%</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5. More than 20%</td>
<td>2</td>
<td>2</td>
<td>50</td>
</tr>
</tbody>
</table>

The purpose of this question was to show how low the cost of roofing is when compared to the house cost. More than 3/4 of house owners indicated that the roofing cost was less than 5% of the house cost. See Figure 172.

Figure 172: Percentage of roofing cost to the total cost. Mostly less than 5%. 
Question No. 16. Does the roofing assembly work well?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes</td>
<td>71</td>
<td>70</td>
<td>16</td>
<td>23</td>
<td>44</td>
</tr>
<tr>
<td>2. No</td>
<td>16</td>
<td>16</td>
<td>14</td>
<td>88</td>
<td>39</td>
</tr>
<tr>
<td>3. I do not know</td>
<td>14</td>
<td>14</td>
<td>5</td>
<td>38</td>
<td>14</td>
</tr>
<tr>
<td>4. Other Remarks (specify)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>6</td>
</tr>
</tbody>
</table>

This question asked about the effectiveness of the roofing assemblies. Surprisingly, 70% of owners indicated that they have a well-working roofing. See Figure 173.

Figure 173: Roofing assembly effectiveness.
Chapter 7: Questionnaire Analysis And Results

Question No. 17. Are you satisfied with it as a whole?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes</td>
<td>80</td>
<td>80</td>
<td>16</td>
<td>20</td>
<td>44</td>
</tr>
<tr>
<td>2. No</td>
<td>22</td>
<td>22</td>
<td>20</td>
<td>91</td>
<td>56</td>
</tr>
</tbody>
</table>

This question was designed to test the satisfaction of owners with their roofing systems. More than 3/4 of owners expressed their satisfaction.

Question No. 18. Are you unsatisfied with any component?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes</td>
<td>23</td>
<td>23</td>
<td>18</td>
<td>78</td>
<td>50</td>
</tr>
<tr>
<td>2. No</td>
<td>71</td>
<td>70</td>
<td>16</td>
<td>23</td>
<td>44</td>
</tr>
<tr>
<td>3. If Yes, what component?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- All components</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>67</td>
<td>6</td>
</tr>
<tr>
<td>-- The waterproofing</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>86</td>
<td>17</td>
</tr>
<tr>
<td>-- The slope</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Application (labor qualification)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- The gap between the parapet and the roof deck</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- The expansion joints</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Screed &amp; sealant</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Fixed tiles</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
</tbody>
</table>

This question asks owners about the roofing component(s) that they are unsatisfied with. Most owners were satisfied with all roofing components; however, some roofing components have not satisfied some owners. Waterproofing was the roofing component with the widest dissatisfaction. See Figure 174.
Figure 174: Owners dissatisfaction with roofing components. Waterproofing is the most unsatisfactory with component.
7.2.3 **Thermal Insulation**

This study is not about thermal insulation. It is about roofing, concentrating mainly on waterproofing. However, if roofing is discussed, it is unavoidable to talk about thermal insulation since it is considered a main roofing component. Therefore, thermal insulation was not overlooked and the following few questions cover it.

<table>
<thead>
<tr>
<th>Question No. 19</th>
<th>If you used thermal insulation, what type?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ANSWERS</strong></td>
<td>Total No. of Houses</td>
</tr>
<tr>
<td>1. Extruded Polystyrene</td>
<td>14</td>
</tr>
<tr>
<td>2. Expanded Polystyrene</td>
<td>3</td>
</tr>
<tr>
<td>3. Polyurethane boards</td>
<td>3</td>
</tr>
<tr>
<td>4. Polyurethane Foam</td>
<td>1</td>
</tr>
<tr>
<td>5. Light weight concrete</td>
<td>7</td>
</tr>
<tr>
<td>6. Polystyrene hordi</td>
<td>1</td>
</tr>
<tr>
<td>7. Fiber glass</td>
<td></td>
</tr>
<tr>
<td>8. Others (specify)</td>
<td>34</td>
</tr>
<tr>
<td>-- Red Block Hordi</td>
<td>32</td>
</tr>
<tr>
<td>-- Perlite</td>
<td>1</td>
</tr>
<tr>
<td>-- False ceiling</td>
<td>1</td>
</tr>
<tr>
<td>-- None</td>
<td>29</td>
</tr>
</tbody>
</table>

This question was asked to see how popular the different types of thermal insulation materials are. It was found that thermal insulation is unpopular among owners. The most popular thermal insulation material is the red clay hordi which is the least effective material with respect to thermal insulation effectiveness. This material was selected by most owners because of its light weight and its acoustic insulation. It was not selected because of its thermal insulation properties. Most owners did not know if it has
thermal insulation characteristics. The second most popular type is extruded polystyrene which was used by 14 owners only. See Figure 175.
Question No. 20. On what basis did you choose this particular type?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problem</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I heard that it is the best</td>
<td>11</td>
<td>11</td>
<td>4</td>
<td>36</td>
<td>11</td>
</tr>
<tr>
<td>2. I read that it is the best</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>3. Like what my neighbor, friend or relative has</td>
<td>12</td>
<td>12</td>
<td>2</td>
<td>17</td>
<td>6</td>
</tr>
<tr>
<td>4. Supplier convinced me</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>50</td>
<td>8</td>
</tr>
<tr>
<td>5. I know from previous experience</td>
<td>8</td>
<td>8</td>
<td>1</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>6. Other reasons (specify)</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- I asked experts</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Red Hordi is light in weight</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>-- Red Hordi is acoustic insulator</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>-- Red Hordi was the common</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>practice</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Red Hordi cost was low</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>-- Red Hordi lasts for a long time</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- False ceiling has its aesthetic look</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- False ceiling is available and easy</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>to install</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Expanded polystyrene costs less</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>compared to others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Expanded polystyrene was the</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>common thermal insulation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>material on the market</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Other thermal insulation materials</td>
<td>1</td>
<td>1</td>
<td></td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>were not popular and unknown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Friend convinced me</td>
<td>2</td>
<td>2</td>
<td></td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>-- Engineer convinced me</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>-- Work experience</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>-- Thermal insulation was not put into</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>consideration when we selected red hordi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The purpose of this question was to know the basis on which owners based their selections. Most owners based their selection on the commonness of the material among other people. See Figure 176.
Figure 176: selection basis of thermal insulation materials.
Question No. 21. Why did you decide to put thermal insulation in the roof?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To make the house more comfortable</td>
<td>30</td>
<td>30</td>
<td>8</td>
<td>27</td>
<td>22</td>
</tr>
<tr>
<td>2. To save some of the energy cost</td>
<td>29</td>
<td>29</td>
<td>9</td>
<td>31</td>
<td>25</td>
</tr>
<tr>
<td>3. To make the burden less on the AC units</td>
<td>15</td>
<td>15</td>
<td>8</td>
<td>53</td>
<td>22</td>
</tr>
<tr>
<td>4. Like my friends</td>
<td>6</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question asked about reasons that made owners decide to put thermal insulation. See Figure 177.

Figure 177: Reasons for using thermal insulations.
### Question No. 22. Do you feel that you save some of the energy cost?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Houses</th>
<th>% of Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes, how much percent of yearly cost?</td>
<td>31</td>
<td>30</td>
<td>8</td>
<td>26</td>
</tr>
<tr>
<td>2. No, Why?</td>
<td>11</td>
<td>11</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>3. I don't know (not sure)</td>
<td>13</td>
<td>13</td>
<td>7</td>
<td>53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of Answers</th>
<th>% of Answers</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes, how much percent of yearly cost?</td>
<td>31</td>
<td>31</td>
<td>10%, 15%(3), 20%(2), 25%(2), 30%, 40%(3), 45%, 50%(2), 80%</td>
</tr>
</tbody>
</table>
| 2. No, Why? | 11 | 11 | - You feel the walls are hot when touching them  
- I feel that 90% of heat input is from the walls and windows  
- Because I didn't insulate the walls and I didn't use double glass windows |
| 3. I don't know (not sure) | 13 | 13 | |

This question asks about the saving of yearly energy cost and the percentage of that saving from the total yearly cost. From the answers given, most owners indicated that they saved some of the yearly cost. The saving ranges between 10% and 80%. Some owners indicated that they didn’t feel that they made any saving at all. Some other owners did not know whether they made any saving or not.
**Question No. 23. Do you think thermal insulation is effective in doing its function?**

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes, I feel it in my electric bill</td>
<td>21</td>
<td>21</td>
<td>6</td>
<td>29</td>
<td>17</td>
</tr>
<tr>
<td>2. Yes, I feel it in the inside environment of the house</td>
<td>26</td>
<td>26</td>
<td>8</td>
<td>31</td>
<td>22</td>
</tr>
<tr>
<td>3. No, I think it was a waste of money</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>4. No, I think it was a mistake</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I don't know</td>
<td>15</td>
<td>15</td>
<td>3</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>6. Others</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Only partially; effectiveness of red clay hordi is not much.</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Ventilation openings such as windows cannot be controlled</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question was asked in order to get the owners' opinion with respect to the effectiveness of the thermal insulation material that they are using. The great majority of owners thought positively in favor of thermal insulation.
7.2.4 WATERPROOFING

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. To protect it against harsh environment like humidity</td>
<td>16</td>
<td>16</td>
<td>3</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>2. To protect it against rain water</td>
<td>98</td>
<td>96</td>
<td>35</td>
<td>34</td>
<td>97</td>
</tr>
<tr>
<td>3. Like my friends</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Others (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Experts convinced me</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Contractor convinced me</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--To protect it against leakage in general</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
</tbody>
</table>

This question enquires about the reason(s) that made owners decide to put waterproofing. Almost all owners agreed that the main reason was protection against potential leakage caused by rain water.
### Question No. 25. If you use waterproofing, what type?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hot-installed asphalt-based bitumen</td>
<td>20</td>
<td>19.6</td>
<td>6</td>
<td>30</td>
<td>17</td>
</tr>
<tr>
<td>2. Cold-installed asphalt-based bitumen</td>
<td>20</td>
<td>19.6</td>
<td>10</td>
<td>50</td>
<td>28</td>
</tr>
<tr>
<td>3. Rubber-like black polyurethane</td>
<td>11</td>
<td>11</td>
<td>5</td>
<td>45</td>
<td>14</td>
</tr>
<tr>
<td>4. Self-adhesive membrane</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Paint-like white acrylic</td>
<td>13</td>
<td>13</td>
<td>9</td>
<td>69</td>
<td>25</td>
</tr>
<tr>
<td>6. Others (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--The agent presented the product</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Liquid applied white polyurethane; Volcum 350/351</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Hot asphalt only</td>
<td>16</td>
<td>16</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>--Hot asphalt and jute</td>
<td>22</td>
<td>22</td>
<td>10</td>
<td>45</td>
<td>28</td>
</tr>
<tr>
<td>--Sealant in the screed concrete</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Commercial Paper</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question was asked to know the types of waterproofing materials that are used in Saudi Arabia and also to know the usage share of each type. From the results of the survey, it can be seen that bituminous products are the most used products. Bituminous sheets were used by almost 40% of owners. The second most common waterproofing material was the asphalt and jute system. Both materials are bituminous products. See Figure 178 and Figure 179.
Figure 178: The commonness of waterproofing materials.
Figure 179: Waterproofing materials as related to roofing problems.
**Question No. 26.** On what basis did you choose this particular type?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>No. of House</th>
<th>% of House</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I heard that it is the best</td>
<td>25</td>
<td>25</td>
<td>7</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>2. I read that it is the best</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>43</td>
<td>8</td>
</tr>
<tr>
<td>3. Like what my neighbor, friend or</td>
<td>21</td>
<td>21</td>
<td>7</td>
<td>33</td>
<td>19</td>
</tr>
<tr>
<td>relative has</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Supplier convinced me</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td>33</td>
<td>11</td>
</tr>
<tr>
<td>5. I know that it is good from</td>
<td>17</td>
<td>17</td>
<td>3</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>previous experience</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Other reasons (specify)</td>
<td>16</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Experts convinced me</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Its low cost</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>38</td>
<td>8</td>
</tr>
<tr>
<td>-- A/E recommended it</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>-- Asphalt was the common material</td>
<td>11</td>
<td>11</td>
<td>2</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>at that time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- After comparing it with other</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>products in the market</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Acrylic does the job and it costs</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>less</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Asphalt was the cheapest system</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- It was the best at that time</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>6</td>
</tr>
<tr>
<td>-- The contractor convinced me</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>-- Asphalt and jute system was the</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>only system available</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- I never heard any complaint from</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>people who previously used asphalt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+ jute system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Bitumen rolls were the common</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>material</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Availability &amp; Commonness</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
</tbody>
</table>

The purpose of this question was to know the basis on which owners based their selection. Hearing about the product from others was the most common selection base. Owners do not go to the trouble of analyzing different materials. Hearing about them and seeing them used by others made owners decide to select their roofing systems. See Figure 180 and 181.
Figure 180: Basis for waterproofing selection.
Figure 181: Criteria of material selection as related to roofing problems.
Question No. 27. Do you think waterproofing is effective in doing its function?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes, I never got any problem during rain</td>
<td>75</td>
<td>74</td>
<td>12</td>
<td>16</td>
<td>33</td>
</tr>
<tr>
<td>2. No, I encountered many problems and leaks</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>100</td>
<td>53</td>
</tr>
<tr>
<td>3. I don't know, it was not challenged</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>63</td>
<td>14</td>
</tr>
</tbody>
</table>

This question asked about the effectiveness of the waterproofing material within the roofing system. Surprisingly, 3/4 of owners indicated that they never got any problem. See Figure 182.

Figure 182: Owners' opinions about the effectiveness of waterproofing
7.2.5 Roofing Construction

Section 5 of this questionnaire discusses how the roof was constructed so that we can pin-point the roofing defects that are attributed to bad design or construction methods. This area of roofing work is known to have most of the problems, and definitely needs improvement.

<table>
<thead>
<tr>
<th>Question No. 28. Does your roof have sloped concrete screed?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Answers</strong></td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>1. Yes</td>
</tr>
<tr>
<td>2. No</td>
</tr>
<tr>
<td>3. Other Remarks (specify)</td>
</tr>
<tr>
<td>-- The slope was done with fixed tiles</td>
</tr>
<tr>
<td>-- Via Light Weight Concrete</td>
</tr>
<tr>
<td>-- The slope was made with the roof deck concrete pouring</td>
</tr>
<tr>
<td>-- I don't know</td>
</tr>
<tr>
<td>-- My slope is not good</td>
</tr>
</tbody>
</table>

This question inquired about whether the roof has a slope or not. Luckily, almost all roofs have slopes. The slopes were made in four different ways. The first and most common way was through sloped concrete screed. More than half of owners used this way. The second most common way was making the slope with fixed tiles. The third way is via the use of light weight concrete. The last and least common and probably most economical way of sloping was making the slope with the main concrete pouring. Only one owner had done that. See Figure 183 and Figure 184.
Figure 183: Roofing slope.
Figure 184: Roofing slopes including roofing with problems.
**Table:** How many drainage outlets does your house roof have?

<table>
<thead>
<tr>
<th>Answers</th>
<th>No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. One</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>2. Two</td>
<td>36</td>
<td>35</td>
<td>11</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>3. Three</td>
<td>22</td>
<td>22</td>
<td>8</td>
<td>36</td>
<td>22</td>
</tr>
<tr>
<td>4. Four</td>
<td>27</td>
<td>27</td>
<td>9</td>
<td>33</td>
<td>25</td>
</tr>
<tr>
<td>5. Five and more (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Five</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Six</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>-- Seven</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Eight</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Nine</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Ten</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question asked about the number of drainage outlets of roofs. Most surveyed roofs (40%) have only one or two drainage outlets. See Figure 185 and Figure 186.
Figure 185: Number of drainage outlets.

Figure 186: Roofing with problems as related to the number of drainage outlets.
Question No. 30. What is(are) the size(s) of the roof's outlets?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>% of Houses</th>
<th>% of Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 2 inches or less</td>
<td>26</td>
<td>25</td>
<td>11</td>
<td>42</td>
</tr>
<tr>
<td>2. 3 inches</td>
<td>31</td>
<td>30</td>
<td>12</td>
<td>39</td>
</tr>
<tr>
<td>3. 4 inches</td>
<td>47</td>
<td>46</td>
<td>15</td>
<td>32</td>
</tr>
<tr>
<td>4. Other size(s) (specify)</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The size of the drainage outlets was asked about in this question. Fortunately 46% of owners used 4-inch size which is the best. However, 26% used 2-inch which is a dangerous size to use. See Figure 187 and Figure 188.

Figure 187: Size of drainage outlets.
Figure 188: Roofing with problems as compared to the size of drainage outlets.
**Question No. 31. How are your drainage outlets fixed?**

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Just below the top layer of roofing system</td>
<td>77</td>
<td>76</td>
<td>24</td>
<td>32</td>
<td>67</td>
</tr>
<tr>
<td>2. Just below the thermal insulation layer</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>3. Just below the roofing membrane level</td>
<td>14</td>
<td>14</td>
<td>6</td>
<td>43</td>
<td>17</td>
</tr>
<tr>
<td>4. Other Remarks (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Planted in the roof concrete</td>
<td>9</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--At the same level as the top layer</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--At the same level as the sloped concrete screed</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>--The same level as waterproofing</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>--Above the waterproofing</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>6</td>
</tr>
<tr>
<td>--I don't know</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
</tbody>
</table>

The drainage outlets are the roofing equipment that get rid of water which otherwise would stay on the roof. Therefore, their location is very important in order for them to do their job properly. This question inquires about their location. If they are not located at the places where water accumulates, they will be useless and the water will stay on the roof. From the results we got, we can say that the great majority of owners put the drainage outlets at the wrong locations. Only 14% had installed the drainage outlets at the correct level. See Figure 189 and Figure 190.
Figure 189: Levels of drainage outlets.
Figure 190: Roofing problems as related to drainage outlet levels.
Question No. 32. Have you carried out maintenance to the roofing or renewed or changed the roofing membrane?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes</td>
<td>22</td>
<td>22</td>
<td>19</td>
<td>86</td>
<td>53</td>
</tr>
<tr>
<td>2. No</td>
<td>77</td>
<td>77</td>
<td>17</td>
<td>22</td>
<td>47</td>
</tr>
<tr>
<td>3. Other Remarks (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Tiles filler</td>
<td>13</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Replacement of the whole roof</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Rebuilding of the whole house</td>
<td>13</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Sloped concrete was added after having problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--I made a gap around the parapet and filled it with cement plus sika</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--I removed the whole sloped concrete screed layer and installed Indian type sloped concrete layer.</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Chinco was installed over the whole roof after several leakage problems.</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Sealant Replacement</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question was asked to know if there was any disturbance or maintenance to the original construction of the roof. Most owners indicated that there were no changes on the original roofing work. Three houses had disastrous problems where owners had to replace the whole roof. One owner rebuilt the whole building. See Figure 191.
Figure 191: Maintenance work.
Question No. 33. How did you treat critical locations such as upstands and piping?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. By flashing</td>
<td>13</td>
<td>13</td>
<td>4</td>
<td>31</td>
<td>11</td>
</tr>
<tr>
<td>2. Other Methods (specify)</td>
<td>24</td>
<td>24</td>
<td>2</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>--No special treatment, like the roof</td>
<td>11</td>
<td>11</td>
<td>4</td>
<td>36</td>
<td>11</td>
</tr>
<tr>
<td>--By making a channel around the parapet</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Concentrating the waterproofing materials at these locations</td>
<td>9</td>
<td>9</td>
<td>5</td>
<td>56</td>
<td>14</td>
</tr>
<tr>
<td>--Marble flashing (footing)</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Waterproofing is extended at the parapet</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Reinforcement beam around the circumference</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--By welding the membrane around the piping</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--By using tape around the piping</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>--By using white cement around the piping</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>--By using silicon around the piping and other areas</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--By using cement-based waterproofing material</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--By using hot asphalt plus jute</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>--By using Acrylic coating</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--I don't know</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Not applicable</td>
<td>33</td>
<td>33</td>
<td>11</td>
<td>33</td>
<td>31</td>
</tr>
<tr>
<td>--No answer</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Other Methods (not specified)</td>
<td>5</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Critical locations on the roof such as upstands and piping are the locations that are candidate for having trouble; hence, they need different treatment from the rest of the roof. This question inquired about the different methods that owners used to treat critical locations. Unfortunately, a number of owners did not treat these locations in a way
different from the main roof. Only 13% used flashing in treating these locations. See Figure 192 and Figure 193.

![Bar Chart](image.png)

- By flashing: 13
- No special treatment, like the roof: 11
- Concentrating the waterproofing materials at these locations: 8
- By using silicon around the piping and other areas: 5
- By using hot asphalt plus jute: 5
- Other Methods (not specified): 0

**Figure 192: Treatments of critical locations.**
Figure 193: Relationship between treatments of critical locations and roofing problems.
### Question No. 34. How did you treat terminating ends at the parapet or other critical locations?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Total No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. By flashing</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td>33</td>
<td>11</td>
</tr>
<tr>
<td>2. Inserting the membrane in the wall</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>3. Welding the membrane on the wall</td>
<td>16</td>
<td>16</td>
<td>5</td>
<td>31</td>
<td>14</td>
</tr>
<tr>
<td>4. Other Methods (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- No special treatment, like the roof</td>
<td>45</td>
<td>45</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>- No membrane; only asphalt</td>
<td>16</td>
<td>16</td>
<td>4</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>- Concentrating the waterproofing materials at these locations</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Using asphalt</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>- By making a channel around the parapet for thermal expansion</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>- By making a 2-cm gap between the tiles and the parapet filled with slanted ceramics</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Reinforced up-side-down connecting concrete beam</td>
<td>9</td>
<td>9</td>
<td>4</td>
<td>44</td>
<td>11</td>
</tr>
<tr>
<td>- Marble flashing (footing)</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Ceramic + concentrated waterproofing + white cement</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Waterproofing is extended at the parapet</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>60</td>
<td>8</td>
</tr>
<tr>
<td>- Cant strip of cement plus silica</td>
<td>4</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Cant strip of cement</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>38</td>
<td>8</td>
</tr>
<tr>
<td>- Ceramic flashing (footing)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>- Slanted tiles</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>- Sealed expansion joints</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>- Plastering on the waterproofing membrane</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Tiles footing</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>33</td>
<td>3</td>
</tr>
<tr>
<td>- Can't remember</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Not applicable</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
</tbody>
</table>

Terminating ends of the waterproofing materials are very important because two different materials have to be connected together and if they are not connected correctly, a harsh environment will cause them to be disconnected. For example, the bituminous
sheeting and the parapet wall. This question asked owners about the different ways of treating the terminating ends. Unfortunately, only 12% used flashing and 16% treated them as the main roof. See Figure 194 and Figure 195.

Figure 194: Treatments of terminating ends.
Figure 195: Roofing problems related to the terminating ends.
### Chapter 7: Questionnaire Analysis and Results

#### 7.2.6 Problems Encountered

**Question No. 35. Do you encounter any problems with the roof assembly?**

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes</td>
<td>36</td>
<td>35</td>
<td>36</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2. No</td>
<td>65</td>
<td>64</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Others Remarks(specify)</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This question asked owners if they encounter problems with their roofing. Surprisingly, the great majority indicated that they did not encounter any problems. Only 31% said that they encounter some problems.

**Question No. 36. If yes, what are these problems?**

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Leakage</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>100</td>
<td>58</td>
</tr>
<tr>
<td>2. Cracks</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>100</td>
<td>33</td>
</tr>
<tr>
<td>3. Others (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-- Breakage of expansion joint sealant</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Leakage on the outsides of the roof</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Falling of roof pieces</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>-- Leakage around drainage outlets</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Fixed tiles pop out</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Leakage through an opening between the roof tiles and upstands</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>25</strong></td>
<td><strong>3</strong></td>
<td><strong>3</strong></td>
<td><strong>100</strong></td>
<td><strong>8</strong></td>
</tr>
<tr>
<td>-- Wet spot in the ceiling</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>-- Cracking of the concrete screed</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- The roof deck concrete was permeable</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>-- Corrosion of roof rebars</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>100</td>
<td>8</td>
</tr>
</tbody>
</table>
Chapter 7: Questionnaire Analysis and Results

This question asked owners about the types of problem faced. It turned out that leakage and cracking are the most common problems in troubled roofs. The most serious problems are the deterioration of the whole roofs. In this survey, three houses had suffered from this problem: one in Khobar, one in Doha and one in Dammam. Owners had to take the whole roof out and make it again. The total cost for doing this was about SR 200,000 each. See Figure 196.

Figure 196: Common roofing problems.
### Question No. 37. If yes, what do you think the reason is?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of House with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. There were not enough drain outlets</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2. The size of drain outlets was too small</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>40</td>
</tr>
<tr>
<td>3. Incorrect location on drain outlets</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>4. There was no slope to drains</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>5. The slope was not good or enough to get rid of water</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>6. Terminating end was not designed properly</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>67</td>
</tr>
<tr>
<td>7a. Other reasons (Specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--The roof deck concrete pouring was made on a hot day and dried quickly before the completion of the whole roof</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>--Improper bitumen application</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>--Concrete shrinkage caused its cracking</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>--Installation of sloped screed was too late</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>--Vibrating of the roof deck concrete pouring was not adequate</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>--The slope to falls was not correctly made</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Reason</td>
<td>Count 1</td>
<td>Count 2</td>
<td>Count 3</td>
<td>Count 4</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>Contractor did not use enough sealant in the expansion joint gaps</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Somebody broke the elbow of an electric conduit of an AC unit; water came through the conduit to the electric panel</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Breaking of the membrane welds</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Blockage of the 2-inch drainage outlets by pigeon dung</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Workmanship; air bubbles</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>The concrete mix was bad. There was no aggregate and the sand quality was bad. The mix was local mix at the site; not at the patch plant</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Installation of waterproofing and expansion joints was not right</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The work of the contractor was not good</td>
<td>12</td>
<td>12</td>
<td>8</td>
<td>67</td>
</tr>
<tr>
<td>No expansion joints, therefore, expansion and contraction cause the tiles to pop out</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Harsh environment</td>
<td>10</td>
<td>10</td>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>Leakage through the AC pipes</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drainage outlets were blocked w/o cleaning</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Leakage through the electric wire conduit of the satellite dish</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The water accumulates around the stair house and then leaks inside</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Leakage at the corners</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor workmanship</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>The concrete mix was not good</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
</tbody>
</table>

This question asked about the reasons that caused the problems in roofs. Most owners blamed the roofing contractor and the harsh environment. Other reasons included the slope, the drainage outlet size, number, and locations.
### Question No. 38. Do you get support from your supplier?

<table>
<thead>
<tr>
<th>ANSWERS</th>
<th>Tot. No. of Houses</th>
<th>% of Houses</th>
<th>Houses with Problems</th>
<th>% of Houses with Problems</th>
<th>% of This Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Yes</td>
<td>29</td>
<td>28</td>
<td>8</td>
<td>28</td>
<td>22</td>
</tr>
<tr>
<td>2. No</td>
<td>21</td>
<td>21</td>
<td>9</td>
<td>43</td>
<td>25</td>
</tr>
<tr>
<td>3. Other Remarks (specify)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--Not required</td>
<td>21</td>
<td>21</td>
<td>8</td>
<td>38</td>
<td>22</td>
</tr>
<tr>
<td>--Not applicable</td>
<td>21</td>
<td>21</td>
<td>6</td>
<td>29</td>
<td>17</td>
</tr>
<tr>
<td>-- Haven't encountered any problems</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>3</td>
</tr>
</tbody>
</table>

This question was asked to know the feelings of owners toward contractors and to know how contractors are satisfying their customers. Most owners indicated their satisfaction with their contractors' support. This tells us that the roofing contractors are doing a professional job with respect to customer support and satisfaction.

**REMARKS ABOUT THE SUBJECT: (Use the back of the page)**

The followings are the owners' comments:

1. **GENERAL INFORMATION**
   - The roof expansion is serious.
   - The materials are too expensive.
   - The slanted roof is better than the flat roof. It has fewer problems than the flat roof; therefore, it is recommended.
   - Things depend on each other; therefore, all components need to be good.
   - Most of the cracks are close to the parapet.
The problems of bathrooms are more than the problems of roofs and hence they should be addressed.

More than 50% of all KFUPM houses suffer from leaks.

Not a lot of information about roofing materials is available.

The advancement in ready mix concrete manufacturing contributed to the reduction of roofing problems.

There are many roofing problems but they are not serious.

In Tabuk, there is no roofing awareness at all.

Ten owners in Tabuk stated that waterproofing is only used for foundations. They do not believe that waterproofing could be used for roofs.

2. OWNERS

90% of house owners encountered problems.

Owners do not know where to go to find information.

The owner should watch over his house himself.

Owners hire cheap contractors.

Truthful advice that will help owners should be given to them, not commercial advertisements.
3. **CONTRACTORS**

- Most contractors are not truthful.
- The contractors usually convince owners of a lot of things.

4. **SUPERVISING/CONSULTING A/E**

- The supervising A/E is very important in making a good roofing system.
- Experienced supervising engineers in roofing are few.
- A supervising/Consulting engineer is a must.
- The municipality should enforce a policy requiring owners to hire a supervising engineer.

5. **THERMAL INSULATION**

- Thermal insulation and waterproofing are a must.
- Thermal insulation materials are very costly; therefore, their cost should be paid in monthly installments.
- Thermal insulation and waterproofing are very important for roofs and buildings. They should never be ignored by owners.
- Thermal insulation is effective but it is not advertised well.
- Thermal insulation materials were not presented to owners in a good way.
- Thermal insulation is necessary for residential houses.
- Thermal insulation on the roof affects only 10%; 80% walls and 10% windows.
6. **WATERPROOFING**

- The waterproofing is a must.
- Before applying waterproofing, all cracks in the roof deck must be treated. They are usually numerous and distributed over the whole roof.
- It is not recommended to use acrylic based waterproofing materials on roofs.
- Waterproofing will eventually fail because of the welds.
- There is no need for waterproofing if there is a slope.

7. **FIXED TILES**

- If fixed tiles are to be used as the loading layer, then the sand under the tiles should be mixed with cement.
- Make a gap between the fixed tiles and the parapet.
- Sand mix for the fixed tiles should be mixed with enough good quality cement.
- Fixed tiles are not recommended for roofs.
- Fixed tiles should have a large slope.
- Tile filling must be done yearly; preferably each six months.

8. **CONSTRUCTION METHODS**

- The workmanship must be good.
- The slope is a must.
- Be aware of drain outlet blockage.
- The wood roof supports should be very strong and fixed on a strong firm ground before pouring.
• Hordi beams and falling beams should be used.

• It is important to use hordi roof so that the roof will last for a long time.

• The concrete mix should be good.

• Steel bar reinforcement should be adequate.

• Workmanship is the most important factor.

• The vertical expansion should be taken into account.

• Pay particular attention to corners.

• It is very important to have a reinforced concrete beam at the parapet; concrete blocks are not adequate.

• Drainage outlets must be checked and cleaned regularly.

• Additives materials in the concrete must be controlled.

• All conduits and piping must be exposed and not covered by the roofing.
7.3 Mock-Ups

Three mock-ups were obtained from two manufacturers and a roofing contractor. These mock-ups constitute three different roofing systems that are considered to be very good systems for application of actual roofing systems.

7.3.1 Bitumat Mock-up

This mock-up was obtained from Bitumat Company Limited, a manufacturer of bituminous roofing membranes with a manufacturing plant located at Dammam second industrial city. The sample roofing system is as follows:

1. Roof deck with inherent 1% slope.
2. Sand cement cant.
3. Concrete primer.
4. Polyflame loose laid roofing membrane.
5. Granule Polyflame base flashing.
6. 150 micron polyethylene separation sheet.
7. Extruded polystyrene insulation boards.
8. 120 gm/m² Alyaf non-woven.
9. Loading layer which is one of the following:
   - 30 mm sand & cement screed and fixed tiles. or
   - Gravel
10. Aluminium counter flashing.

11. Flashing sealant.

### 7.3.2 Dermabit Mock-up

This mock-up was obtained from Dermabit Waterproofing Industries, a manufacturer of bituminous roofing membranes with a manufacturing plant located at Al-Jubail. The sample roofing system is as follows:

1. Concrete roof deck.
2. Screed to slope.
4. Concrete primer.
5. Dermabit 4170 roofing membrane.
7. Extruded polystyrene thermal insulation boards.
8. Fibreglass separation layer.
9. Loading layer which is one of the following:
   - Concrete screed. or
   - Gravel

10. Aluminium counter flashing.

11. Flashing sealant.
7.3.3 AL-AMEEL MOCK-UP

This mock-up was obtained from Al-Ameel Company, a roofing contractor with a main office located in Riyadh and a branch in Dammam. The sample roofing system is as follows:

1. Concrete roof deck.
2. Screed with slope.
4. Concrete primer.
5. Ecogum-3F roofing membrane.
6. Dermabit 3050 Aluminium base flashing which is grooved in the parapet.
7. Aluminium counter flashing which is grooved in the parapet.
8. Flashing sealant.
7.4 CASE STUDIES

During the survey, there are some house cases that are worth special attention due to the complete deterioration of their roofs and the lessons that we should learn so that similar problems won't occur again. In this section four cases will be studied.

7.4.1 CASE NO. 1; BLOCKAGE OF DRAINAGE OUTLETS

Location: Doha

Roof Area: 280 m²

Age: 7 years

The Roofing System

The roofing system consisted of two coats of liquid applied white acrylic, reinforced with plastic wire mesh which was installed by a specialised contractor with a total cost of approximately SR 15,000. The roofing system was as follows:

1. Concrete deck
2. Sloping screed
3. 1st waterproofing coat
4. Plastic wire mesh reinforcement
5. 2nd waterproofing coat
Drainage Outlets

The quantity of drainage outlets was 4 outlets. Their size was 2-inches. The installation level is not known.

Problems

The roof of this house was deteriorated. Roof pieces were falling every day. Steel bar reinforcements are corroded. Big cracks spread throughout the roof. The roof has leaked many times.

Causes of Problems

Ponding of water was on the roof for a long period of time. This long period of ponding was caused by the blockage of the 2-inch drainage outlets. The small size of the outlets was the primary factor since these outlets are susceptible to blockage. There are many secondary factors such as lack of routine inspection. In addition to the fact that the house roof is usually out of sight, out of reach, this particular house has a steel stairway which was installed at the back of the house. This might have contributed to the roof being forgotten. Another factor that might have added to the failure was that the house was rented. The tenant did not do the required roofing inspection.

Conclusions

This house was well constructed with a good roofing system which was installed by a specialised contractor with the right quantity of drainage outlets. However, it prematurely failed mainly because of small size drainage outlets. Making bigger size outlets should not be a problem. The roof would not have failed had the drainage outlets been 3-inch in size or had the tenant inspected the roof periodically or after rain storms.
Recommendations

From this case, we can deduce many recommendations so that similar failure can be prevented:

1. The drainage outlet size should never be smaller than 3 inches.
2. The drainage outlets should be installed at the right level just below the level of the concrete deck.
3. Roofs should be inspected periodically at least twice a year and 8 hours after each rain storm.
4. Rental contract should contain a clause that requires the tenant to perform the required inspection and make him responsible for any roof damage caused by lack of inspection.
5. Stairs that lead to the roof should be visible and easily accessible.

Owner's Decision

The owner decided to take the whole roof including the roof deck out and to construct a new roof with an approximate cost of SR 200,000 which is more than the years' rent that the owner had collected.

The following figures show pictures of this house:
Figure 197: The removal of the roof deck.

Figure 198: The construction of a new roof deck.
Figure 199: The pumping of the concrete to the roof.

Figure 200: Pouring of new concrete deck.
Figure 201: Exterior stairway which might have contributed to the neglect of the already forgotten roof.
7.4.2 Case No. 2: Blockage of Drainage Outlets

Location: Al-Khobar

Roof Area: 250 m²

Age: 10 years

The Roofing System

The roofing system consisted of jute and hot bitumen. It was installed during construction by the general contractor and witnessed by the owner. The total cost of the roofing was approximately SR 15,000. The roofing system was as follows:

1. Concrete deck
2. Hot bitumen
3. Jute saturated with asphalt
4. Screed of sand and cement
5. Fixed tiles with slope

Drainage Outlets

The quantity of drainage outlets was 4 outlets. Their size was 2-inches. The installation level was just below the fixed tiles' level.

Problems

The roof of this house had deteriorated. Roof pieces fell regularly. Steel bar reinforcements were corroded. Big cracks had spread throughout the roof. The roof leaked many times.
Causes of Problems

Ponding of water was on the roof for a long period of time. This long period of ponding was caused by the blockage of the 2-inch drainage outlets. The small size outlets were the primary factor since these outlets were susceptible to blockage. There are many secondary factors such as lack of routine inspection. That the waterproofing was installed on a non-sloped surface could also be another factor of the failure. The deterioration of the tile filler without renewing was a prime source for water seepage to the steel reinforcement of the roof deck. In this particular house tile fillers were not renewed for as long as six years.

Conclusions

A house owner related to this one had built an exactly similar house with the same contractor and the same roofing system. Actually the two houses were constructed simultaneously. The other owner, however, did not face similar problems. The difference between the two is that the second owner periodically inspects the roof and cleans the drainage outlets. He also renews the tile filler each year or each six months, depending on the roof condition.

Recommendations

From this case, we can deduce many recommendations so that similar failure can be prevented:

1. The drainage outlet size should never be smaller than 3 inches.

2. The drainage outlets should be installed at the right level just below the level of the concrete deck.
3. The waterproofing materials should be applied on a sloped surface.

4. Roofs should be inspected periodically at least twice a year and 8 hours after each rain storm.

5. Tile filler should be renewed at least once a year.

Owner's Decision

The owner decided to take the whole roof including the roof deck out and to construct a totally new roof.
7.4.3 Case No. 3: Overdue Installation of Sloping Concrete

Location: Dammam

Roof Area: 335 m²

Age: 8 years

The Roofing System

The roof deck was made with neither waterproofing protection nor sloping screed. The roof was dead level for five years. Leakage was encountered. After that the following roofing system was installed by non-specialised contractor:

1. Concrete deck
2. Commercial paper
3. Hot bitumen
4. Sloping screed.
5. Cant strip
6. Two coats of liquid applied acrylic

Three years after the of roofing system installation, problems started to appear

Drainage Outlets

The quantity of drainage outlets was 5 outlets. Their size was 4-inches.

Problems

The roof of this house had deteriorated. Roof pieces fell regularly. Steel bar reinforcements were corroded. Big cracks had spread throughout the roof. Cracks were
observed at the parapet and joints between parapet and the roof and also at the walls. The roof leaked many times.

**Causes of Problems**

The primary cause for this roof problem and failure was the fact that the roofing system and the sloping screed were installed after the water had saturated the roof deck. Another suspected cause, to a small extent, for failure was the quality of the ready mix concrete of the roof deck. Another cause of problems was the lack of expansion joints.

**Conclusions**

The quantity and the size of the drainage outlets, which were the main cause of problems for the previous two cases, were more than enough. Therefore, there is no shortcoming from this corner. The owner did try to protect the roof but it was already too late. The roofing system cost the owner lots of money but unfortunately it was a total waste.

**Recommendations**

From this case, we can deduce many recommendations so that similar failure can be prevented:

1. Always install the sloping concrete screed during the house construction.
2. Always install the roofing system during the house construction.
3. Expansion joints are very helpful in absorbing expansion and contraction of the roof; therefore, they should be installed at the time of construction.
4. Quality of ready mix concrete should be insured by making slump and strength tests.
Owner’s Decision

The owner decided to demolish the whole building and construct a new one. The house foundations were found intact with no deterioration or settlement.

The following Figures show a few pictures of this building.

Figure 202: The Building before demolition; cracks can be observed.
Figure 203: The demolition of the building.

Figure 204: The land is ready for new construction.
7.4.4 Case No. 4: Additional Floor

Quite a number of owners build their houses as a one-floor villa due to lack of need or some economic constraint. After many years, either the original owner or a new owner of a one-floor villa decide to build another floor in addition to the ground floor. When building an additional floor, the steel bars for the columns need to be uncovered. That means the top cover and the roofing of the first roof need to be removed. The additional floor consumes a lot of water in: column curing, new roof deck for the second roof, building the walls, plastering and all types of curing of concrete and masonry. Most curing and construction water reaches the first roof and ponds there. And then, the water seeps through the first roof and causes leakage and deterioration. The water can stay in the roof undetected for a long period of time causing roof deck deterioration and corroding the reinforcing steel bars of the first roof. Unfortunately, this situation exists in a quite large percentage of buildings due to owners’ ignorance of the negative consequences to the roof or due to the carelessness of the contractor.

In case an additional floor is needed, all measures must be taken to clear the first roof of any quantity of water coming from construction or curing of the additional floor. This should be the first clause of the contract that the contractor signs. The contractor should give the owner in detail the method with which he will prevent water from reaching the first roof.

The following figures give a few examples of houses that have or will have an additional floor.
Figure 205: This house already has an additional floor; the first roof is already deteriorated and the owner sold the house.

Figure 206: This house is in process of receiving an additional floor.
Figure 207: This house is prepared to receive an additional floor.
CHAPTER EIGHT

8.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

8.1 SUMMARY

One of the most important components in a house is its roof. It protects the whole house under it; therefore, it must be protected. Our goal is to protect the roof from deterioration, in other words to prevent the corrosion of the roof steel bars.

Corrosion is a chemical process which is defined by NACE as the deterioration of a substance (usually a metal) or its properties because of a reaction with its environment. In the case of roofs, water is the electrolyte which promotes the corrosion process. Doing the roofing, or waterproofing in particular, is a corrosion control measure which uses means of controlling corrosion by design, materials, modification of environment and protective coatings.

The roofing must satisfy the following objectives: 1) to prevent moisture from entering into the roof deck because moist air is more corrosive than dry air; 2) to reduce temperature because corrosion rate increases as temperature increases; and most
importantly 3) to prevent water from seeping through the roof deck laying the best ground for corrosion to take place.

Lots of houses suffer from roof problems due to the fact that owners were not in a position to select the best roofing materials and the right construction practices. The overall goal of this study was to identify the roofing problems and to recommend corrective measures to eliminate or at least lessen the early appearance of roofing problems in Saudi Arabia’s residential building. To achieve this goal, some objectives were identified. These objectives were: identifying roofing components, construction methods, different types of roofing membranes, roofing problems and ways of preventing roofing problems from happening. To achieve the overall goal, the following was done:

- Review of literature
- Visits to manufacturers
- Survey of local market
- Attendance to roofing seminars
- Meetings with suppliers
- Meetings with roofing contractors
- Meetings with house owners
- Questionnaires to house owners
- Questionnaires to roofing contractors

Two types of questionnaire were distributed to house owners and roofing contractors. There were 102 questionnaires which were acceptably completed by house
owners from Jeddah, Riyadh, Tabuk and the Eastern Province. A total of 24 roofers completed the contractors’ questionnaires.

It was found that most roofing problems were minor problems. Only 36% of house owners encountered major problems. Only 3% faced disastrous problems where they had to rebuild the whole roof. The main roofing problems were leakage and cracking. The roofing problems were found to have been caused by using bad construction practices and unskilled, inexperienced roofers. Bad slope and the use of small drainage outlet size were the direct causes of the three deteriorated roofs. Among bad construction practices are having the sloped concrete screed made without steel reinforcement and/or expansion joints and installing the sloped concrete screed on a non-firm base. A common bad roofing practice is installing the waterproofing membrane on a non-sloped surface. Few cases were attributed to roofing materials.

A total of 52 roofing systems were offered by roofing contractors and a total of 75 different roofing systems were found among house owners. This shows how diverse and unorganized the roofing business is.

The most popular, most economical roofing membrane is asphalt-based bituminous sheets. The average roofing cost is about SR 15,000 which is less than 2% of the total house cost.

It was found that thermal insulation is not a popular roofing component among house owners because, as indicated by most of them, they were unaware of it. Red clay hordi is the most common of the less effective thermal insulation materials. Some house
owners did not know that it has thermal insulation characteristics; they used it merely for its commonness as well as its light weight and acoustic properties.

Finally, it should be recognized that roofing is only one component of a total house, which should be considered as a system with many parts that complement each other. All of these parts should be good because if one part is not done the way it should be, it could negatively affect other parts including the roof. Some roofing problems are caused by other badly made parts.

At the end, we can say that we successfully achieved our objectives and hopefully will reach our goal. Conclusions and recommendations are included in the following sections.
8.2 CONCLUSIONS

8.2.1 GENERAL

Roofing can only protect a roof deck which does not have inherent problems. Protection of the roof deck does not start by making good roofing after the roof deck is cured. Rather it starts at the time of making the roof deck itself, which should include but not be limited to: enough steel bars, good concrete mix using good quality aggregates and sweet water, usage of vibrator during concrete pouring, curing it with sweet water and leaving it to dry and reach its full strength before commencing the roofing work.

1. In Central and Western Provinces, roofing awareness among owners is a lot less than that in the Eastern Province.

2. Flat roofs are still by far the most common type of roofs in Saudi Arabia.

3. Almost half (47%) of house owners have roofing areas between 200 m² and 300 m².

4. A third of house owners have roofing areas between 300 m² and 400 m².

5. Eighty percent of roofing in Saudi Arabia has roofing areas between 200 m² and 400 m².

6. Corrosion is a chemical reaction that needs water to take place. If waterproofing is installed, the reaction should not happen since it is interrupted.

7. The average cost for an average roofing system for an average roofing area of 300 m² is not expensive compared to the total cost of the building. It is about SR 15,000. The
average villa cost is about SR 800,000. Therefore, the roofing cost is less than 2% of the total house cost.

8. All contractors give warranty on their roofing systems for at least one year.

9. Normal warranty period is 5 years.

10. A total of 52 roofing systems were offered by 24 contractors. These roofing systems were developed with respect to the materials of the components used and the order in which these components were installed.

11. About 37% of roofing contractors thought they usually get detailed drawings showing how the roofing is to be done. The other roofers thought the design engineer either doesn’t mention roofing or give very few and useless details.

12. According to roofing contractors, their customers are either satisfied, with no complaints or with few complaints about minor problems.

13. Almost all roofers agree that to make roofing without problems, the roofer should use good quality materials and install them by well trained workers.

14. Waiting until the problem is obvious is the normal practice.

15. In 102 houses, we found 75 different roofing systems. This shows that the roofing business is unorganized and that there is no cooperation or sharing of experience and information among roofing contractors. Many things are not agreed upon among roofers. Each roofer makes his own system.

16. The relationship between the cost of the roofing and the problems encountered is very weak. This means that high roofing cost does not necessarily guarantee high quality roofing systems.
17. The roofing cost for 77% of the houses is less than 5% of the total house cost.

Therefore, the cost of the roofing is very low compared to the house cost.

8.2.2 HOUSE OWNERS

1. Some owners look for cheap price; so, they hire unqualified contractors who do poor job.

2. The great majority of owners installed the drainage outlets at the wrong location.

3. Most owners assumed that their roofing systems work. They trust that roofers will do them a good job. They do not check whether the roofing works or not.

4. Most owners do not recognize the importance of roofing; therefore, they are not willing to pay what it takes to efficiently protect the roof.

5. Two thirds of owners had some knowledge about roofing before they started building their houses.

6. Most owners have adequate or little roofing knowledge.

7. Only one third of owners had no knowledge about roofing.

8. At the time of roofing installation, 50% of owners thought that they had enough roofing knowledge to select the roofing system they had selected. The other 50% were dependent on others to select the roofing for them, such as A/E, the contractor and/or the supplier.

9. According to roofing contractors, most customers have fair knowledge about roofing.

Only 15% of customers have no roofing knowledge.
10. The percentages of houses with roofing problems for owners who thought they had roofing knowledge, owners with little knowledge and owners with no knowledge were very close (34%, 36%, and 36% receptively). We can conclude that owners' roofing knowledge was not the right knowledge. Even when owners decided to select the roofing system, it did not prevent roofing problems.

11. About 72% of owners who reported problems in their houses thought their roofing was effective.

12. About 1/3 (29%) of owners trusted that the roofing contractor had made a good job; 43% of these owners encountered problems.

13. Most owners expressed their satisfaction with their roofing systems.

14. Most owners were satisfied with all roofing components; however, some roofing components did not satisfy some owners. Waterproofing was the roofing component with widest dissatisfaction.

8.2.3 Roofing Contractors

1. More than 50% of roofing contractors are experienced contractors with more than 12 years experience.

2. Only 12.5% of roofing contractors are assumed to be inexperienced with less than 3 years in the roofing business.

3. More than half (54%) of roofing contractors are relatively small contractors with less than 50 workers.

4. About 20% of roofing contractors are large with more than 100 workers.
5. About 46% of roofing contractors indicated that they perform an annual roofing area of more than 50,000 m².

6. About 79% of roofing contractors guarantee both their materials and workmanship. This shows a large degree of confidence among roofing contractors in their work.

7. Among the roofing that was installed by general contractors, 33% had problems, while among the roofing that was installed by specialized contractors 41% encountered problems. This tells us two things: the first is that some general contractors have the necessary labor and experience to install good roofing; the second is that not every roofing contractor is good. Some of the contractors who call themselves specialized are not really specialized and they do bad roofing.

8. Most reputable contractors are supportive to their clients.

9. A few non-responsible contractors in the market give good warranty but do not abide by it.

8.2.4 THERMAL INSULATION

1. Generally thermal insulation is not a popular roofing component.

2. Most owners who did not have thermal insulation had no idea about it.

3. A large percentage of house owners have no idea at all about thermal insulation. More than six thermal insulation manufacturers are operating in the kingdom. They are not doing a good job in introducing their product.
4. Most owners who chose to use thermal insulation materials selected the material that was used by neighbors, friends or relatives. This was the basis that is mostly used by house owners.

5. A great majority of owners who have insulation believe in it and think it is effective.

6. Among owners who used thermal insulation in their houses, 2/3 believe that insulation is effective in doing its function.

7. The best thermal insulation material according to about half of the roofing contractors is extruded polystyrene because of its low cost, long life, easy installation and non-absorbency of water.

8. The most popular thermal insulation material is red clay hordi, which is the least effective material with respect to thermal insulation effectiveness. This material was selected by most owners because of its light weight and its acoustic insulation. It was not selected because of its thermal insulation properties. Most owners did not know that it has thermal insulation characteristics. The second most popular type is extruded polystyrene which was used by 14 owners only. The third most popular thermal insulation material is light weight concrete which was used to do two functions: thermal insulation and as a screed to falls.

9. Most owners decided to use thermal insulation in order to make the house more comfortable and to save some of the energy costs.

10. Most owners who used thermal insulation felt that they saved some energy costs. This saving ranges between 10% and 80%.
8.2.5 Waterproofing Membrane

1. Waterproofing will lengthen the life of the house for at least 20 years or as long as it lives.

2. The most common waterproofing materials that roofing contractors are used were bituminous based waterproofing materials. The second most common materials were polyurethane based materials.

3. The most popular roofing waterproofing materials that were used by house owners were asphalt-based bituminous materials including bituminous sheets and asphalt and jute systems. The second most popular waterproofing materials were polyurethane-based and single-ply membranes.

4. Asphalt and jute system was used by 23% of owners.

5. Liquid applied materials should be installed by an experienced reputable roofer even though it is easy to install. Otherwise the required film may not be applied, making the membrane weak and not effective. The required film thickness should be carefully calculated and the correct amount of materials should be checked by owner.

6. The quality of acrylic-based materials depends on the quality and the amount of solid content with respect to water. The higher the solid content to water ratio the better the material.

7. According to roofing contractors the best roofing membrane is bituminous sheets. The second best is liquid-applied polyurethane-based materials. Aging resistance and experience with the bituminous sheets were the most important criteria that made roofers recommended this roofing membrane.
8. The least popular roofing system is built-up roofing.

9. The most economical roofing membrane is asphalt-based materials.

10. About 96% of house owners used waterproofing in order to protect the roof against rain water.

11. Among the houses surveyed, 39% used asphalt-based bitumen sheets; 40% of these had problems. Liquid-applied polyurethane was used on 11% of the houses; 45% of these had problems. Liquid-applied acrylic-based waterproofing was used on 13% of the houses; 69% of these had problems. Asphalt and jute waterproofing system was used on 22% of the houses; 45% of these had problems. Asphalt only was used on 16% of the houses; only 6% of these had problems.

12. Bituminous sheets, liquid-applied polyurethane and asphalt and jute system showed almost the same performance. Therefore, any one among these can be used to economic advantage.

13. Hot-installed asphalt-based bitumen sheets showed better performance than the cold-applied bitumen sheets.

14. The common selection criterion that made owners select a particular waterproofing materials was hearing about it and seeing people using it.

15. Most owners thought that their waterproofing was effective in doing its function.
8.2.6 Construction Practices

1. With respect to the time of roofing installation, 88% of owners installed their roofing systems during the construction of their houses. This is a good practice. This way the house is protected from the beginning of its life.

2. Some owners installed the roofing after they encountered problems. This is a bad practice because it could be too late; after the problem becomes large it can’t be contained with minor work. The remedy could be the removing of the whole roof or even rebuilding of the whole house. Only a 1/3 (33%) of the houses with problems had their roofing systems installed during the construction of the house. More than 2/3 (69%) of the houses with problems had their roofings installed after problems happened. This shows how important is the installation of roofing during the house construction.

3. Flashing is not a popular component. Only 11% of owners used it.

4. Fixed tiles are a popular roofing component. About 63% of owners used fixed tiles on roofs.

5. Most owners prefer accessible roofs rather than non-accessible.

6. About 96% of roofing contractors indicated that they always perform a flood test when they complete their roofing work.

7. Most roofing contractors (83%) install drainage outlets through the parapet.

8. Only 46% of roofing contractors install drainage outlets just below the roofing membrane level, which is the right level.
9. Forty-two percent of roofing contractors install drainage outlets just below the top layer of the roofing. This could be the right level if the top layer is the waterproofing level.

10. More than 87% of roofing contractors meet the SASO minimum slope requirement of 1%.

11. Light weight concrete is used by 58% of roofing contractors to adjust non-smooth, non-sloped roof deck.

12. Seventeen percent of roofing contractors unfortunately do not make any adjustment to non-smooth, non-sloped roof.

13. Using good quality materials is not good enough to constitute good roofing system.

14. Installing waterproofing on a non-sloped surface is a very common practice.

15. Installing sloped concrete screed without steel enforcement is a very common practice.

16. Installing sloped concrete screed without expansion joints is a very common practice.

17. Installing sloped concrete screed on a non-firm base is a very common practice.

18. Among owners, 50% had witnessed the roofer while installing the roofing; 33% of those encountered some problems.

19. Only 26% of owners asked for a flood test to check the effectiveness of roofing; 31% of those encountered problems.

20. Among the 10% of owners who hired a consultant/engineer, only 20% encountered roofing problems. The largest percentage of owners used only 2 drainage outlets; 31% of these had problems. This shows the relationship between roofing problems and the quantity of drainage outlets.
21. About 46% of houses have 4-inch drainage outlets. These houses have the least percentage of roofing with problems.

22. About 26% of houses have 2-inch drainage outlets. These houses have the largest percentage (42%) of roofs with problems. This shows the relationship between roofing problems and the size of drainage outlets.

23. Among house owners, 76% installed their drainage outlets just below the top layer of the roofing system.

24. Only 14% of house owners installed their drainage outlets at the right level, just below the roofing membrane.

25. Only 13% of owners used flashing when treating critical locations.

26. Many owners did not treat critical locations in a way different from the main roof.

27. Only 12% of owners used flashing in the terminating ends.

28. About 16% of house owners treated the terminating ends as the main roof.

29. Independent stairs that are installed outside the house help the owner to forget about the roof and not do the required inspection, resulting in roofing problems. There have been cases where water accumulates on the roof for many months due to blocked drainage outlets, and no roof inspection was made because of a steel stair case installed outside at the back of the house.

8.2.7 Roofing Problems

1. Most houses do not have major roofing problems.

2. Only 36% of houses were reported to have major problems.
3. Among houses, 3% had disastrous problems where owners had to replace the whole roof.

4. The largest percentage of roofing problems were in houses with no slope.

5. Leakage problems were found in 21% of the houses; cracks were found in 12% and whole roof deterioration in 3% of the houses.

6. Leakage is the number one problem; 83% of roofing contractors indicated that leakage is the problem they always face. Other main problems are: mechanical damage 33%, ridging 29%, breaking of welds 25%, and cracking.

7. The main cause of mechanical damage to the roofing membrane is workmen specially electricians, AC workers and plumbers.

8. Tracing the source of the problems and spot roofing is the approach that 75% of roofing contractors usually take.

9. In the Jeddah area only 6 houses out of 46 houses, i.e. 13%, were reported to have problems. This is a very low percentage compared to the other areas in spite of the fact that most of the roofing works in Jeddah are primitive and not as advanced as the roofing works in the Eastern Province. This low problems rate is due to the scarcity of rain in the Jeddah area.

10. Eastern Province houses, in spite of roofing awareness and advanced roofing work, have a large percentage of problems, occurring specially in Doha which is a comparatively new town.

11. The greatest percentage of houses with problems is 28%, which is surprisingly on the newest group of houses, aged between a month and 2.5 years.
12. The least percentage of houses with problems is 11% for houses with an age between 5 and 7.5 years.

13. Almost half of the houses with problems (47%) are of an age less than 5 years. This means that the house or the roofing age is not a big factor of how roofing works, rather the original design of the roofing is what matters. That is, if the roofing design is good, then it will live for a long time.

14. This research is limited to flat roofs; however, two houses with slanted roofs were included because they were reported to have problems. This shows that slanted roofs were not immune from having roofing problems. So, they should be protected with waterproofing.

15. Results show that small roofing areas are more vulnerable to problems than large roofing areas. About 73% of houses with problems have roofing areas less than 300 m². Only 28% of roofing with problems were for houses with roofing areas more than 300 m².

16. The least percentage of houses with problems is for owners who asked for a flood test.

17. The cost for the roofing for 31% of the houses was less than SR 10,000; 34% of these houses encountered some problems.

18. The cost of the roofing for 33% of the houses was about SR 15,000; 38% of these houses encountered some problems.

19. Among house owners, 12% blamed the contractor for their roofing problems.

20. Among house owners, 10% blamed harsh environment for their roofing problems.

21. The main reasons for having roofing problems can be summarized as follows:
• The small size of drainage outlets.
• Having a bad slope or no slope at all.
• Terminating ends treatment.
• Electricians, AC workers and plumbers when they work on the roof without coordination with roofing contractors.
• Bad concrete mix, such as not using enough cement, using salt water in mixing, bad quality of aggregate, etc.
• Water curing of roof deck with salt water.
• Not having expansion joints.
• Bad workmanship.
• Bad design.
• Harsh environment.
• Treatment of critical locations such as AC pipes, electrical conduits and upstands.

Finally, the roof and roofing of a particular house are parts of the whole house. The whole house is a complete system in which all components work together as a team to support the house. A bad performance of one component negatively affects the performance of other components even if these components were made correctly. For example, if the foundations were not put on a stable ground, this causes house settlement which can cause the cracking of the roof deck, allowing moisture to get in contact with steel bars causing
the deterioration of the roof. Therefore, it is not enough to make good roofing; rather all house components must be good.
8.3 RECOMMENDATIONS

8.3.1 GENERAL

1. Roofing insulation is very important for it protects the roof deck from corrosion and in turn the building will live longer.

2. Owners have to be educated about waterproofing and roofing.

3. Owners should be educated about thermal insulation so that they believe in it. Municipality enforcement is not enough. Owners who do not believe in the effectiveness of thermal insulation will find ways to escape from applying the municipality’s rules.

4. Most owners do not recognize the importance of thermal insulation. In the Kingdom, there are about 10 thermal insulation factories. It is recommended that these factories, with the help of their municipality, make annual campaigns to introduce and promote the use of thermal insulation. More than 75% of house owners are completely ignorant about thermal insulation.

5. Roofing awareness should be raised in the Central and Western Provinces.

6. Although most owners are knowledgeable about roofing, one third of them need to be educated.

7. The Municipality should insist that A/E presents the waterproofing works in detail; that is, with respect to drawings and specifications. This should cover roof, kitchens
and bathrooms because the cost of repairing deteriorated concrete caused by lack of waterproofing is very high.

8. The Municipality should make a requirement to have a complete roofing design included in the house drawings.

9. Engineering offices should have roofing engineers in their staff just like other disciplines.

10. Bituminous sheets are recommended for use for the following reasons:

   - It is the most economical system.
   - The raw material is locally available. Using them will help the local manufacturers and in turn the national economy.
   - You get better value for your money since you do not pay for customs, shipment, etc.
   - Bituminous materials have been used as waterproofing materials for hundreds of years. They have long and successful record.
   - Low cost with good results.

11. Liquid applied acrylic-based materials showed bad performance, so it is not recommended to be used on roofs.

12. There are a lot of unprofessional roofing contractors in the market and they spoil the market (prices & quality). There should be some restrictions on people working in the roofing business.

13. It is recommended that SASO develops standards for all roofing materials, specially for bitumen based materials such as BS 747. Now every manufacturer sets their own
standards and none are the same as each other. It is necessary to develop roofing standards that all manufacturers will follow.

8.3.2 Recommendations to House Owners

1. When making reroofing, it is better to remove the old roofing and correct the original fault rather than making new roofing over the existing one.

2. Owners should not use salt water in concrete mixing or in water curing the concrete.

3. Roofing should be made during the time of house construction so that:
   - Occupants would not be disturbed by new work on the roof.
   - Work would be easier.
   - Work would be cheaper to do.
   - Overall, the house would benefit from roofing during its life and it would be protected from the beginning of its life before problems happen.

4. Sloped concrete screed should be installed during the construction of the house. Some owners make it after facing problems. This is too late. The damage could already have happened. So, making it early would make the house protected from an early age.

5. Although popular, fixed tiles should not be used in roofs. The gaps between tiles are usually filled with tile filler which deteriorates quickly. If fixed tiles are used, the tile filler condition should be checked every six months and renewed if necessary. The other thing that should be done when using fixed tiles is that the leveling sand used under the tiles should be mixed with cement so that a hard base is created under the tiles.
Chapter 8: Summary, Conclusions And Recommendations

6. Use an inverted roof system with the thermal insulation on top of the waterproofing materials. This way the waterproofing is protected from mechanical impact and weather conditions.

7. Owners should not hire unqualified roofers or unskilled labor because of their low price. If they do, they will eventually lose out and their roofing systems will most probably fail.

8. Owners should hire a specialized roofing contractor. Ref.[112] gives four main areas to consider when hiring a roofing contractor:
   - Experience; range of materials handled and length of time they have been dealt with. Also, training of workers.
   - Reputation; seek past clients’ views concerning quality of service given and progress in schedule.
   - Site Supervisor; ensuring adequate quality control through the completion of the finished roof.
   - Financial Security; to prevent possible disappointment at mid-contract as a result of cash flow difficulties and to insure accountability following the contract.

9. The potential roofing contractor should be carefully evaluated because not every roofer is specialized even though he calls himself specialized. Some general contractors have better experience in roofing than some roofing contractors.

10. Owners should ask roofers to present a valid roofer registration.

11. Owners should hire a consultant/engineer to check on the roofing work.
12. While encouraging the good faith of roofers, owners have to check the functionality of
their roofing assembly by flood testing, hiring consultants, etc.

13. Owners should recognize that a good roofing system is not a cheap job.

14. Owners should recognize the importance of roofing in protecting the whole house.
   They should recognize that SR 25,000 to 30,000 is a reasonable roofing cost.

15. To protect it from cracks and to allow for contractions and expansion, steel
    enforcement and expansion joints should be used for the sloped concrete screed.

16. Sloped concrete screed should be installed on a firm base. Installing it on the thermal
    insulation materials should be avoided.

17. The waterproofing membrane should always be installed on a sloped surface.

18. The minimum roof slope should not be less than 1%.

19. Use liquid-applied polyurethane in the locations where you can’t use bituminous
    sheets.

20. Drainage outlets should be installed just below the waterproofing membrane level.

21. Owners should watch electricians, AC workers and plumbers when they work on
    roofs. They should inspect the waterproofing materials for any damages.

22. Workers of other disciplines specially electricians, AC workers and plumbers, should
    coordinate their work with roofing workers.

23. Owners should insure cooperation between the general contractors and the roofing
    contractors.

24. All conduits and piping on the roof must be exposed and not covered by the roofing.
25. Owners should ask the roofing contractor to perform a flood test when he completes the waterproofing work.

26. Owners should insist on having an official warranty for their roofing system from reputable roofing contractors who will abide by their warranty.

27. Owners should carry out a bi-annual inspection of their roofs or before the rainy season to clear all gutters and drainage outlets and remove any debris from the roof, or they should hire a contractor to do a yearly inspection for them. It is not a good practice to wait until problems happen. It might be too late. Normally the following should be checked:

- Remove any debris such as leaves, nails, etc.
- Note the general condition of the roofing membrane.
- Inspect and clean gutters and outlets individually.
- Inspect flashing, capping etc. in all critical locations.

28. Any staircase should be accessible from the inside of the house.

8.3.3 Recommendations to Roofing Contractors

1. Roofing contractors should register as roofers at the chamber of commerce.

2. Roofers should educate and advise owners on the advantages of flashing.

3. Roofing contractors should not do the wrong roofing just because the owner wants it.

4. Roofing contractors should not abuse the trust they enjoy from owners. They should do their job in a professional manner.
5. It is recommended that roofing contractors make their own society so that they can cooperate among themselves and agree on certain roofing practices and share their experience with each other.

6. Roofing contractors should not use low quality material just to be competitive with other contractors.

7. Roofing contractors should not install roofing in a non-effective way while he knows that it won’t work and the owner will eventually face problems.

8. Roofing contractors should use state-of-the art technologies to check the quality of their work before performing a flood test. For example, they should use non-destructive evaluation for heat welded seams.

8.3.4 Recommendations to Both Owners and Roofers

1. Roofing should not commence before the full curing of the roof deck. That is, after at least 28 days from concrete pouring.

2. Use good quality materials and skilled workers.

3. Select a good roofing system.

4. Roofing should be done in proper way, with proper materials and at the right time.

5. Have as many drainage outlets as possible.

6. The minimum number of drainage outlets should not be less than 3.

7. The minimum size of drainage outlets should not be less than 3 inches.

8. The optimum recommended size of drainage outlets is 4 inches.

9. Do not use 2-inch drainage outlets.
10. Eliminate sharp points when doing surface preparation. Sharp points may cause damage to the roofing membranes.

11. Install cant strip to avoid future cracking at the corners.

12. Hot-installed bitumen sheets showed better performance than cold-applied bitumen sheets. Therefore, it should be selected over the cold applied.

13. Install the roofing membrane above the sloping concrete screed.

14. Install the roofing membrane properly with its standard overlap of 10 cm.

15. Terminating ends must be treated differently from the rest of the roof.

16. Install aluminum strip flashing with sealant at critical locations and terminating ends.

17. Install curved pipes on different roof locations to allow water vapor to get out of the roof.

18. Have a water test before covering the roofing membrane for at least two days.

19. Use extruded polystyrene thermal insulation. It does not absorb water; so, its thermal resistance remains good and almost unchanged for a long period of time.

20. Cover the roofing system with proper covering.

21. Spread gravel or loose laid tiles on non-accessible roofs or roofs with light foot use like A/C maintenance. This makes accessibility to the waterproofing membrane easy for repair in the future.

22. Steel pipes and elbows should be fixed onto the roof deck and used to encase electrical cables. PVC pipes are easy to break by workers, specially at the elbows.
8.3.5 **Recommendations to Designers (A/Es), Suppliers and Manufacturers**

1. Thermal insulation manufacturers should do a yearly campaign to introduce their product and make seminars for house owners.

2. A/E should differentiate in his design between dry climate locations and humid locations. He should also make instructions and guidelines to contractors to use the best available construction chemicals to prevent corrosion and hence extend the life span of buildings in humid locations and coastal areas.

3. A/E should be knowledgeable about roofing materials and their prices. For any particular material, there is a minimum price. This material cannot be cheaper than the minimum price.

4. It is recommended that each meter of the roofing roll has the name and the specifications on it so that other low quality materials won't be sold as good quality materials.

8.3.6 **Recommendation for Further Studies**

Waterproofing is a very wide field which we do not use for roofs only, but for other house components as well.

We use waterproofing in the highest component which is the roof. Waterproofing is used also on the lowest components which are the foundations and basement. Not only that, but it is also used on the middle parts of the house protecting the roof of the ground floor from water which could come from the kitchens and bathrooms of the first floor. Therefore, waterproofing effectiveness in foundations and basements should be
investigated. Many owners whom we have met indicated that they are facing leakage problems from kitchens and bathrooms of the first floors. Therefore, waterproofing practices in bathrooms and kitchens of the first floor are also good candidates for further study.

This study, which needs more expansion in terms of population under study, deals only with residential buildings. It is recommended that further study be pursued for public buildings. These are expected to have more problems because officials are bonded by law to accept low bids. They end up paying dearly in the long run [96].
APPENDIX- A

QUESTIONNAIRE TO ROOFING CONTRACTORS
Dhahran
December 1994

Dear Roofer:

We would like to inform you that the Construction Engineering & Management Program of the College of Environmental Design at King Fahd University of Petroleum & Minerals is conducting a research project which investigates the roofing problems in Saudi Arabia's residential buildings.

Attached is a questionnaire which is a part of this project. Please answer all questions in the questionnaire carefully to the best of your knowledge, and note that some questions may require more than one answer. In addition to that, we need your permission to attend roofing works that you are currently doing and have some pictures taken during roofing work.

You should know that all information and pictures will be confidential and will only be used for this research objectives.

Please cooperate with the researcher Abdulaziz O. Al-Ajaji and call him on 876-4099 (Work) or 891-3641 (Home) had questions arise.

Your cooperation will always be appreciated. Thank You.

Dr. SADIA. ASSAF
Research Committee Chairman
A.1 Roofer Information

1. How long you have been in roofing business?
   - Less than 3 years
   - Between 3 and 7 years
   - Between 7 and 12 years
   - More than 12 years
   - Additional Remarks

2. How many employees do you have who are assigned for roofing work?
   - Less than 50 workers; Approximately
   - Between 50 and 100 workers; Approximately
   - Between 100 and 200 workers; Approximately
   - More than 200 workers; Approximately

3. Approximately, how many square meters do you perform annually?
   - Less than 10,000 m²
   - Between 10,000 and 20,000 m²
   - Between 20,000 and 50,000 m²
   - More than 50,000 m²

4. It is appreciated if you kindly list 10 residential villas you have worked on?

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5. In Saudi Riyals, what is the average roofing cost of an average roofing system for an average size villa (300 m²)?

☐ Less than 10,000 SR
☐ Between 10,000 and 20,000 SR
☐ Between 20,000 and 35,000 SR
☐ More than 35,000 SR

6. When a roofing work is completed, how do you check that you have done a good functionally working roofing system?

☐ By doing a flood test
☐ By satisfying a customer’s desire
☐ I have good materials and trained labor so I trust that all my work is good
☐ Other methods/remarks-----------------------------------------------

7. How many years is your warranty for the roofing system you are doing?

☐ 1 year for -----------------------------------------roofing system
☐ 5 years; for---------------------------------------------roofing system
☐ 10 years; for-----------------------------------------------roofing system
☐ More than 10 years; State------for-------------------roofing system

8. What are the limitations on your roofing warranty?

☐ Workmanship only
☐ Materials only
☐ Comprehensive materials and workmanship
☐ Comprehensive materials, workmanship and all other damages to the house
☐ Other remarks-----------------------------------------------

9. On what basis do you give your warranty?

☐ I trust my labor
☐ I trust that my materials are the best
☐ My experience with materials and application methods
☐ Others, Specify---------------------------------------------
10. Is there any roofers' pre-qualifications?

☐ Yes  (Elaborate)
☐ No

A.2 Roofing Components

11. What are the roofing components you use?

☐ Flashing
☐ Gravel
☐ Fixed tiles
☐ loose tiles
☐ Expansion joints
☐ Protection layer
☐ Thermal insulation
☐ Roofing membrane (Waterproofing)
☐ Screed concrete
☐ Sealant in the screed concrete
☐ Others (specify)

12. Using the components of the previous questions, please list different roofing components according to their location on the roof starting from the top of the roofing for the different roofing systems you do mostly.

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13. What types of waterproofing membrane are you using on roofs?
- Asphalt-based bitumen sheets
- Acrylic-based material
- Polyurethane-based material
- Built-up roofing
- Others; Specify-------------------------------------

14. In your judgment, what is the best roofing membrane?
- Asphalt-based bitumen sheets
- Acrylic-based material
- Polyurethane-based material
- Built-up roofing
- Single ply membrane such as EPDM & PVC
- Others; Specify-------------------------------------

15. Regarding the pervious question, why do you prefer that roofing membrane?
- Because it resists aging and lasts for long time
- We have historical record that it resists aggressive environment
- The factory give the warranty
- Our experience with it
- Others; Specify-------------------------------------

16. What is/are the most popular roofing membrane(s)?
- Asphalt-based bitumen sheets
- Acrylic-based material
- Polyurethane-based material
- Built-up roofing
- Single-ply membrane such as EPDM & PVC
- Others; Specify-------------------------------------
17. What is/are the most economical roofing membrane(s)?
   - Asphalt-based bitumen sheets; Why?
   - Acrylic-based material; Why?
   - Polyurethane-based material; Why?
   - Built-up roofing; Why?
   - Single-ply membrane such as EPDM & PVC; Why?
   - Others; Specify

18. What type of thermal insulation are you using?
   - Expanded polystyrene
   - Extruded polystyrene
   - Polyurethane boards
   - Polyurethane foam
   - Light weight concrete
   - Others, Specify

19. In your judgment, what is the best thermal insulation material and why?
   - Expanded polystyrene
   - Extruded polystyrene
   - Polyurethane boards
   - Polyurethane foam
   - Light weight concrete
   - Others, Specify

20. How detailed are the engineering drawings that you usually get from house designer for roofing insulation?
   - No mention
   - No details
   - Detailed
   - Other remarks
A.3 Roofing Construction Methods

21. Where do you locate the drainage outlets?
- Through the parapets
- In the middle of roofing area
- Others; Specify--------------------------------------------------------

22. At what level do you design the drain outlets?
- Just below the top layer of roofing system
- Just below the thermal insulation layer
- Just below the roofing membrane level
- Other levels (specify)

23. What slope percentage do you use?
- 1%
- Up to 3%
- More than 3%
- Other remarks--------------------------------------------------------

24. How do you adjust non-smooth, non-sloped roof deck?
- No adjustment, just lay the roofing membrane on the roof deck
- Blister the roof and lay the membrane on the blistered roof
- Use light weight concrete for smoothing and sloping
- Use sloping concrete screed
- Others; Specify--------------------------------------------------------

A.4 Roofing Customers

25. How do you evaluate your customer satisfaction?
- No complaints; therefore very satisfied
- Few complaints
- Lots of complaints
- Other remarks--------------------------------------------------------
26. What are your customers’ complaints?
   - No complaints
   - Minor problems
   - Other remarks------------------------------------------

27. How knowledgeable are most of your customers on roofing?
   - Excellent
   - Very Good
   - Good
   - Fair
   - Poor
   - Other remarks------------------------------------------

A.5 Roofing Problems

28. What are the roofing problems in Saudi Arabia including those associated with roofing membrane?
   - Leakage
   - Ridging
   - Crazing
   - Cracking
   - Blistering
   - Breaking of welding
   - Mechanical damage
   - Dust on the roof when applying liquid membrane
   - Others, Specify----------------------------------------
29. What percentage of the following roofing problems have you encountered?

- Leakage
- Ridging
- Crazing
- Cracking of (membrane, blistering under the membrane, etc.)
- Bad Design
- Others, Specify

30. How do you make problem-free roofing?

- Using skilled labor
- Using good quality materials
- Good selection of roofing assembly
- Installation at the right time and right weather
- Make good slope on the roof
- Make enough drainage outlets
- Others, Specify

31. How do you tackle the roofing problems when they happen?

- Making a new roofing above the old one
- Removing the old roofing completely and reroofing
- Trace the source of the problem and spot roofing
- Others, Specify

32. How do we know that we have roofing problems?

- By yearly physical inspection
- By wet ceiling
- Leakage drops
- Removing the loading layer
- Others, Specify

33. Any further comments; include any suggested solutions to roofing problems.
التعليم المكاني
جامعة الملك فهد للبترول والمعادن
كلية تصاميم البيئة
برنامج هندسة وإدارة التشريده

المكرم: مقاول التسقيف

 السلام عليكم ورحمة الله وبركاته

نفدتكم بمحبة قسم هندسة وإدارة التشريده في كلية تصاميم البيئة بجامعة الملك فهد للبترول
والمعادن بصدع عمل بحث يتعلق ببعض السطوح السطح السكينية بالملكة وخصوصا العوازل
المائية وذلك لدراسة مشاكل التسرب في السطوح ولعمل ذلك فإنا نرفق بهذه الرسالة استبان
حول هذا الموضوع.

الاستيعابان يحتوي على مجموعة من الاستفسار يرجى منكم التكرم مشكورين بإجابة على
الاستفسارات الواردة في هذا الاستيعابان بكل تجد مع ملاحظة ان بعض الاستفسارات قد يتطلب أكثر من
إجابة واحدة. كما نطلب الآن منكم بحضور بعض أعمال التسقيف التي تعملونها في الوقت
الراهن واخذ بعض الصور الفوتوغرافية لأعمال التسقيف شاركين لكم حس تعاونكم.

وهي الصدد لأد من اختراق أن جميع المعلومات والصور ستكون سرية ومحفوظة لدى
الباحث وستستخدم فقط للمساعدة بتحقيق أهداف هذا البحث.

نرجو التعاون مع الباحث عبد العزيز عمر العباجي وسؤاله إذا كان هناك أي استفسار
والإتصال به على الهاتف رقم 1913441 في المنزل أو في العمل على الهاتف رقم
8794-99

ولكم منا جزيل الشكر

الدكتور سعدي عساف
رئيس اللجنة المشرفة على البحث
ب-1: معلومات عن مقالة التسقية

س 1: كم سنة مضت لكم وأنتم تعملون في أعمال التسقية؟
    ج: أقل من 3 سنوات
    * من 3 إلى 7 سنوات
    * من 7 إلى 12 سنة
    * أكثر من 12 عاماً
    ملاحظات أخرى

س 2: كم عدد الموظفين لديكم الذي يعملون في أعمال التسقية؟
    ج: أقل من 5 موظف، تقريباً...
    * مابين 5 و 100 موظف، تقريباً...
    * مابين 100 و 200 موظف، تقريباً...
    * أكثر من 200 موظف، تقريباً...

س 3: تقريباً، كم متر مربعًا تشتغله في السنة؟
    ج: أقل من 1,000 ألف متر مربع.
    * مابين 1,000 و 2,000 ألف متر مربع.
    * مابين 2,000 و 5,000 ألف متر مربع.
    * أكثر من 5,000 ألف متر مربع.
س4: سنكون عتيدة لك إذا تكرم وعددت 10 فلل سكنية عملت بها أعمال التسقيف.

<table>
<thead>
<tr>
<th>الرقم</th>
<th>اسم المشروع</th>
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<th>اسم الشخص الذي يمكن الاتصال به</th>
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س5: بالرالي السعودي ماهر معدل التكلفة الإجمالية لعمل تسقيف لسطح مساحته 300م2. 

جه: 
* أقل من 1000 ألف ريال. 
* ما بين 1000 و 2000 ألف ريال. 
* ما بين 2000 و 3500 ألف ريال. 
* أكثر من 3500 ألف ريال.

س6: عندما تنتهي من عمل تسقيف ما فحامي الطرق التي من خلالها تعرف انه عملت عملاً متقناً؟ 

جه: 
* عمل اختيار الفجر بالماء. 
* أرضي مطالب الزبون. 
* أعلم أن عمالي مهرب ومرازي جيدة فلذلك أنا على ثقة أن عملي دائماً متقناً. 

طريقة أخرى: .................................
س7: كم سنة تعطى ضمانيًا لنظام التسقيف التي تعمل وماهي حدود الضمان؟
ج7:
- سنة واحدة لنظام التسقيف
- 5 سنوات لنظام التسقيف
- 10 سنوات لنظام التسقيف
- أكثر من 10 سنة، حدد إنظام التسقيف
- تعليق

س8: ما هي حدود الضمان؟
ج8:
- ضمان على العمال فقط
- ضمان على المواد فقط
- الضمان يشمل العمال والمواد
- الضمان يشمل المواد والعمال وجميع التكاليف التي سببها مشاكل التسقيف
- تعليق آخر

س9: على أي أساس تعطي الضمان؟
ج9:
- واثق بعمالي
- واثق أن المواد لدي مثارة
- خبرتي بالمواد وطرق التسقيف
- تعليق

س10: هل هناك أي رخص للمقاولون لكي يعملوا بالتسقيف؟
ج10:
- نعم ولكن ليس على نطاق الرسمي ولكن على نطاق الشركات الكبيرة مثل ارامكو وسابك
- الوزارات الحكومية
- العمر الزمني للمقاول
- عددعمال المقاول
- عدد الأعمال المجزية
ب - مكونات التسقيف

س 11: ما هي مكونات التسقيف التي تستخدمها؟

ج 11:
* حزام معدني
* طبقة واقية
* بحص
* عزل حراري
* بلاط مثبت
* عازل مائي
* بلاط غير مثبت
* صه ميول
* فواصل مقد

مكونات أخرى...

س 12: مستعملًا المكونات في السؤال السابق عدد مكونات التسقيف المختلفة على حسب مرتبها في أنظمة التسقيف المستعمل بدأ من الطبقة العليا للنظام التسقيفي؟

ج 12:
(أ) (ب) (ج) (د)

س 13: ما هو نوع العازل المائي الذي تستخدم في تسقّيف السطوح؟

ج 13:
* لفائف البيتروم المعدل والموكس
* السوائل ذات الأساس أكريلك
* السوائل ذات الأساس بوليوريثين
* المراحل ذات الطبقة الواحدة مثل إي بي دي إم زي في سي
* الإسلف ذات الطبقات المتعددة
* مواد أخرى...
س 14: في تقديم ماهر أحسن عازل مائي ولماذا؟
ج 14:
* لائحة البيوتويلن المعدل والمؤكد
* السوائل ذات الأساس أكريلك
* السوائل ذات الأساس بوليوريثين
* العوازل ذات الطبقة الواحدة مثل إي بي دي إم وبي في سي
* الإسفتل ذات الطبقات المتعددة
* مواد أخرى...

س 15: في السؤال السابق لماذا فشلت هذا النوع من العزل المالئ؟
ج 15:
* لأنه يقاوم طول الزمن ويبقى لفترة طويلة
* لدينا وثائق تاريخية لمقاومته عوامل الطقس القاسية
* المضخع يمنع ضمانا
* خبرتنا في استعمالها
* أسباب أخرى...

س 16: ما هي أكثر أنظمة التسقيف استعمالاً؟
ج 16:
* لائحة البيوتويلن المعدل والمؤكد
* السوائل ذات الأساس أكريلك
* السوائل ذات الأساس بوليوريثين
* العوازل ذات الطبقة الواحدة مثل إي بي دي إم وبي في سي
* الإسفتل ذات الطبقات المتعددة
* مواد أخرى...

س 17: ما هي أكثر أنظمة التسقيف إقتصادية؟
ج 17:
* لائحة البيوتويلن المعدل والمؤكد لماذا؟
* السوائل ذات الأساس أكريلك لماذا؟
* السوائل ذات الأساس بوليوريثين لماذا؟
* العوازل ذات الطبقة الواحدة مثل إي بي دي إم وبي في سي لماذا؟
* الإسفتل ذات الطبقات المتعددة لماذا؟
* مواد أخرى...
س 18: ما هو نوع العزل الحراري الذي تستخدمه؟

ج 18:
- بولستايرين مضغوط
- بولستايرين غير مضغوط
- رغوة البليوريثين
- الراوح البوليوريثين
- أنواع أخرى (حدود)
- أسمنت رغوي خفيف الوزن

س 19: في اعتقادك ما هو أحسن العوازل الحرارية وماذا؟

ج 19:
- بولستايرين مضغوط
- بولستايرين غير مضغوط
- رغوة البليوريثين
- الراوح البوليوريثين
- أسمنت رغوي خفيف الوزن
- أنواع أخرى (حدود)

س 20: هل هناك رسوم هندسية مفصلة لمواقع السطح في الخريطة التي صممتها المكتب الهندسي للقيلا؟

ج 20:
- ليس هناك لها ذكر
- لانفصارات
- رسوم مفصلة
- ملاحظات أخرى

ب - 3: طرق التسقية

س 21: أي تركب مخارج المياه فوق السطح؟

ج 21:
- من خلال جهاء السطح
- في وسط السطح
- مواقع أخرى

س 22: على أي مستوى تصمم مخارج المياه في السطح؟

ج 22:
- تنخفض قليلاً تحت مستوى اعلى طبقة في نظام التسقية
- تنخفض قليلاً تحت مستوى العزل الحراري
- تنخفض تحت مستوى العزل المائي
- مستوى آخر
س 34: ما هي النسبة المئوية التي تستعمل للميلول؟
ج: 1%
1/2
1/3
أكثر من 1/3
* ملاحظات أخرى

س 35: كيف تعالج السقف غير المستوي والذي ليس له لامبول؟
ج: ليس هناك أي معالجة إذا أبدأ العمل على أي سقف كان
* وضع طبقه لياسه فوق السطح حتى يكون السطح ناعماً ثم أبدأ في التسقيف.
* اضع طبقه من الأسمنت الرغوي للتعقيم والميلول.
* اضع صه ميلول.
* طريقة أخرى.

ب - 4: زبان النسقيف

س 36: كيف تقيم رضا زبائنك؟
ج: لاشكوى، لذلك فالزبون راضي
* شكاوى قليلة.
* شكاوى كثيرة.
* تعليق آخر.

س 37: ما هي شكاوى الزبائن؟
ج: ليس هناك شكاوى
* شكاوى بسيطة.
* تعليق آخر.

س 38: كيف تقيم معرفة زبائنك بأعمال التسقيف؟
ج: جيد
* جيد جدا
* ممتازة
* مرتفع، لا يأت
* ملاحظات أخرى.
58 - 0: مشاكل تسقيف

لا يمكنني قراءة النص العربي من الصورة المقدمة. يرجى تقديم نص مكتوب يسهل قراءته.
س 31: إذا حدثت مشاكل في التسقيف فكيف تتعامل معها؟

ج 31:

* وضع تسقيف جديد فوق القديم.
* خلع التسقيف القديم ووضع تسقيف جديد مكانه.
* البحث عن موقع المشكلة ومعالجة السقف معالجة مؤقتة أو في موقع المشكلة فوق.
* تعليق آخر.

س 32: كيف نعلم أن لدينا مشكلة في السقف؟

ج 32:

* بالتفتيش سنويًا على السطح.
* بؤرة رطوبة في السقف من الداخل.
* بؤرة تسرب.
* إزالة الطبقة العلوية الواقية.
* تعليق آخر.

أي تعليق على الموضوع مع مراعاة وضع حلول لمشاكل التسقيف.
APPENDIX- B

QUESTIONNAIRE TO HOUSE OWNERS
Dear House Owner:

We would like to inform you that the Construction Engineering & Management Program of the College of Environmental Design at King Fahd University of Petroleum & Minerals is conducting a research project which investigates the roofing problems in Saudi Arabia's residential buildings. Your house was randomly chosen to be a part of this research.

Attached is a questionnaire which is a part of this project. Please answer all questions in the questionnaire carefully to the best of your knowledge, and note that some questions may require more than one answer. In addition to that, we need your permission to see the roof of your villa and have photographs taken for your roofing system as well as drainage outlets.

You should know that all information and pictures will be confidential and will only be used for this research objectives.

Please cooperate with the researcher Abdulaziz O. Al-Ajaji and call him on 876-4099 (Work) or 891-3641 (Home) had questions arise.

Your cooperation will always be appreciated. Thank You.

Dr. SADI A. ASSAF
Research Committee Chairman
B.1 House Information

1. How old is your house?
   - 1 month to 2.5 years
   - 2.5 years to 5 years
   - 5 years to 7.5 years
   - 7.5 years to 10 years
   - more than 10 years

2. What type of roof does your house have?
   - Flat roof
   - Slanted roof
   - Both slanted and flat
   - Corrugated sheet metal
   - Other type (specify)

3. What is the total roofing area?
   - 100 m² or less
   - Between 100 m² and 200 m²
   - Between 200 m² and 300 m²
   - Between 300 m² and 400 m²
   - More than 400 m²
   - Other size (specify)

B.2 Roofing Insulation Assembly

4. Is there roof insulation on your house?
   - Yes
   - No
   - I don't know

5. If the answer to question 4 is no, Why?
   - I don't think it is worth it or it is effective
   - It costs too much
   - My roof has large slope
   - My roof has concrete sealant
   - No body I know has it
   - My roof has light weight concrete
   - Other reasons (specify)
6. If the answer to question 4 is yes, Why?
   - I see that my neighbor or my relative has insulation
   - I think it is effective
   - I heard that it is effective
   - It comes with the contract
   - Other reasons (specify)

7. Did you have any knowledge about roof insulation systems before you start building your house?
   - Yes
   - No
   - A little

8. Do you think you had enough knowledge about roof insulation when you decided to make roof insulation and to select the type of insulation you have selected?
   - Yes
   - No

9. When did you install roof insulation, i.e. what is the age of your house roof insulation?
   - During the construction of the house
   - After I had problems in the roof
   - Other Remarks (specify)

10. What are the components of the roof assembly of your house? (mark more than one if applicable)
    - Flashing
    - Gravel
    - Fixed tiles
    - Loose tiles
    - Expansion joints
    - Protection layer
    - Thermal insulation
    - Roofing membrane (Waterproofing)
    - Screed concrete
    - Sealant in the screed concrete
    - Others (specify)
11. Who installed the roof assembly?
☐ The general contractor
☐ The supplier
☐ Specialized contractor
☐ Others (specify)-------------------------------------

12. How was the roof assembled? Put in order starting from the top component, assign numbers starting from 1, 2, 3,...etc.
☐ Flashing
☐ Gravel
☐ Fixed tiles
☐ Loose tiles
☐ Expansion joints
☐ Protection layer
☐ Thermal insulation
☐ Roofing membrane (Waterproofing)
☐ Screed concrete
☐ Sealant in the screed concrete
☐ Others (specify)
-----------------------------------------------------------------

13. How do you know that you have got a functionally working good roofing system?
☐ I trust that the roofing contractor had made a good job
☐ I ask the contractor to make flood test and I witnessed that
☐ I was witnessing the roofer while he was making the roofing
☐ Other ways of checking (specify)
-----------------------------------------------------------------

14. How much was the cost of the roof assembly in Saudi Riyals?
☐ Less than 10,000 SR
☐ Between 10,000 and 20,000 SR
☐ Between 20,000 and 30,000 SR
☐ More than 30,000 SR

15. What was the percentage of the roof assembly cost to the total cost of the house?
☐ Up to 5%
☐ Between 5% and 10%
☐ Between 10% and 15%
☐ Between 15% and 20%
☐ More than 20%
16. Does the roofing assembly work well?
   ☐ Yes
   ☐ No
   ☐ I do not know
   ☐ Other Remarks (specify)

17. Are you satisfied with it as a whole?
   ☐ Yes
   ☐ No

18. Are you unsatisfied with any component?
   ☐ Yes
   ☐ No
   ☐ If Yes, what component?

B.3 Thermal Insulation

19. If you used thermal insulation, what type?
   ☐ Extruded Polystyrene
   ☐ Expanded Polystyrene
   ☐ Polyurethane boards
   ☐ Polyurethane Foam
   ☐ Light weight concrete
   ☐ Polystyrene hordi
   ☐ Fiber glass
   ☐ Others (specify)

20. On what basis did you choose this particular type?
   ☐ I heard that it is the best
   ☐ I read that it is the best
   ☐ Like what my neighbor, friend or relative has
   ☐ Supplier convinced me
   ☐ I know from previous experience
   ☐ Other reasons (specify)

21. Why did you decide to put thermal insulation in the roof?
   ☐ To make the house more comfortable
   ☐ To save some of the energy cost
   ☐ To make the burden less on the AC units
   ☐ Like my friends
22. **Do you feel that you save some of the energy cost?**
   - Yes, how much percent of yearly cost?
   - No, Why?

23. **Do you think thermal insulation is effective in doing its function?**
   - Yes, I feel it in my electric bill
   - Yes, I feel it in the inside environment of the house
   - No, I think it was a waste of money
   - No, I think it was a mistake
   - I don't know
   - Others----------------------------------------

**B.4 Waterproofing**

24. **Why did you decide to put waterproofing on the roof of your house?**
   - To protect it against harsh environment like humidity
   - To protect it against rain water
   - Like my friends
   - Others (specify)

25. **If you use waterproofing, what type?**
   - Hot-installed asphalt-based bitumen
   - Cold-installed asphalt-based bitumen
   - Rubber-like black polyurethane
   - Self-adhesive membrane
   - Paint-like white acrylic
   - Others (specify)

26. **On what basis did you choose this particular type?**
   - I heard that it is the best
   - I read that it is the best
   - Like what my neighbor, friend or relative has
   - Supplier convinced me
   - I know that it is good from previous experience
   - Other reasons (specify)
27. Do you think waterproofing is effective in doing its function?
☐ Yes, I never got any problem during rain
☐ No, I encountered many problems and leaks
☐ I don't know, it was not challenged

B.5 Roofing Construction

28. Does your roof have sloped concrete screed?
☐ Yes
☐ No
☐ Other Remarks (specify)

29. How many drainage outlets does your house roof have?
☐ One
☐ Two
☐ Three
☐ Four
☐ Five and more (specify)
☐ Other Remarks (specify)

30. What is(are) the size(s) of the roof's outlets?
☐ 2 inches or less
☐ 3 inches
☐ 4 inches
☐ Other size(s) (specify)

31. How are your drainage outlets fixed?
☐ Just below the top layer of roofing system
☐ Just below the thermal insulation layer
☐ Just below the roofing membrane level
☐ Other Remarks (specify)

32. Have you carried out maintenance to the roofing or renewed or changed the roofing membrane?
☐ Yes
☐ No
☐ Other Remarks (specify)
33. How did you treat critical locations such as upstands and piping?
   - By flashing
   - Other Methods (specify)

34. How did you treat terminating ends at the parapet or other critical locations?
   - By flashing
   - Inserting the membrane in the wall
   - Welding the membrane on the wall
   - Other Methods (specify)

**B.6 Problems Encountered**

35. Do you encounter any problems with the roof assembly?
   - Yes
   - No
   - Others Remarks (specify)

36. If yes, what are these problems?
   - Leakage
   - Cracks
   - Others (specify)

37. If yes, what do you think the reason is?
   - There were not enough drain outlets
   - The size of drain outlets was too small
   - Incorrect location on drain outlets
   - There was no slope to drains
   - The slope was not good or enough to get rid of water
   - Terminating end was not designed properly
   - Other reasons (specify)

38. Do you get support from your supplier?
   - Yes
   - No
   - Other Remarks (specify)

**REMARKS ABOUT THE SUBJECT:** (Use the back of the page)
سلام عليكم ورحمة الله وبركاته

نفيذكم بأن قسم هندسة وإدارة التشغيل في كلية تصاميم البيئة بجامعة الملك فهد للبترول والمعادن قد صعد عمل بحث يتعلق ببعض المواقع للفلاحة المتصلة بالبيئة بالمملكة، وكما يلاحظ تلك المشاكل النسبيّة في الحفر، فلعل ذلك ينتفع بفعالية وفعالية الطلب منكم، وإلقاء الرسالة من هنا، حيث هذا الموضوع وقعت الاختيار على أن يكون منزلك جزءًا من هذا البحث.

الاستبيان يحتوي على مجموعة من الأسئلة ونرجو منكم التكرم مشكورين بالإجابة على الأسئلة الواردة في هذا الاستبيان. بكون حرصين كبيرة أو عدم ملاحظة بعض الاستجابة قد تنطوي أكثر من جواب واحد. كما نطلب أن يكون منكم في الصعود على طلّب منزلك وآخذ بعض الصور للفعاليّة ونوفّرها مع ملاحظة الهدف من هذا البحث.

وهذا الصدد لا بد من احترام أن جميع المعلومات والصور ستكون قرينة ومحفوظة لدى الباحث، وستعمل فقط للمساعدة لتحقيق أهداف هذا البحث.

نرجو التعاون مع الباحث عبد العزيز العجاجي وسائبه إذا كان هناك أي استفسار والإتصال به على الهاتف رقم 9134119 في المنزل أو في العمل على الهاتف رقم 876499.

ولكم منا جزيل الشكر.

الدكتور سعيد عصاف
رئيس اللجنة المشرفة على البحث
1-1 معلومات عن المنزل:

س1: ما هو العمر التقريبي لمنزلك؟
ج1:
- * من شهر إلى 2.5 سنة
- * من 2.5 سنة إلى 5 سنوات
- * من 5 سنوات إلى 7.5 سنة
- * من 7.5 سنة إلى 10 سنوات
- * أكثر من 10 سنوات

س2: ما هو نوع سطح منزلك؟
ج2:
- * سطح مستوي
- * سطح مائل
- * سطح مائل ومستوي
- * سطح حديدي
- * نوع آخر (حدد)...*

س3: ما هي المساحة التقريبية للسطح؟
ج3:
- * 100 متر مربع أو أقل
- * ما بين 100 إلى 200 متر مربع
- * ما بين 200 إلى 300 متر مربع
- * ما بين 300 إلى 400 متر مربع
- * أكثر من 400 متر مربع
- * مساحة أخرى (حدد)...*

1-3 عزل السطح

س4: هل سطح بيتك معزول؟
ج4:
- * نعم
- * لا
- * لا يوجد في البيت...*
س 5: إذا كانت الإجابة على السؤال 4 بلى فلا ماذا؟
ج: لا اعتقدي أنه مجد أو نافع
* تكاليفه كبيرة
* يحتوي سقف بيت على ميول كبيرة
* تحتوي صبة الميول على عازل مائي
* يحتوي السقف على أسمنت رغوي
* أسباب أخرى (حدد)...  

س 6: إذا كانت إجابة سؤال 4 بنعم فلا ماذا؟
ج: لا تعني رأيت أحد الجيران أو الاقرب يضع عازلا لسقف بيتهم
* اعتقدي أنه مجد ونافع
* سمعت عنه مجد ونافع
* عقد انشاء البيت يلزم المقاول بعمال العازل
* أسباب أخرى (حدد)...  

س 7: هل كان لديك دراية بأنظمة عزل السطوح قبل شرائك في بناء منزلك؟
ج: نعم
* لا
* القليل من المعرفة

س 8: هل تعتقد أنه كان لديك المعرفة الكافية بعزل السطوح عندما قررت وضع عازل للسقف وعندما وقع اختيارك على عازل السقف الذي اخترته؟
ج: نعم
* لا

س 9: متى وضعت العازل على السطح أو يعني آخر ماعصر عازل السطح لديك؟
ج: في انتهاء بناء المنزل
* عندما حدثت مشاكل في السطح
* ملاحظات أخرى...
س 10: ما هي مكونات سقف منزلك (علم على أكثر من واحدة إذا أردت)؟
ج: 1.
* شريحة معدنية
* بحص
* بلاط مثبت
* بلاط غير مثبت
* فواصل قسم
* طبقة حماية من البلاستيك أو الألياف
* عازل حراري
* عازل مائي
* صب مبول
* عازل مائي للرسانة المبول
* مكونات أخرى (عددًا)...

س 11: من عمل التسقيف في منزلك؟
ج: 11.
* المقاول العام
* الموزع
* مقالب خاصة
* آخرين (عددًا)

س 12: كيف عمل التسقيف عندك؟ عدد بالترتيب من أعلى طبقة إلى تحت استعمل الأرقام من 3.2.1.0.0...؟
ج: 12.
* بحص
* شريحة معدنية
* بلاط مثبت
* بلاط غير مثبت
* فواصل قسم
* عازل حراري
* عازل مائي
* صب مبول
* عازل مائي للرسانة المبول
* مكونات أخرى (عددًا)....
س١٣: كيف تعلم أن مقارنة التسقيف عمل للتكبّرا متنيناً وخالي من المشاكل؟

ج13: 
* أثق أن مقارنة التسقيف يعرف عمله وآثق به.
* طلبت من المقاول أن يعمل إختبار الغمر بالماء وكتبت شاهداً على ذلك.
* كنت أراقب عمل المقاول عندما كان يسقف في السطح.

طريقة أخرى للمعرفة

س١٤: كم كانت التكلفة الإجمالية للتسقيف لديك بالريال السعودي؟

ج14:

* أقل من 10 آلاف ريال، عدد 
* ما بين 10 و 15 الف ريال، عدد 
* ما بين 15 و 20 الف ريال، عدد 
* ما بين 20 و 30 الف ريال، عدد 
* أكثر من 30 الف ريال، عدد

س١٥: ما هي النسبة المئوية لتكلفة التسقيف بالنسبة إلى التكلفة الكلية للمiesz؟

ج15:

* أقل من 5٪ 
* ما بين 5٪ و 10٪ 
* ما بين 10٪ و 20٪ 
* أكثر من 20٪

س١٦: هل يعمل نظام التسقيف لديك بكفاءة؟

ج16:
* نعم 
* لا 
* لا أعلم، لم يتعرض للإختبار

س١٧: هل انت مسرورًا من عمل التسقيف لديك؟

ج17:
* نعم 
* لا
س.18: هل انت غير مسرور من أي من مكونات التسهيف؟
ج.18:
* نعم
* لا
* إذا كان الجواب نعم فما هو هذا الجزء؟

1-3: العلاج الحراري

س.19: إذا كنت ركبت عازلا حرارياً فما نوعه؟
ج.19:
* بولستايرين غير مضغوط
* بولستايرين مضغوط
* الراحة بوليوريثين
* رغوة بوليوريثين
* اسمنت رغوي
* فوردي بوليستايرين
* ليف زجاجي
* مادة أخرى (حدد)

س.20: على أي أساس وقع اختيارك على هذا النوع؟
ج.20:
* سمعت أنه الأحسن
* قرأت أنه الأحسن
* مثل ماختار جاري أو قريب أو صديقي
* الميزicare اقتنع
* أعلم أنه جيد من تجربة سابقة
* أسباب أخرى (حدد)

س.21: لماذا قررت ان تضع عازلا حرارياً على السطح؟
ج.21:
* حتى يكون المنزل أكثر راحة
* حتى يوفر جزءاً من تكاليف الكهرباء
* حتى يخف الحمل على وحدات التكييف
* فعلت مافعل جاري / صديقي / قريب
س24: هل تشعر أنك وفرت شيئًا من تكاليف الطاقة الكهربائية؟

ج24: 
نعم، ما هي النسبة المئوية لل توفير السنوي.
* لا، لماذا...

س23: هل تعتقد أن العزل الحراري قمًا، لتأديه المهمة التي وضع من أجلها؟

ج23: 
نعم، اشعر بذلك عندما أرى فاتورة الكهرباء.
نعم، اشعر بذلك في الجو الداخلي للمنزل.
لا، اعتقد أنه كان مضيعه للمال.
لا، اعتقد أنه كان خطأ.
لا أعلم.
* آراً بآخرى...

1- العزل المائي:

س24: لماذا قررت وضع عازل مائي على سطح منزلك؟

ج24: 
لحمايته من عوامل البيئة كالطقوبة.
لحمايته من التصر في حالة نزول الأمطار.
مثل الآخرين.
* أسباب أخرى...

س25: إذا كان لديك عازلًا مائيًا على سطح منزلك فما هو نوعه؟

ج25: 
بتيمين أساس أسفلتي مركب بالشعلة عارية.
بتيمين أساس أسفلتي مركب بالبارد.
طلاء بالبوليوئين الأسود.
لفائف عازل تلتتصق بنفسها.
* أكريلك أبيض.
* نوع آخر (حدد)...
س٢٦: على أي أساس اختبرت هذا النوع بالذات ؟
ج٢٦:
سمعت أنه الأحسن
قرأت أنه الأحسن
مثل عازل جاري أو صديقي أو قريب
الموضع اقتنعي
أعلم أنه جيد من تجارب سابقة
* أسباب أخرى (حدد).

س٢٧: هل تعد ماء المائي للسطح فعالًا لتأديته المهمة التي وضع من أجلها ؟
ج٢٧:
نعم، لم أواجه أي مشاكل أثناء نزول المطر.
لا، فقد واجهت مشاكل وتسرب الماء من خلال السقف
لأعلم، لم يجري

١٠٠-٤: طريقة التسقيف

س٢٨: هل يحتوي نظام التسقيف لديك صبه ميول ؟
ج٢٨:
نعم
لا

* ملاحظات أخرى.

س٢٩: كم يحتوي سقف منزلك من مخارج المياه؟
ج٢٩:
واحد
اثنان
ثلاثة
اربعاء
خمسة أو أكثر

* ملاحظات أخرى.
س٣٠: ماهو قطر مخارج المياه لديك؟

ج: 
* ٣ بوصة أو أقل
* ٤ بوصة
* مقاس آخر (حدد)

س٣١: هل عملت صيانة أو جددت أو غيرت التسقيف في منزلك؟

ج: 
* نعم (اشرح)
* لا

ملاحظات أخرى...

س٣٢: كيف وضعت مخارج المياه في السطح؟

ج: 
* تنخفض قليلاً عن مستوى أعلى طبقة في التنقيف.
* تنخفض قليلاً عن مستوى العازل الخراي.
* تنخفض قليلاً عن مستوى العازل المائي.

ملاحظات أخرى...

س٣٣: كيف تعالج المناطق المحساسة في السطح مثل الأتربيب والجدران فوق السطح بحيث لا يتبخر الماء منها حولها؟

ج: 
* باستعمال صفيحة معدنية
* باتباع طرق أخرى

س٣٤: كيف عالجلت الحاجة النهائية للعازل المائي حول محيط السطح أو حول المناطق المحسورة الأخرى؟

ج: 
* باستعمال وزره معدنية
* يدخل طرف العازل داخل الجدار
* يتلحم العازل المائي على السطح
* طرق أخرى (حدد)
1- المشاكل الحالية

س٣٥: هل واجهت مشاكل في التصنيف لديك؟

ج٣٥: * نعم
* لا

س٣٦: إذا كان الجواب نعم للسؤال السابق فما هي هذه المشاكل؟

ج٣٦: * نسب
* تشقات
* مشاكل أخرى (حدد)

س٣٧: إذا كان هناك مشاكل في نظام التصنيف فمهاي اسباب ذلك بتعمق؟

ج٣٧: * العوامل المناخية القاسية
* عمل المداول لكي متناً
* أعمال التصنيف لم تكن صحيحة
* مخارج التصنيف ضيقة مما جعلها تسد
* لم تكن هناك صميم على في اتجاه التصنيف
* أسباب أخرى

س٣٨: هل يهتم بك موزع ومكتب مراد التصنيف؟

ج٣٨: * نعم
* لا
* لم أجب
* ملاحظات أخرى

تعليقات عن الموضوع
APPENDIX- C

A GLOSSARY OF

ROOFING/WATERPROOFING TERMS
The following definitions of terms were taken from different sources. Some of the terms have very similar definitions which were supplied by different sources and they are given here for clarity. The great majority of these terms were directly taken from the following sources:


**Abrasion:** (1). The removal of surface material from any solid through the frictional action of another solid. (2). Wearing away of sedimentary rock chiefly by a current of water laden with sand and other rock debris. A spot denuded of skin, rubbing or scraping of membrane.

**Adhesive:** A cementing substance that produces a steady and firm attachment between two surfaces.

**Air Barrier:** A membrane or building element that provides resistance to air leakage.

**Air Leakage:** The movement of air through spaces between constituent parts of a roof system or other enclosure element as a result of air pressure differences between one and the other side.

**Air Space:** A cavity or unfilled space between two constituent parts in a roof system or other enclosure element of a building.

**Aggregate:** (1) crushed stone, crushed slag or water-worn gravel used for surfacing a built-up roof; (2) any granular mineral material; Gravel, crushed stone, slag, or mineral granules either (1) embedded in a conventional built-up membrane's bituminous flood coat or (2) applied to a loose-laid roof system as a protective ballast; Material such as natural gravel, small size broken stone or crushed slag, used as a protective surfacing or ballast in roofing systems.

**Alligatoring:** The cracking of the surfacing bitumen on a built-up roof, producing a pattern of cracks similar to an alligator's hide; the cracks may not extend through the surfacing bitumen; Deep shrinkage cracks, progressing down from the surface, in smooth-surfaced membrane coatings and sometimes in bare spots of aggregate-surfaced membranes. It is a consequence of photo-oxidative hardening; Hardening and shrinking of exposed bitumen coatings due to oxidation, that produces small islands of bitumen between deep cracks, the overall appearance of which somewhat resembles alligator hide.

**Anionic emulsion:** An emulsion in which the emulsifying system establishes a predominance of negative charges on the discontinuous phase.

**Application:** The act of putting on or building up the felts and flashing of a built-up roofing, or all the elements of any roofing system.

- **Cold Application:** The applying of felts in a built-up roofing with cold bituminous cements.
- **Horizontal Application:** Mineral-surfaced roofing applied with the laps parallel to the eaves of a sloping roof.
- **Hot Application:** The application of felts in built-up roofing using heated bitumen.
- **Phased Application:** The practice of laying one or more plies of a built-up roofing at one time with the additional plies laid at a later time.
- **Separate Layer Application:** Felts applied with a small edge lap for each of several separate plies.
- **Shingle Application:** Felts applied in an overlapping manner similar to shingle application, with the amount of overlap arranged to give the number of plies desired.
- **Two-and-Two Application:** A four-ply roofing laid in shingle fashion with the first two giving double coverage and the last two separate double coverage.
- **Vertical Application:** Mineral-surfaced felt applied with the laps at right-angles to the eaves and parallel to the rake. Also called up-and-over when it continues over the ridge. Sometimes laid slightly on the bias to encourage drainage away from the laps.

**Application rate:** The quantity (mass, volume or thickness) of material applied per unit area.

**Asbestos:** A group of natural fibrous impure silicate materials.
Asphalt: A dark brown to black cementitious material in which the predominating constituents are bitumens, which occur in nature or are obtained in petroleum processing; Dark brown to black, highly viscous, hydrocarbon produced from the residuum left after the distillation of petroleum, used as the waterproofing agent of a built-up roof; Dark brown to black hydrocarbon solids or semi-solids that gradually liquefy when heated. It occurs in natural deposits at a few places throughout the world, but the source of asphalt for roofing is the residuum of petroleum distillation.; A brown to black, hard, brittle or plastic bituminous material composed principally of hydrocarbons, prepared by pyrolysis from coal tar, certain petroleum; melts on heating, insoluble in water but soluble in gasoline; used for paving and roofing and in paints.

**Dead-Level Asphalt:** a roofing asphalt conforming to the requirements of ASTM Specification D312, Type I. It is generally used on inclines up to 1/2 in./ft. slope.

**Flat Asphalt:** a roofing asphalt conforming to the requirements of ASTM Specification D312, Type II. It is generally used on inclines from 1/2 in. to 1 1/2 in./ft. slope.

**Steep Asphalt:** a roofing asphalt conforming to the requirements of ASTM Specification D312, Type III. It is generally used on inclines up to 3 in./ft. slope.

**Special Steep Asphalt:** a roofing asphalt conforming to the requirements of ASTM Specification D312, Type IV. It is generally used on inclines ranging from 2-6 in./ft. slope.

Asphalt, air blown: An asphalt produced by blowing air through molten asphalt at an elevated temperature to raise its softening point and modify other properties.

Asphalt Emulsion: Asphalt cement in water containing a small amount of emulsifying agent.

Asphaltene: A high molecular weight hydrocarbon fraction precipitated from asphalt by a designated paraffinic naphtha solvent at a specified temperature and solvent-asphalt ratio.

*Discussion*—The asphaltene fraction should be identified by the temperature and solvent-asphalt ratio used.

Asphalt felt: An asphalt-saturated felt.

Asphalntite: A natural asphalt found below ground level.

Asphalt mastic: A mixture of asphaltic material and graded mineral aggregate that can be poured when heated, but requires mechanical manipulation to apply.

Asphalt Primer: Low-viscosity, liquid asphaltic material applied to and absorbed by non bituminous surfaces, as in waterproofing.

Asphalt Roofing: A roofing material made by impregnating a dry roofing felt with a hot asphalt saturate, applying asphalt coatings to the weather and reverse sides and embedding a mineral surfacing in the coating on the weather side [9].

Asphalt rock (rock asphalt): A naturally occurring rock formation, usually limestone or sandstone, containing throughout its mass a minor amount of asphalt.

Asphalt, steam blown: An asphalt produced by blowing steam through molten asphalt to modify its properties.
Attic: A roof space between the top floor ceiling and the roof of a building.

Backnailing: "Blind" (i.e., concealed by overlapping felt) nailing in addition to hot mopping to prevent membrane slippage; the practice of blind-nailing roofing felts to a substrate in addition to hot-mopping to prevent slippage.

Barge Board: A board, often decorative, covering the projecting portion of a gable roof.

Bald roof: See smooth-surfaced roof.

Ballast Aggregate: concrete pavers, or other material designed to prevent wind uplift or flotation of a loose-laid roof system.

Base Ply: One layer of felt secured to the deck over which a built-up roof is applied; The lowermost ply of roofing material in a roof membrane assembly; the bottom or first ply in a built-up roofing membrane when additional plies are to be subsequently installed; A felt (often coated) placed as the first (nonshingled) ply in a multi-ply built-up roof membrane.

Base Sheet: A product used as the base ply in a built-up roofing membrane; A saturated or coated felt installed as the first ply in some multi-ply built-up roof membranes; a product intended to be used as a base ply in a built-up roofing system; A felt that previously has been saturated (impregnated with asphalt) and later coated with harder, more viscous asphalt, which increases its resistance to moisture; A heavy sheet of saturated or coated felt placed as the first ply in a built-up roofing membrane of roof system.

Bitumen: (1) a class of amorphous, black or dark colored, (solid, semi-solid or viscous) cementitious substances, natural or manufactured, composed principally of high molecular weight hydrocarbons, soluble in carbon disulfide, and found in asphalts, tars, pitches and asphaltites; (2) a generic term used to denote any material composed principally of bitumen; A generic term applied to mixtures of predominantly hydrocarbons in viscous or solid form, derived from coal or petroleum. The roofing industry uses it to describe either coal tar pitch or asphalt; Generic term for an amorphous, semisolid mixture of complex hydrocarbons derived from petroleum or coal. In the roofing industry there are two basic bitumens: asphalt and coal tar pitch. Before application, they are (1) heated to a liquid state, (2) dissolved in a solvent, or (3) emulsified.

Bitumen Trap: See pitch pocket; See Envelope.

Bituminized, adj: Impregnated with bitumen. Example: bituminized fiber pipe.

Bituminous: Containing or treated with bitumen. Examples: bituminous concrete, bituminous felts and fabrics, bituminous pavement.

Bituminous Emulsion: (1) a suspension of minute globules of bituminous material in water or in an aqueous solution; (2) a suspension of minute globules of water or of an aqueous solution in a liquid bituminous material (invert emulsion).

Bituminous Grout: A mixture of bituminous material and fine sand that will flow into place without mechanical manipulation when heated.

Blast-Furnace Slag: The nonmetallic product, consisting essentially of silicates and alumino-silicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace.
Blind Nailing: The use of nails that are not exposed to the weather in the finished roofing.

Blister: An enclosed pocket of air mixed with water or solvent vapor, trapped between impermeable layers of felt, or between the felt and substrate; a raised portion of a roofing membrane resulting from local internal pressure; (2) the similarly formed protuberances in coated prepared roofing; Spongy, humped portion of a roof membrane, formed by entrapped air-vapor mixture under pressure, with the blister chamber located either between felt plies or at the membrane-substrate interface; An enclosed raised spot or area containing gas or liquid that shows at the surface of prepared or built-up roofing.

Surface Blisters: Small blisters from pin head size to usually less than 25 mm in diameter appearing in the surface coatings of roofing. They frequently occur in clusters and result from exposure to sunlight and weather. Also called weather blisters, pin blisters, blueberries, pimpling, and bitumen bubbling.

Structural Blisters: Blisters between plies of felt in a built-up roofing membrane, or between the membrane and its substrate, ranging in size from 25 mm dia. and barely visible height to 5 m² in area and 300 mm in height. Also called interply or interface blisters.

Blocking: (1) wood built into a roofing system above the deck and below the membrane and flashing to (a) stiffen the deck around an opening, (b) act as a stop for insulation, (c) serve as a nailer for attachment of the membrane or flashing; (2) wood cross-members installed between rafters or joists to provide support at cross-joints between deck panels. (3) cohesion or adhesion between similar or dissimilar materials in roll or sheet form that may interfere with the satisfactory and efficient use of the material. Continuous wood components anchored to the deck at roof perimeters and openings and doubling as cross-sectional fillers and anchorage bases, used in conjunction with nailers; Continuous strips, usually of wood, secured to roof decks at the perimeter edges and around roof openings to provide securement for the roofing membrane and flashing, or for other building parts.

Bond: (1) To hold together two roofing components by means of an adhesive. (2) The adhesive strength that prevents delamination of two components. (3) A guarantee relating to roofing performance.

Blueberry: See strawberry.

Bond: The adhesive and cohesive forces holding two roofing components in intimate contact.

Brooming: Field procedure of pressing felts into a layer of fluid hot bitumen to ensure continuous adhesion—i.e., elimination of blister-originating voids—of the bitumen film; embedding a ply by using a broom to smooth it out and ensure contact with the adhesive under the ply; The pressing of felts in close contact with the layer of bitumen immediately following the application of bitumen and felt, by the use of a wide stable of deck type broom or other suitable push bar as wide as the felt.

Btu (British thermal unit): Heat energy required to raise 1 lb. of water 1°F.

Buckle: Large elongated bulge or fold in a roofing membrane as a result of separation from the substrate accompanied by expansion or stretching.

Building: In this research, the meaning of building will be known from the context; however, in most cases it will mean house or residential villa.

Built-Up Roof Covering: Two or more layers of felt cemented together and surfaced with cap sheet, mineral aggregate, smooth coating or similar surfacing material; A continuous, semiflexible membrane consisting of plies of saturated felts, coated felts, fabrics or mats assembled in place with alternate layers of bitumen and surfaced with mineral aggregate, bituminous materials, or a granule surfaced sheet
(abbreviation, BUR); Continuous, semiflexible roof covering of laminations or plies of saturated or coated felts alternated with layers of bitumen, surfaced with mineral aggregate or asphaltic materials.

**Cant Strip:** A beveled strip used under flashing to modify the angle at the point where the roofing or waterproofing membrane meets any vertical element; A continuous strip of material of triangular section placed at the intersection of a roof deck with a higher wall or other vertical surface. The roofing membrane and flashing are eased through the change in direction from essentially horizontal to vertical along its 45° sloping surface.

**Cap flashing:** See flashing.

**Cap Sheet:** Roofing made of organic or inorganic fibers, saturated and coated on both sides with a bituminous compound, surfaced with mineral granules, mica, talc, aluminum, inorganic fibers or similar materials; A granule-surfaced coated sheet used as the top ply of a built-up roof membrane; A granule-surfaced coated felt used as the top ply of a built-up roofing membrane; Mineral-surfaced coated felt used as the top ply of a built-up roof membrane; The top ply of a built-up roofing membrane acting as the finished surface of a roof; Any mineral-surfaced or other coated felt or sheet designed for that purpose.

**Cationic Emulsion:** An emulsion in which the emulsifying system establishes a predominance of positive charges on the discontinuous phase.

**Caulking:** A composition of vehicle and pigment, used at ambient temperatures for filling joints, that remains plastic for an extended time after application. Any of a wide range of bituminous, rubber, plastic or other materials suitable for filling seams or cracks to make them tight against water leakage.

**Cement:** A substance used to make objects adhere to each other. In the roofing industry loosely applied to mean caulking and mastic.

- **Flash**ing **Cement:** A trowelable mixture of asphalt, volatile solvent and mineral fillers used as a cold coating in the application of flashing, for sealing around roofing details and for cold patching.
- **Plastic** **Cement:** Same as flashing cement.
- **Portland Cement:** Hydraulic cement used for making concrete and grout.

**Cementing:** Solidly mopped application of asphalt, cold liquid asphalt compound, coal tar pitch or other approved cementing material.

**Centistoke (cSt):** Unit of viscosity (antonym of fluidity). Water has a viscosity of roughly 1 cSt, light cooking oil 100 cSt.

**Channel Mopping:** See mopping, strip.

**Coal Tar:** A tar obtained from carbonization of coal, usually in coke ovens or retorts, containing several hundred organic chemicals; A dark brown to black, semi-solid hydrocarbon obtained as residue from the partial evaporation or distillation of coal tar; A dark brown to black cementitious material produced by the destructive distillation of coal; Tar derived from the destructive distillation of coal during the conversion of coal into coke.

**Coal-Tar Felt:** (1) A felt that has been saturated with refined coal tar; (2) An asphalt felt that has been coated on both sides with harder, more viscous asphalt; (3) A glass fiber felt that has been simultaneously impregnated and coated with asphalt on both sides.
**Coal-Tar Pitch**: A dark brown to black, solid cementitious material obtained as residue in the partial evaporation or distillation of coal tar; A coal tar used as the waterproofing agent in dead-level or low-slope built-up roof membrane, conforming to ASTM Specification D450, Type I; Dark brown to black solid hydrocarbon obtained from the residuum of distilled coke-oven tar, used as the waterproofing agent of dead-level or low-slope built-up roofs; A dark brown to black hydrocarbon solid or semisolid specifically refined for roofing from coal tar.

**Coal-Tar Waterproofing Pitch**: A coal tar used as the dampproofing or waterproofing agent in below-grade structures, conforming to ASTM Specification D450, Type II.

**Coal-Tar Bitumen**: A bituminous material derived as a by-product in the manufacture of coke from bituminous coal. It is used as the waterproofing agent in dead-level or low-slope built-up roof membrane, conforming to ASTM Specification D450, Type III.

**Coating**: A thin layer of a substance used to cover other materials, to provide an aesthetic or protective function.

**Coke-Oven Tar**: See coal tar.

**Cold-Process Roofing**: A continuous, semiflexible membrane consisting of plies of felts, mats, or fabrics laminated on a roof with alternate layers of roof cement and surfaced with a cold-applied coating; Bituminous membrane comprising layers of coated felts bonded with cold-applied asphalt roof cement and surfaced with a cutback or emulsified asphalt roof coating; (1). Roofing comprised of layers of bituminous-coated felt adhered with cold-applied bituminous cement, and surfaced with emulsion or cutback. (2). Sometimes applied to any roofing system that uses bituminous materials applied cold.

**Collar**: A metal cap flashing around a vent pipe projecting above a roof deck.

**Condensation**: The conversion of water vapor or other gas to liquid as the temperature drops or atmospheric pressures rises. (See also dew point); Process through which water vapor (a gas) liquefies as air temperature drops or atmospheric pressure rises; The change from water vapor to liquid water, resulting from a drop in temperature of an air vapor mixture.

- **Concealed Condensation**: That which takes place within a roofing system and is not seen.
- **Interstitial Condensation**: That which occurs in the interstices between constituent parts of a roof system. Same as concealed.
- **Surface Condensation**: That which appears on the colder exposed surfaces of a roofing system.

**Conductor**: A pipe for conveying rain water from a roof gutter to a drain, or from a roof drain to a storm drain. Also called a leader, down spout or down pipe.

**Conductance, Thermal**: The thermal transmission in unit time through unit area of a particular body or assembly having defined surfaces, when unit average temperature difference is established between the surfaces. \( C = \frac{W}{m^2 \cdot K} = \frac{\text{Btu}}{\text{h} \cdot \text{ft}^2 \cdot \text{F}} \)

**Conductivity, Thermal**: The thermal transmission, by conduction only, in unit time through unit area between two isothermal surfaces of an infinite slab of a homogeneous material of unit thickness, in a direction perpendicular to the surface, when unit temperature difference is established between the surfaces. \( k = \frac{W}{m \cdot K} = \frac{\text{Btu}}{\text{in.} \cdot \text{h} \cdot \text{ft}^2 \cdot \text{F}} \)

**Cone Penetration**: See penetration.
Coated Sheet (or Felt): (1) an asphalt felt that has been coated both sides with harder, more viscous asphalt; (2) a glass fiber felt that has been simultaneously impregnated and coated with asphalt or coal tar on both sides.

Cold-Process Roofing: A continuous, semi-flexible roof membrane, consisting of plies of felts, mats, or fabrics that are laminated on a roof with alternate layers of cold-applied roof adhesive and surfaced with a cold-applied coating.

Combination Sheet: A glass fiber felt integrally attached to kraft paper.

Control-flow: Relating to roof drainage. A type of drain or a system of drains that regulates the flow of water so that rain water can be drained away at a uniform rate no matter how heavy the rainfall.

Coping: A covering piece on top of a wall exposed to the weather, usually sloped to carry off water; the covering piece on top of a wall exposed to the weather, usually sloped to shed water. The cap or highest covering course of a wall, usually overhanging the wall and having a sloping top to shed water.

Cornice: Projection at the top of a wall. Term applied to construction under the eaves where the roof and side walls meet. The top course, or courses of a wall when treated as a projecting crowning member.

Corrosion-Resistant: Any nonferrous metal or any metal having an unbroken surfacing of nonferrous metal or steel with not less than 10 percent chromium or with not less than 0.20 percent copper.

Counterflash: Formed metal or elastomeric sheeting secured on or into a wall, curb, pipe, rooftop unit or other surface, to cover and protect the upper edge of a base flashing and its associated fasteners; formed metal or elastomeric sheeting secured on or into a wall, curb, pipe, roof-top unit, or other surface, to cover and protect the upper edge of a base flashing and its associated fasteners; formed metal or elastomeric sheeting secured on or into a wall, curb, pipe, rooftop unit or other surface, to cover and protect the upper edge of a base flashing and its associated fasteners.

Course: (1) the term used for each application of material that forms the waterproofing system or the flashing; (2) one layer of a series of materials applied to a surface (i.e., a five-course wall flashing is composed of three applications of mastic with one ply of felt sandwiched between each layer of mastic).

Coverage: The surface area to be continuously covered by a specific quantity of a particular material; area that should be continuously coated by a specific unit of a roofing material, after allowance is made for a specified lap.

Crack: Membrane fracture produced by bending, often at a ridge (see Ridging); a separation or fracture occurring in a roof membrane or roof deck, generally caused by thermal induced stress or substrate movement; A break in a roofing membrane as a result of flexing, often at a ridge or wrinkle.

Crazing: A network of fine hairline cracks on or under the surface of a material such as enamel, glaze, metal, or plastic; Surface deterioration by the formation of a pattern of fine hairline cracks.

Creep: (1) Permanent elongation or shrinkage of the membrane resulting from thermal or moisture changes. (2) Permanent deflection of structural framing or structural deck resulting from plastic flow under continued stress or dimensional changes accompanying changing moisture content or temperature; the time-dependent part of a strain resulting from stress; the permanent deformation of a roofing material or roof system caused by the movement of the roof membrane that results from continuous thermal stress or loading.
Cricket: A relatively small, elevated area of a roof constructed to divert water from a horizontal intersection of the roof with a chimney, wall, expansion joint, or other projection; Ridge built up in a level valley or perimeter to direct rainwater to a drain, A small false roof, or the elevation of a part of a roof surface, as a means of diverting water from behind a projection such as a chimney. Also used to direct water to drains in a horizontal roof valley formed by the intersection of two sloping roofs. Also called a saddle.

Crushed Stone: The product resulting from the artificial crushing of rocks, boulders, or large cobblestones, substantially all faces of which have resulted from the crushing operation.

Curb: A masonry or wood edge extending 8" to 12" above roof deck at openings for skylights, scuttles, ducts, expansion joints, etc., or as supports for structures erected over roofs. Purpose: To provide support for base and cap flashing; A low wall of wood or masonry built above the level of the roof, surrounding a roof opening such as is required for installation of fans and other equipment, and at the edges of movement joints in a roof deck.

Curing: Final step in the irreversible polymerization of a thermosetting plastic, usually requiring some combination of heat, radiation, and pressure.

Curl ed Felt: Membrane defect characterized by a continuous, open longitudinal seam with top felt rolled back from underlying felt.

Cutback: A solution of bitumen in a volatile solvent used as a primer, cold-application cementing agent or roof coating. Filled cutbacks may contain mineral particles and inorganic fibers.; solvent-thinned bitumen used in cold-process roofing adhesives, flashing cements, and roof coatings.

Cutoff: A detail designed to prevent lateral water movement into the insulation where the membrane terminates at the end of a day's work, or used to isolate sections of the roofing system. It is usually removed before the continuation of the work; A membrane placed along joints to separate roof insulation into multiple areas, or turned over the edges to protect insulation at the roof perimeter, or to seal the edge of insulation at the end of a day's work during roofing application.

Dampproofing: Treatment of a surface or structure to resist the passage of water in the absence of hydrostatic pressure; The treatment of a building material or component surface with a bituminous or other coating to provide some measure of resistance to the passage of moisture into or through the material or component.

Dead Level: Absolutely horizontal, or zero slope (see also slope); A roof deck with no intentional slope to the roof drains.

Dead Level Asphalt: A roofing asphalt conforming to the requirements of Specification D 312, Type I.

Dead Level Roofing: A roofing system applied on a surface with a 0 to 2 % incline.

Dead Loads: Non-moving rooftop loads, such as mechanical equipment, air conditioning units, and the roof deck itself.

Deck: The structural surface to which the roofing or waterproofing system (including insulation) is applied; Structural supporting surface of a roof system; The structural infill between main structural supports, to the top surface of which a roofing system is applied.
Delamination: Separation of felt plies in a built-up membrane; separation of insulation boards into horizontal strata.

Dew point: Temperature at which water vapor starts to condense in cooling air at existing atmospheric pressure and vapor content; The temperature at which a sample of humid air, cooled from some temperature, becomes saturated and at which water vapor begins to condense to liquid water.

Dipper: A ladle for pouring bitumen.

Direction Change: A change in the orientation of the principal dimension or of the support of adjoining units of the roofing system.

Dormer: A separate smaller roofed structure that projects from a sloping roof to provide more space below the roof and to accommodate a vertical window.

Double Pour: The process of applying two layers of aggregate and bitumen to a built-up roof; to apply two layers of aggregate and bitumen to a built-up roof; Doubling of the flood-coat, graveling-in operation, to provide additional waterproofing integrity to the membrane, The application of the top covering of bitumen and gravel surfacing of a built-up roofing in two separate operations; A quantity of gravel is spread over a first pour coat of bitumen, loose gravel is removed, and additional gravel is spread into a second-pour coat of bitumen.

Dry Felt: (1) see felt;(2) a felt which has not been saturated with bitumen.

Dry Laid: Any roofing felt laid without bitumen or other adhesive.

Drain: A device that allows for the flow of water from a roof area. (See NRCA Construction Details;); An outlet to allow water to flow from a roof surface into a drain pipe and away from the building through a drainage system.

Dip Edge: The formed edge on metal flashing used at the eaves or other roof details to encourage water to drip away from vertical surfaces of the building detail.

Drippage: Bitumen that flows and drips through holes or over the edge of a roof deck.

Dropback: A reduction in the softening point of bitumen that occurs when bitumen is heated in the absence of air. (See Softening Point Drift.)

Dry Laid: Any roofing felt laid without bitumen or other adhesive.

Duck Boards: Slatted wood-board panels for placement on a roof to provide a walkway or roof surfacing for light traffic.

Edge Sheets: Felt strips that are cut to widths narrower than the standard width of the full felt roll, used to start the felt shingling pattern at a roof edge. They are also commonly called "starting strips."

Edge stripping: Application of felt strips to cover a joint between flashing and built-up membrane.

Edge Venting: the practice of providing regularly spaced protected openings along a roof perimeter to relieve moisture vapor pressure; usually combined with venting channels in the insulation and stack venting towards the center of the roof.
Elastomer: Macromolecular material that rapidly regains its original shape after release of a light deforming stress; a macromolecular material that returns rapidly to its approximate initial dimensions and shape after substantial deformation by a weak stress and the subsequent release of that stress.

Elastomeric: Having elastic properties, capable of expanding or contracting with the surfaces to which the material is applied without rupturing; a rubber like synthetic polymer that will stretch when pulled and will return quickly to its original shape when released.

Embedment: (1) The process of pressing a felt, aggregate, fabric, mat, or panel uniformly and completely into hot bitumen or adhesive; (2) the process of pressing granules into coating in the manufacture of factory prepared-roofing.

Emulsion: Intimate mixture of bitumen and water, with uniform dispersion of the bitumen globules achieved through a chemical or clay emulsifying agent; the intimate dispersion of an organic material and water achieved by using a chemical or clay emulsifying agent.

Envelope: Continuous edge formed by folding an edge base felt over the plies above and securing it to the top felt. The envelope thus prevents bitumen seepage through the exposed edge joints of the laminated, built-up roofing membrane; A continuous membrane edge seal formed at the perimeter and at penetrations by folding the base sheet or ply over the plies above and securing it to the top of the membrane.

Equilibrium moisture content: (1) The moisture content of a material stabilized at a given temperature and relative humidity, expressed as percent moisture by weight; (2) the typical moisture content of a material in any given geographical area; The balanced moisture content attained by a material at any particular temperature and humidity conditions expressed as a percentage of moisture mass to material mass.

Equiviscous Temperature (EVT): The temperature determined by the manufacturer at which the asphalt has a viscosity of 125 centistokes and is considered to be the proper temperature for asphalt applications; The temperature at which the viscosity of an asphalt is 125 centistokes the recommended asphalt temperature plus or minus 25°F at the time of application; Temperature at which asphalt has the correct viscosity (50-150 cSt) for hot mopping; the temperature at which the viscosity is 75 centipoise for asphalt and 25 centipoise for coal tar products; the recommended temperature plus or minus 25°F at the time of application; The temperature at which bitumens will have the correct viscosity for spreading in roofing application.

Ethylene Propylene Diene Monomer (EPDM): Thermosetting, synthetic rubber used in single-ply elastomeric sheet roof membranes.

Expansion Joint: A structural separation between two building elements that allows free movement between the elements without damage to the roofing or waterproofing system.; A deliberate joint separation of two parts of a building through floors, walls and roof to allow expansion and contraction movement of the parts. The joint is provided with a flexible watertight connecting detail.

Exposure: (1) The transverse dimension of a roofing element not overlapped by an adjacent element in any roof system. The exposure of any ply in a membrane may be computed by dividing the felt width minus 2 inches by the number of shingled plies; thus, the exposure of 36 inch-wide felt in a shingled, four-ply membrane should be 8 1/2 inches; (2) the time during which a portion of a roofing element is exposed to the weather. Correct felt exposure in a shingled, built-up membrane is computed by dividing the felt width minus 2 in. by the number of plies—e.g., for four plies of 36-in.-wide felt, exposure = (36-2)/4 = 8 1/2 in.; The amount of any particular roofing unit exposed to the weather or not covered by an overlapping unit in a roofing system that utilizes overlapping application. The dimension describing this
is measured in the direction of the overlap and is normally the unit width minus a small amount to ensure complete coverage, divided by the number of plies. For a two-ply membrane from 1 m wide roofing felt allowing 50 mm to ensure coverage the exposure would be \((1000 - 50)/2 = 475\) mm. For shingle type roofing the allowance is called the headlap.

**Fabric:** Woven cloth of organic or inorganic filaments, threads, or yarns. A woven cloth of organic or inorganic fibers treated with bitumen and used for special flashing applications.

**Factory Mutual (FM):** an organization that classifies roof assemblies for their fire characteristics and wind uplift resistance for insurance companies in the United States.

**Factory Square:** 108 square feet of roofing material.

**Fall:** The vertical distance in millimeters through which a roof incline falls in a unit horizontal distance of one meter.

**Fallback:** Reduction in bitumen softening point, sometimes caused by refluxing or overheating in a closed container.; A reduction of bitumen softening point related to contamination, incompatibility or over heating. Also referred to as softening-point drift.

**Fascia:** The finish member covering the edge or eaves of a flat or sloping overhanging roof.

**Feather:** To reduce the edge of a material to a very small dimension like a feather edge.

**Felt:** A general term used to describe sheet roofing material consisting of a mat of organic or inorganic fibers untreated, or saturated, or saturated and coated with bitumen and supplied for use in roll form; It is matted organic or inorganic fibers, saturated or coated with bituminous compound; A flexible sheet manufactured by the interlocking of fibers through a combination of mechanical work, moisture and heat. Felts are manufactured principally from vegetable fibers (organic felts), glass fibers (glass fiber felts), or polyester fibers (polyester felts); other fibers may be present in each type; Flexible sheet manufactured by interlocking fibers with a binder or through a combination of mechanical work, moisture, and heat.

- **Asbestos Felt:** Felt containing from 75% to 85% of asbestos fiber.
- **Asphalt Felt:** Felt for which the bituminous saturant or coating is asphalt.
- **Coated Felt:** Asphalt-saturated felt coated on one or both sides with filled asphalt.
- **Dry Felt:** Organic-fiber roofing felt before any treatment with bitumen. Used as an underlayment for built-up roofing over wood-board decks to prevent bitumen drippage or to provide a slip sheet.
- **Class Felt:** Felt made from glass fiber.
- **Mineral-Surfaced Felt:** Bitumen-coated felt surfaced on one side with natural or synthetic colored granules.
- **Organic Felt:** Felt made from organic fibers and in particular wood fibers.
- **Perforated Felt:** Bitumen-saturated felt perforated with closely-spaced small holes to allow for escape of air and moisture during application.
- **Rag Felt:** A term sometimes used to describe organic-fiber felt. A hangover from earlier days when a percentage of rag fiber was used.
- **Saturated Felt:** Felt which has been impregnated with bitumen by passing it through vats of hot saturant.
- **Stripping Felt:** Narrow widths of felt used to complete flashing details, particularly to cover the edges of metal flanges incorporated into built-up roofing.
- **Tar Felt:** Felt for which the saturant is coal tar pitch, more properly called coal tar pitch felt.
Felt, Non-Bituminous Saturated: A felt for special-purpose roofing weighing not less than 12 pounds per 100 square feet, not less than 0.022 inch in thickness, containing a fire- and water-retardant binder, and reinforced with glass fibers running lengthwise of the sheet not more than 1/2 inch apart.

Felt layer: Spreader-type, wheel-mounted equipment for laying felt and simultaneously dispensing hot asphalt in a single operation; a machine used for applying bitumen and built-up roofing felts; A piece of mobile mechanized roofing equipment for spreading bitumen and laying felt in a single continuous operation.

Felt Mill Ream: the mass in pounds of 480 square feet of dry, unsaturated felt; also termed "point weight".

Firewall: Any wall built for the purpose of restricting the spread of fire in a building. Such walls of solid masonry or concrete usually divide a building from the foundations to about a meters above the roof.

Fill: Aggregate and cement mixtures placed on a roof deck in varying thickness to level out depressions and irregularities, or to form slopes to roof drains.

Filler: Finely-divided mineral matter used as an extender and to improve the properties of asphalt coatings for shingle and built-up roofing felts, and bituminous-plastic cement or mastic. Also called a stabilizer.

Fine Mineral Surfacing: Water-insoluble, inorganic material, more than 50 percent of which passes the No. 35 sieve, used on the surface of roofing.

Finger wrinkling: Wrinkling of exposed felts in small, finger-sized ridges parallel to the longitudinal direction of the felt roll, caused by transverse moisture expansion of the felt.

Fire-Retardant Shakes and Shingles: Wood shakes and shingles complying with U.B.C. Standard No. 32-8 or 32-11 impregnated by the full-cell vacuum-pressure process with fire-retardant chemicals, and have been qualified by U.B.C. Standard No. 32-7 for use on Class A, B or C roofs. Each bundle of treated wood shakes and shingles shall bear labels identifying their roof covering classification and approved quality control agency.

Fishmouth: Membrane defect consisting of an opening in the edge lap of a felt in a built-up membrane, a consequence of an edge wrinkle; (1) a half-cylindrical or half-conical opening formed by an edge wrinkle; (2) in shingles, a half-conical opening formed at a cut edge. An opening occurring at the lapped edge of applied felts in built-up roofing because of adhesion failure. May be isolated occurrences or in a more or less regular pattern.

Flashing: The system used to seal membrane edges at walls, expansion joints, drains, gravel stops, and other places where the membrane is interrupted or terminated. Base flashing covers the edges of the membrane. Cap flashing or counterflashing shields the upper edges of the base flashing; Connecting devices that seal membrane joints at walls, expansion joints, drains, gravel stops, and other places where the membrane is interrupted. Base flashing forms the upturned edges of the watertight membrane. Cap or counterflashing shields the exposed edges and joints of the base flashing; A building device used to prevent water from penetrating the exterior surface of a building element or material, or to intercept and lead water out of it. Flashing can be considered as a continuation of the roofing membrane to protect and weatherproof any element of the building or roof deck that departs from the roof deck level or incline.

Base Flashing: The extension over a cant strip and up the vertical surface, of the roofing membrane at the base of a vertical wall or item intersecting or penetrating the roof.
**Cap Flashing:** The sheet-metal coping for the top of a higher wall such as a parapet, or the cover over a detail such as expansion joint.

**Counter Flashing:** The material, usually sheet metal, protecting the top edge and covering or partially covering the base flashing. Sometimes also called a cap flashing.

**Eaves Flashing:** The treatment of the edge of a roof with felt and metal flashing. The portion of the metal eaves flashing exposed on the elevation may be called a fascia flashing.

**Gravel Stop:** A formed strip of metal at the edges of a gravel-surfaced roof to prevent the gravel from rolling or washing off. Usually combined with the eaves flashing to add a crisp finished appearance to the roof edge.

**Step Flashing:** Individual pieces of flashing material used to counterflash chimneys, dormers and such projections along steep-sloping roofs. The individual pieces are overlapped and stepped up the vertical surface.

**Through-the-Wall (or Thru-wall) Flashing:** Flashing extending completely through a masonry wall to lead water that penetrates higher up out of the wall at the flashing.

**Flashing Cement:** A trowelable mixture of cutback bitumen and mineral stabilizers and other stabilizers or without asbestos; Trowelable, plastic mixture of bitumen and asbestos (or other inorganic) reinforcing fibers and a solvent (a stiffer, more sag-resistant material than plastic cement).

**Flash point:** Temperature at which a test flame ignites the vapors above a liquid surface.

**Flood Coat:** the top layer of bitumen into which the aggregate is embedded on an aggregate-surfaced built up roof; The top layer of bitumen for an aggregate-surfaced built-up roofing membrane, poured or flooded onto the finished felts and over which the aggregate is spread. Also called a pour coat.

**Fluid Applied:** an elastomeric material, fluid at ambient temperature, that dries or cures after application to form a continuous membrane. Such systems normally do not incorporate reinforcement.

**Flux:** Bituminous material used as a feed stock for further processing and as a material to soften other bituminous materials.

**Gable:** The triangular end of an exterior wall from the level of the eaves to the ridge of a double-sloped roof. A gable roof is a ridged or double-sloped roof which terminates at one or both ends in a gable. A gable end is the end wall of a building with a gable formed by the roof.

**Gambrel:** A type of roof which has its slope broken by an obtuse angle, so that the lower slope is steeper than the upper slope. A double-sloped roof having two inclines on each slope.

**Glass Felt:** Glass fibers bonded into a sheet with resin and suitable for impregnation in the manufacture of bituminous waterproofing materials, roof membranes, and shingles.

**Glass Mat:** A thin mat composed of glass fibers with or without a binder.

**Glaze coat:** (1) The top layer of asphalt in a smooth surfaced built-up roof assembly; (2) a thin protective coating of bitumen applied to the lower plies or top ply of a built up roof membrane when application of additional felts or the flood coat and aggregate surfacing are delayed.; Also refers to the top layer of asphalt in a smooth-surfaced built-up roofing.

**Grain:** Weight unit equal to 1/7000 lb., used in measuring atmospheric moisture content.

**Granule:** See Mineral granules.
**Gravel:** Coarse, granular aggregate resulting from natural erosion or crushing of rock, used as protective surfacing or ballast on roof systems; Mineral particles of a graded size that are embedded in the coating asphalt of shingles and mineral-surfaced roofing; Small pieces of aggregate larger than sand grains resulting from the natural erosion or the crushing of rock used as a protective surfacing or ballast in roofing.

**Gravel Spreader:** A piece of mobile mechanical roofing equipment that dispenses bitumen and spreads gravel in one continuous operation.

**Gravel stop:** The upward projecting edge of an eaves flashing to stop gravel from rolling or being washed off from an aggregate surfaced built-up roofing; Flanged device, usually metallic, with vertical projection above the roof level, designed to prevent loose aggregate from rolling or washing off the roof and to provide a finished edge detail for the roof.

**Gravelling in:** Embedding aggregate surfacing into a built-up bituminous membrane flood coat; The operation of spreading a gravel surfacing over the flood coat of a bituminous built-up roofing.

**Grout:** A fluid cement-mortar mixture used to fill joints and cavities of masonry or concrete building construction. On roof decks the joints between many types of precast roof deck slabs are grouted.

**Gutter:** Trough at the eaves of a roof to convey rain water from the roof to a downspout.

**Header:** The beam into which the common joists are fitted when framing around a roof opening. The headers are placed so as to fit between two long beams or trimmers to support the joists ends.

**Headlap:** The minimum distance, measured at 90 degrees to the eaves along the face of a shingle or felt, from the upper edge of the shingle or felt to the nearest exposed surface.

**Hip:** The sloping line along the outer angle formed by the meeting of two sloping sides of a roof whose eaves meet at a right-angle. A hip roof is one that rises by inclined planes from all four sides of a building to form hips at the intersection of adjacent roof slopes.

**Holiday Area:** The areas where interply bitumen mopping or other fluid-applied coating are discontinuous.

**Hood:** A sheet-metal cover over equipment, stack vents or similar roof details; Sheet metal cover over piping or other rooftop equipment.

**Hot stuff or hot:** Roofer's term for hot bitumen.

**Hygroscopic:** Attracting and absorbing atmospheric moisture.

**Ice dam:** Drainage-obstructive ice formation at eaves of snow-covered sloped roof, a mass of ice formed at the transition from a warm to a cold roof surface, frequently formed by refreezing melt water at the overhang of a steep roof, causing ice and water to back up under roofing materials.

**Incline:** The slope of a roof expressed either in percent or in the number of vertical units of rise per horizontal unit of run; The angle made by a roof plane with a horizontal plane. Interchangeable with slope or fall.

**Inorganic:** Comprising matter other than hydrocarbons and derivatives, not of plant or animal origin.
Insulation: Throughout this research, the word insulation will mean roof insulation. That is thermal insulation and/or waterproofing: A material used as part of a building enclosure to retard the flow of heat through the enclosure. See Thermal insulation.

Interlayment: A layer of felt or nonbituminous saturated felt not less than 18 inches wide, shingled between each course of roof covering.

Interlocking Roofing Tiles: Individual units, typically of clay or concrete, possessing matching ribbed or interlocking vertical side joints that have been designed to restrict lateral movement and water penetration.

Jack: A flanged metal sleeve used as part of the flashing around small items that penetrate a roof.

Job-Average Basis: A technique for determining the average dimensions or quantities of materials, by analysis of roof test cuts. The technique requires a minimum of three test cuts per roof area, plus one cut for each additional 10,000 square feet of roof area. Job-average basis is computed by dividing the sum of all measurements taken by the number of measurements taken. The results would describe the job-average for the quantity or dimension.

Joist: One of a number of the smaller closely-spaced parallel structural supports for a flat roof deck spanning between walls, roof beams or purlins, or to support a flat ceiling below a sloping roof.

Kettle: Equipment used for heating bitumen to the temperatures required for application.

Kettle Temperature: The temperature to which bitumen is heated in the roofing kettle, often considerably higher than that at the point of application.

Kettle Thermometer: A thermometer used for checking the temperature of the heated bitumen in the kettle.

Knot: An imperfection or non-homogeneity in materials used in fabric construction, the presence of which causes surface irregularities.

Lap: Dimension by which a felt covers an underlying felt in a multi-ply built-up bituminous membrane. Edge lap indicates the transverse cover, end lap indicates the cover at the end of the roll. These terms also apply to single-ply membranes; That part of a roofing unit that covers the preceding course in any overlapping roofing application. Applied to shingles, built-up roofing felts, and most other types of roofing.

Edge Lap: The amount of overlap of the edge of a ply of roofing felt over the previous ply. Also called the side lap.

End Lap: The amount of overlap at the start of a roll of felt over the end of the previously laid roll.

Head Lap: In shingle or other overlapped unit roofing the amount that the head of an underlying unit is lapped by the lower edge of the uppermost overlying unit at that location. For double-coverage units the head lap is the unit width minus twice the exposure.

Lap Cement: A cut-back asphalt used for cementing the overlaps of cold-application roll roofing.

Leaching: The dissolving-out of soluble substances when water runs slowly through a roofing system, often responsible for ugly staining on ceilings and walls when the water drains to the interior.

Leader: Drain pipe, downspout or conductor. Also rain water leader abbreviated to RWL.

Leanto: A sloping roof resting against a higher wall of a building.
**Glossary of Roofing/Waterproofing Terms**

**Loose-laid roof system:** Design concept in which insulation boards and membrane are not anchored to the deck but ballasted by loose aggregate or concrete pavers.

**Live Loads:** Moving roof installation equipment, wind, snow, ice or rain.

**Mastic:** Trowellable bituminous paste made by adding mineral fillers to concentrated cutbacks. Also called plastic or flashing cement.

  _Mastic Pan:_ A flanged metal collar incorporated into a built-up roofing membrane around a penetrating item through the roof and filled with mastic.

**Mastic Asphalt:** An in situ hot applied material providing a durable surface usually 20 mm thick [50].

**Mansard:** A roof which rises by inclined planes from all four sides of a rectangular building. Each sloping roof has two inclines, the lower one usually very steep and the upper one almost flat.

**Membrane:** A flexible or semi-flexible roof covering or waterproofing layer, whose primary function is the exclusion of water; It is usually built-up on site from single or multiple ply of material, e.g. polyvinyl chloride roofing in single-ply and bituminous-felt roofing in multiple ply.

**Membrane Migration:** Progressive movement of roofing membranes in one or in both directions that can occur on roofs due to thermal shrinkage. It can move improperly-adhered insulation and tear flashing at roof edges.

**Metal Flashing:** (See Flashing.) Metal flashing is frequently used as through-wall flashing, cap flashing, counterflashing or gravel stops.

**Metal Roofing:** Metal shingle or sheets for application on solid roof surfaces, and corrugated or otherwise shaped metal sheets or sections for application on roof frameworks or on solid roof surfaces.

**Mill Deck:** A type of wood roof-deck constructed from wood planks placed on edge vertically and spiked or nailed together.

**Mineral Fiber Felt:** a felt with mineral wood as its principal component.

**Mineral Granules:** Natural or synthetic aggregate particles, ranging in size from 500 micrometer (1 micrometer = \(10^{-6}\) m) to 1/4-in. diameter, used to surface cap sheets asphalt shingles, and some cold-process membranes; opaque, natural, or synthetically colored aggregate commonly used to surface cap sheets, granule-surfaced sheets, and roofing shingles.

**Mineral Stabilizer:** a fine, water-insoluble inorganic material, used in a mixture with solid or semi-solid bituminous materials.

**Mineral-Surfaced Roofing:** built-up roofing materials whose top ply consists of a granule-surfaced sheet.

**Mineral-Surfaced Sheet:** Asphalt-saturated felt, coated on one or both sides and surfaced on the weather-exposed side with mineral granules.

**Mini Mopper:** A small container with wheels that can be pushed along over the roof to dispense bitumen for the laying of roofing felts.

**Modified Bitumen:** Composite sheets consisting of a copolymer modified bitumen often reinforced and sometimes surfaced with various types of films, foils and mats.
**Modified Bitumen Membrane Roof Covering:** One or more layers of polymer modified asphalt sheet membranes complying with U.B.C. Standard No. 32-13. The sheet materials may be fully adhered or mechanically attached to the substrate or held in place with an appropriate ballast layer.

**Mole Run:** Meandering ridge in a roof membrane not associated with insulation or deck joints.

**Monomer:** Class of molecules with molecular weight ranging roughly between 30 and 250, capable of combining into huge, polymeric macromolecules, 100 to 10,000 times as large as the basic monomeric molecules, through chain like repetition of the basic monomeric chemical structure.

**Mop:** A tool used for the application of hot bitumen made from a bundle of cotton or other yarn attached to a long wooden handle. Bitumen soaked up and held by it when dipped into a container of hot material is transferred to and spread on the roof.

**Mop-and-Flop:** Application technique in which roof-system components (insulation boards, felt plies, cap sheets, and so on) are first placed upside down adjacent to their final locations, coated with adhesive, turned over and adhered to the substrate.

**Mopping:** Application of hot, fluid bitumen to substrate or to plies of built-up membrane with a manually wielded mop or a mechanical applicator; The fact of spreading hot bitumen with a mop; Also may refer to a layer of hot bitumen mopped between plies or over roofing felts.

- **Full Mopping:** Application to provide a continuous reasonably-uniform layer of bitumen over the entire surface being mopped. Also called solid mopping.
- **Solid mopping:** A continuous coating.
- **Spot mopping:** Pattern of hot bitumen application in roughly circular areas, generally about 18-in. diameter, on a grid of unmopped, perpendicular bands on the roof; Application of bitumen in roughly circular spots (400 mm to 500 mm in diameter) in a uniform pattern providing unmopped strips in a grid pattern or between staggered spots.
- **Sprinkle mopping:** Application by haphazardly sprinkling or dribbling of small amounts of bitumen onto a surface with a mop or broom. Also called drip or dribble mopping. Random pattern of bitumen beads hurled onto the substrate from a broom or mop.
- **Strip mopping:** Mopping pattern featuring parallel mopped bands; Application of bitumen in parallel bands roughly 200 mm wide with 100 mm unmopped bands between. Also called channel or ribbon mopping.

**Nailer:** Nailier: A member, usually of wood, set into or secured to nonnailable roof decks or walls to allow for positive anchorage by nailing of roofing felts, insulation or flashing. Also called nailing strips.

**Nailing:** Fastening of roofing materials by nails or other hammer-driven special fasteners.

- **Back Nailing:** The practice on sloping roofs of blind nailing overlapping roofing felts to a nailable substrate or to specially provided nailing strips in addition to adhering all the plies with bitumen to prevent slippage.
- **Blind Nailing:** Application of roofing in such a manner as to cover all nail heads by over-lapping material.
- **Concealed Nailing:** Same as blind nailing.
- **Exposed Nailing:** Application where the nail heads are exposed to the weather.

**Neoprene:** Synthetic rubber (chemically polychloroprene) used in fluid- or sheet-applied elastomeric single-ply membranes or flashing.
Nineteen-Inch Selvage: a prepared roofing sheet with a 17-inch granule surfaced exposure and a nongranule surfaced 19-inch selvage edge. This material is sometimes referred to as SIS or as Wide Selvage Asphalt Roll Roofing Material Surface with Mineral Granules.

Ninety-Pound: a prepared organic felt roll roofing with a granule surfaced exposure that has a mass of approximately 90 pounds per 100 square feet.

One-on-one: Nonshingled application pattern of a single ply of felt followed later by application of a second ply (see Phased application).

Organic: Comprising hydrocarbons or their derivatives, or matter of plant or animal origin; being or composed of hydrocarbons or their derivatives, or matter of plant or animal origin.

Overhang: The part of a roof structure that extends beyond the exterior walls of a building.

Overheating: The heating of bitumen for application of roofing to a temperature that permanently alters the characteristics of the material.

Parapet Wall: A low wall along the edge of and surrounding a roof deck. It is generally an extension of exterior building walls or party and fire walls that usually extend about a meters or less above the roof; that part of any wall entirely above the roof.

Parting agent: Powdered mineral (talc, mica, and so forth) placed on coated felts to prevent adhesion of concentric felt layers in the roll (sometimes called a releasing agent or anti stick compound); Fine sand, mica, talc or similar material spread over the surface of coated bituminous felt to prevent sticking in the roll.

Penetration: A measure of the hardness related to viscosity of bitumen as determined by an empirical test that gives the depth of penetration of a weighted needle into a sample after a definite time and at a particular temperature.

Penetration Point: The vertical distance that a specific nail can penetrate through inside a specimen under special test conditions. For example, if the nail penetrates a distance of 6-7 mm inside the specimen in 5 second at 25°C, the penetration point of asphalt is 60-70 [25].

Perlite: Aggregate used in lightweight insulating concrete and preformed insulating board, formed by heating and expanding siliceous volcanic glass.

Perm: A unit indicating the degree of permeability of a porous reservoir structure; Perm = (bl*ft*cp)/(day*ft*psi) or (ft³*ft*cp)/(day*ft²*psi), a unit of water vapor transmission defined as 1 grain of water vapor per square foot per hour per inch of mercury pressure difference (1 inch of mercury = 0.491 psi). The formula for perm is:

\[ P = \text{GRAINS OF WATER VAPOR/SQUARE FOOT \cdot HOUR \cdot INCH MERCURY} \]

Permeance: The rate of water vapor transmission per unit area at a steady state through a membrane or assembly. Index of a material's resistance to water-vapor transmission. (See Perm.)

Permeability: The ability of a material to permit a substance to pass through it.

Phased application: Installation of a roof system or water proofing system during two or more separate time intervals. Applying the felt plies of a built-up roof or waterproofing membrane in two or more operations, separated by a delay normally of at least 1 day.
Picture framing: Rectangular membrane ridging pattern formed over insulation-board joints.

Pitch: A black or dark brown solid cementitious residue that results from the distillation of tar. A tar derived from coal is referred to as coal tar, and a pitch derived from coal tar as coal tar pitch. **Roofers' Pitch:** Coal tar pitch.

Pitch Pocket: A flanged, open-bottomed, metal container placed around columns or other roof penetrations that is filled with hot bitumen or flashing cement to seal the joint. The use of pitch pockets is not recommended by NRCA.; A flanged metal collar placed over penetrating items on roofing and filled with coal tar pitch. Plastic or mastic pans also sometimes called pitch pockets.

Pimpling: See blisters, surface.

Plank Deck: Wood deck of planks usually 40 mm to 90 mm thick and 150 mm to 200 mm wide laid on the flat with tongue-and-grooved or splined edges, and spiked together.

Plaza: A roof terrace.

Plastic cement: Trowelable, plastic mixture of bitumen and asbestos (or other inorganic) stabilizing fibers and a solvent, used mainly for horizontal surfaces as opposed to flashing cement, which is designed for vertical surfaces requiring sag resistance.

Plasticizer: High-boiling-point solvent or softening agent added to a polymer to facilitate processing or increase flexibility or toughness in the manufactured material.

Plastomeric: a plastic like polymer consisting of any of various complex organic compounds produced by polymerization which are capable of being molded, extruded or cast into various shapes or films. Generally they are thermo plastic in nature, i.e., they will soften when heated and harden when cooled.

Ply: Layer of felt in a built-up roof membrane; a four-ply membrane has at least four plies of felt at any vertical cross section cut through the membrane; A single layer or thickness of roofing material in a roofing membrane.

Podium: A roof terrace.

Polymer: Long, chain macromolecules produced from monomers, for the purpose of increasing tensile strength of sheets used as membranes or flashing.

Polymer Modified Bituminous Roofing: A prefabricated reinforced sheet that is formulated with polymer modified bitumen and is processed on a polyester or fiberglass, polyethylene film, or a combination thereof. The asphalt is generally modified with atactic poly-propylene, synthetic rubber, and other agents which enhance the asphalt's properties.

Polyvinyl chloride (PVC): Thermoplastic polymer, formulated with a Plasticizer, used as a single-ply sheet membrane material or liquid coating.

Pond: Roof surface that is incompletely drained.

Ponding: The collection of water in shallow pools on the top surface of roofing. This is generally from rain, but certain roofs are designed to hold a shallow depth of water over the whole roof surface for evaporative cooling in summer often with a water supply to the roof.
Glossary of Roofing/Waterproofing Terms

Positive Drainage: Drainage condition in which consideration has been made for all loading deflections of the deck, and additional roof slope has been provided to ensure drainage of the roof area within 48 hours of rainfall.

Pour: Layer of bitumen deposited on the roof surface or the felts by pouring from a bitumen container.
  Double Pour: The application of the top layer of bitumen and the gravel-surfacing of a built-up roofing in two separate operations. This is accomplished by spreading gravel into a first pour coat, brooming off the loose gravel, and then applying additional gravel to a second pour coat.
  Pour Coat: Same as pour.
  Top Pour: The application by pouring of the top layer of bitumen on a built-up roofing. Often used to describe the top layer of bitumen no matter how applied.

Primer: Thin, liquid, bituminous solvent applied to seal a surface, absorb dust, and promote adhesion of subsequently applied bitumen.; A thin solution of a coating applied to a surface to improve the adhesion of a heavier coating. Usually refers to a cutback bituminous coating of thin consistency.

Promenade: A roof terrace.

Protected Membrane Roof (PMR): Roof assembly with insulation on top of the membrane instead of vice versa, as in the conventional roof assembly (also known as an inverted or upside-down roof assembly); A roofing membrane with insulation and protective surfacing or landscaping outward from it.

Purlin: Horizontal structural member spanning between beams, frames or trusses to support a roof deck or the rafters or joists supporting a roof deck.

Re-covering: Covering an existing roof assembly with a new membrane instead of removing the existing roof system before installing the new membrane.

Re-entrant Corner: Inside corner of a surface, producing stress concentrations in the roofing or waterproofing membrane.

Rafter: One of a number of closely spaced structural members of a sloped roof, usually extending from the eaves to a ridge or hip on a small roof or between purlins on larger roofs to carry the roof deck.

Rake: Edge of a roof at its intersection with a gable; the slope edge of a roof at the first or last rafter.

Reglet: Horizontal groove in a wall or other vertical surface adjoining a roof surface for anchoring flashing; A horizontal groove or slot in a wall or other vertical surface projecting above a roof surface into which flashing can be secured and sealed.

Reinforced Membrane: Roofing or waterproofing membrane reinforced with felts, mats, fabrics or chopped fibers.

Relative Humidity (RH): Ratio (expressed as percentage) of the mass per unit volume (or partial pressure) of water vapor in an air-vapor mixture to the saturated mass per unit volume (or partial pressure) of the water vapor at the same temperature; the ratio of the weight of moisture in a given volume of air-vapor mixture to the saturated (maximum) weight of water vapor at the same temperature, expressed as a percentage. For example, if the weight of the moist air is 1 pound and if the air could hold 2 pounds of water vapor at a given temperature, the relative humidity (RH) is 50 percent; A ratio expressed as a percentage of the mass of water vapor present in an air vapor mixture and the mass of
water vapor that would be present in the sample of air if it were saturated at the same temperature. It can be stated also as a good approximation that it is the ratio of the vapor pressure of water present in a sample of air to the saturation vapor pressure at the same temperature.

Rep: Unit of vapor permeance resistance; reciprocal of perm.

Replacement: The practice of removing an existing roof system and replacing it with a new roofing system.

Reroofing: Removing and replacing an existing roof system (as opposed to mere Re-covering); also called tear off-replacement; the process of re-covering or replacing an existing roofing system. (See Re-covering and Replacement.).

Resin: Basic raw material for manufacturing polymers, a synthetic polymer containing no deliberately added ingredients.

Ridge: The horizontal line where two opposite sloping sides of a roof join at the highest level of the roof.

Ridge Board: A horizontal board in wood frame construction at the upper end of the common rafters to which the rafters are nailed.

Ridge Cap: The covering of wood, metal or other roofing material that tops the ridge of a roof.

Ridge Course: The last or top course of roll roofing, shingles or tiles on a sloping roof cut to length as required.

Ridging: Membrane defect characterized by upward displacement of the membrane, usually over insulation-board joints (see Picture framing); An upward, tenting displacement of a roof membrane frequently occurring over insulation joints, deck joints and base sheet edges.; A roofing defect characterized by narrow or relatively narrow ripples in a membrane generally along the machine direction for roofing felts and over deck or insulation joints and usually less than 25 mm in height.

Roll roofing: Coated felts, generally mineral-surfaced, supplied in rolls and designed for use without field-applied surfacing; Smooth-surfaced or mineral-surfaced coated felts.

Roof: Construction on top of a building that together with walls forms a separator between inside and outside environments. A roof system is a structurally supported, air, heat, interior moisture and rain control combination.

Dead Flat Roof: No intentional slope.

Extra Steep Roof: Slope over 1:1 (45°).

Flat Roof: Slope from 1:50 to 1:6 (1° to 10°).

Steep Roof: Slope from 1:5 to 1:1 (10° to 45°).

Roof Coating: A thin layer of filled bitumen applied to saturated felt. Filled or unfilled bitumen cutback, asphalt emulsion, or a compatible paint applied in a thin layer to provide a protective cover for roofing materials.

Roof-Deck: The structural infill between structural supports which forms the load carrying base for the rest of the roofing system.

Roof Divider: A building detail used to limit the size of a continuous roof membrane, dividing a roof into a number of smaller areas. The divider extends only to the roof deck and is not an expansion joint.

Roof Drain: The termination or fitting at the roof of an interior drain pipe or leader for draining water from a roof.

Roof Guard: A contrivance fitted to a steep sloping roof to prevent the sliding of snow or ice.

Roof Insulation: Any medium or low-density material suitable and used as part of a roofing system to reduce heat loss or gain through the roof.
Roof Terminal: The upper end of a vent stack above a roof. Drains also sometimes called terminals.

Roof Terrace: A traffic-bearing or landscaped roof. Also called promenade, podium or plaza-deck roofs or roof gardens.

Roof Assembly: Assembly of interacting roof components (including the roof deck) designed to weatherproof and, normally, to insulate a building's top surface.

Roof-Covering Classification: The classification assigned to a roof covering or roof-covering assembly by Section 3204 or the classification of a covering established by testing in accordance with U.B.C. Standard No. 32-7.

Roofing: (1). The material used for constructing a water-shedding or waterproofed roof. (2). That part of the architectural specifications and building construction contract that deals with the supply and application of roofing materials and systems.

Built-Up Roofing: A continuous, semi-flexible roof covering built-up on site from alternate layers of bitumen and bitumen-saturated or coated felts often abbreviated to BUR.

Composition Roofing: All types of asphalt rolled roofing and shingles.

Mineral-Surfaced Roofing: Roofing that is coated on both sides with asphalt and finished on the weather side with natural or synthetic colored mineral granules, usually for only part of the width of the felt.

Prepared Roofing: Same as composition.

Roll Roofing: Any roofing material which is supplied from the manufacturers in rolls, but more specifically applied to coated felts either smooth or mineral-surfaced used for roofing without additional top coatings or surfacings.

Smooth-Surface Roofing: Roofing felt that is asphalt-coated on both sides with either a smooth or veined surface. Built-up roofing that may have an applied coating but which has no protective surfacing of gravel or other aggregate.

Wide-Selvage Roofing: Mineral-surfaced roofing designed for double coverage in which the selvage is slightly greater than half the width of the felt.

Roofing Ply: A layer of felt in a built-up roofing membrane.

Roofing Square: 100 square feet of roofing surface.

Roofing Tiles: Units, typically clay or concrete, which comply with U.B.C. Standard No. 32-12.

Roof Assembly: Roof assembly is the group of components that are put to protect the roof. This exclude the main concrete pouring which is put first. It includes all other materials which are put above the main concrete; Assembly of interacting components (not including the roof deck) designed to weatherproof, and normally insulate, a building's top surface.

Run: The horizontal distance to which the fall or vertical distance for an inclined roof is referenced. A unit horizontal distance of one meters is taken for the run to which the fall in millimeters is given to describe the incline.

Saddle: a small structure that helps channel surface water to drains, frequently located in a valley, and often constructed like a small hip roof or like a pyramid with a diamond shape base. (See Cricket.); A ridge in a roof deck that divides two sloping parts of the surface so that water will be diverted to roof
drains. Usually constructed in a level valley, or behind a projection above a sloping roof. Also called a cricket.

**Saturant:** A bitumen of low softening point for impregnating the dry felts in the manufacture of saturated roofing felts.

**Saturated Felt:** Felt that has been immersed in hot bitumen; a felt that has been partially saturated with low softening point bitumen.

**Saw Tooth:** A roof formed by a number of north light trusses. When viewed from the end of the building such a roof presents a serrated or toothed profile.

**Scraper:** A tool or a piece of equipment for removing aggregate surfacing from built-up roofing for repair or re-roofing. Also called a spud or spudder.

**Screed:** Lightweight fill placed on the surface of a roof deck to create slopes to roof drains. Also the guide used to achieve the sloped fill.

**Screen:** An apparatus with circular apertures for separating sizes of materials.

**Scupper:** Channel through parapet, designed for peripheral drainage of the roof, usually as safety overflow system to limit accumulation of ponded rain water caused by clogged drains; An outlet in the wall of a building or a parapet wall for drainage of overflow water from a floor or roof directly to the outside. Special scupper drains connected to internal drains are also sometimes installed at roof and wall junctions.

**Scuttle:** Curbed opening, with hinged or loose cover, providing access to roof [synonymous with hatch]; a hatch that provides access to the roof from the interior of the building.; A small opening provided with a waterproof cover through the ceiling and roof to provide access to the roof from the interior. The scuttle may have its own curb, or may be placed on a built-up curb. Also called a roof hatch.

**Seal:** (1) A substance used to close a crack or other aperture against air or water leakage. (2). Narrow strips of bituminous material used to fill or cover such apertures; (3) To secure a roof from the entry of moisture.

**Sealant:** A mixture of polymers, fillers, and pigments used to fill and seal joints where moderate movement is expected; it cures to a resilient solid.

**Self-Healing:** Property of the least viscous roofing bitumens, notably coal tar pitch, that enables them to seal cracks formed at lower temperatures; Used in reference to bitumen that softens with heat from the sun and flows to seal cracks that earlier formed in the bitumen from other causes.

**Selvage:** Edge or edging that differs from the main part of (1) a fabric, or (2) granule-surfaced roll roofing material; The portion of mineral-surfaced roofing where the mineral surfacing is omitted to allow for the overlapping sheet to achieve better adhesion. For double-coverage application the selvage width is half the width of the roll plus about 25 mm and for single-coverage the roll width less 50 mm.

**Selvage Joint:** Lapped joint detail for two-ply, shingled roll roofing membrane, with mineral surfacing omitted over a transverse dimension of the cap sheets to improve mopping adhesion. For a 36-in.-wide sheet, the selvage (un-surfaced) width is 19 in; a lapped joint designed for mineral-surfaced cap sheets. The mineral surfacing is omitted over a small portion of the longitudinal edge of the sheet below in order to obtain better adhesion of the lapped cap sheet surface with the bituminous adhesive.
Shark Fin: Curled felt projecting up through the aggregate surfacing of a built-up membrane; an upward-curved felt side lap or end lap.

Sheathing: Board or sheet-type material fixed to studding or roof rafters or joists as the base for application of wall cladding or roof covering.

Sheathing Paper: A medium-to heavyweight wood-fiber paper or felt often fastened to sheathing as the base for the application of exterior covering materials.

Shed: A roof having only one incline that slopes from a higher to a lower wall. A leanto roof is sometimes also called a shed roof.

Shedding: The loss of mineral surfacing from prepared roofing.

Sheet: An unrolled piece of roofing felt.

Shingle: (1) A small unit of prepared roofing material designed for installation with similar units in overlapping rows on inclines normally exceeding 25 percent; (2) to cover with shingles; (3) to apply any sheet material in overlapping rows like shingles.

Shingling (1) the procedure of laying parallel felts, so that one longitudinal edge of each felt overlaps and the other longitudinal edge underlaps, and adjacent felt. (See Ply.) Normally, felts are shingled on a slope so that the water flows over rather than against each lap; (2) the application of shingles to a sloped roof. Pattern formed by laying parallel felt rolls with lapped joints so that one longitudinal edge overlaps the longitudinal edge of one adjacent felt, whereas the other longitudinal edge underlaps the other adjacent felt. (See Ply.) Shingling is the normal method of applying felts in a built-up roofing membrane; The application of any roofing material by overlapping of units in horizontal courses with the overlapping down the slope to shed water. The usual method of laying roofing felts in built-up roofing with overlapping sufficient to produce the number of plies desired.

Sieve: An apparatus with apertures for separating sizes of material.

Single-Ply Membrane: Membrane, either sheet- or fluid-applied, with only a single layer of material, designed to prevent water intrusion into the building.

Skater's Cracks: Curved cracks observed in smooth-surfaced built-up membranes.

Slag: Porous aggregate used as built-up bituminous membrane surfacing, comprising silicates and alumino-silicates of calcium and other bases, developed with iron in a blast furnace; a hard, air-cooled aggregate that is left as a residue from blast furnaces, used as a surfacing aggregate; A gray porous aggregate produced by air cooling and crushing residue from blast furnaces, used as a protective surfacing for built-up roofing.

Slippage: Relative lateral movement of adjacent felt plies in a built-up membrane. Occurs mainly in sloped roofing membranes, exposing the lower plies, or even the base sheet, to the weather; Sliding movement usually down a slope between adjacent plies of felt along the bitumen film separating them. It can also take place between gravel surfacing and roofing, between roofing membrane and the insulation, or between the insulation and the roof through a roofing membrane to deck.

Slip Sheet: Sheet material placed between two layers of a roofing system to assure that there is no adhesion between them.
Slope: The incline of a roof surface in degrees, as a slope ratio of fall to run, or as a percentage of fall to run. Tangent of the angle between the roof surface and the horizontal, in inches per foot. The Asphalt Roofing Manufacturers' Association ranks slopes as follows:

Level: 1/2-in. maximum
Low slope: over 1/2 in. up to 1 1/2 in.
Steep slope: over 1 1/2 in.

Smooth-Surfaced Roof: A built-up roof membrane surfaced with a layer of hot-mopped asphalt, cold-applied asphalt-clay emulsion, cold-applied asphalt cutbacks, elastomeric coating or sometimes with an unmopped inorganic felt.

Soffit: The underside of any subordinate member of a building. For roofs the underside of a roof overhang.

Softening Point: The heat that asphalt needs so that it becomes soft under special test condition [25]. Temperature at which bitumen becomes soft enough to flow, as measured by standard laboratory test in which a steel ball falls through a measured distance through a disk made of the tested bitumen.

Softening-Point Drift: Change in softening point during storage or application. (See also Fallback.)

Split: Membrane tear resulting from tensile stress.

Splitting: A tear extending through the BUR membrane; The formation of long cracks usually completely through a built-up roofing membrane representing a tension failure of the membrane.

Spot Cementing: Discontinuous application of asphalt, cold liquid asphalt compound, coal tar pitch or other approved cementing material.

Spray Pond: Intentional ponded water on a roof with a system of piping and jets to spray water above the roof to achieve good evaporative cooling.

Spudding: The process of removing the roofing aggregate and most of the bituminous top coating by scraping and chipping.

Spudder: Heavy steel implement with a dull, bevel-edged blade designed to remove embedded aggregate from a built-up membrane surface (also called scraper).

Square: The term used to describe 100 square feet of roof area.

Stack: A vertical vent pipe penetrating above a roof such as that used to provide an escape for foul gases from plumbing fixtures.

Stack Effect: Air flow into a building at the lower levels and out at the higher levels caused by the pressure difference that exists because of the temperature differences of the air masses inside and outside of buildings similar to the phenomenon that produces draft in a chimney.

Stack Vent: A vertical outlet in a built-up roof system designed to relieve the pressure exerted by moisture vapor between the roof membrane and the vapor retarder or deck.

Stack Venting: The practice of providing small vertical pipe outlets
Strawberry: A small bubble or blister in the flood coating of a gravel-surfaced roof membrane.

Strainer: A wire, plastic or cast-metal cage placed over the top of a roof drain to prevent debris and leaves on the roof from entering the drain.

Stripping: (1) Technique of sealing the joint between base flashing and membrane plies or between metal and built-up membrane with one or two plies of felt or fabric and hot- or cold-applied bitumen. (2) Taping joints between insulation boards or deck units; (3) Narrow widths of felt used to complete flashing details, particularly to cover the edges of metal flanges.

Substrate: Surface (structural deck, insulation, or vapor retarder) upon which the roof membrane is placed. Also, the deck, vapor retarder, or membrane surface upon which insulation, or other roof system component, is placed.

Sump: Depression in roof deck around drain.

System: An assembly of interacting components. A roof system is designed to weatherproof and normally also to insulate the top of a building.

Tanker: A tank truck specially designed with heating and pumping equipment for conveying and dispensing liquid bitumen.

Tapered Edge Strip: A tapered insulation strip used to (1) elevate the roof at the perimeter and at curbs that extend through a roof; (2) provide a gradual transition from one layer of insulation to another.

Tar: A brown or black bituminous material, liquid or semi-solid in consistency, in which the predominating constituents are bitumens obtained as condensates in the processing of coal, petroleum, oil-shale, wood, or other organic materials. Black or dark brown liquid or semi-liquid condensates derived from the heating or baking, sometimes called destructive distillation, of wood, peat, oil shale, bone, petroleum, coal or other organic materials. The word is incorrectly used to describe coal tar pitch as in the expression "tar-and-gravel roofing".

Tearoff: Removing a failed roof system down to the structural deck.

Test Cut: A sample of the roof membrane that is cut from a roof membrane to: (a) determine the approximate quantities of components; (b) diagnose the condition of the existing membrane (e.g., to detect leaks or blisters).

Thermal: Relating to heat.

Thermal Bridge: A heat-conductive element in a roof or wall that extends from the warm to the cold side and provides less heat-flow resistance than the adjacent construction. May be of considerable consequences when it passes through the insulation of a well-insulated wall or roof.

Thermal Conductance (C): A unit of heat flow and a measure of the heat-insulating efficiency of a material or component of a particular thickness. The symbol "C" and units W/(m² °C) are used; Heat energy in Btu per hour (Btuh) transferred via conductance only through a 1 ft² area of homogeneous material per °F temperature difference from surface to surface. The unit is (Btuh/ft²-°F) [in metric terms, W/m² K]; a unit of heat flow that is used for specific thicknesses of material or for materials of combination construction, such as laminated insulation. The formula for thermal conductance is:

\[ C = k / \text{THICKNESS IN INCHES} \]
Thermal Conductivity (k): The heat flow across a surface per unit area per unit time divided by the negative of the rate of change of temperature with distance in a direction perpendicular to the surface. The heat energy that will be transmitted by conduction through 1 square foot of 1-inch thick homogeneous material in one hour when there is a difference of 1 degree Fahrenheit perpendicularly across the two surfaces of the material. The formula for thermal conductivity is: $k = \frac{\text{Btu}/\text{SQUARE FOOT} \times \text{INCH}}{\text{HOUR} \times \text{DEGREE FAHRENHEIT}}$. Heat energy (Btu/h) transferred via conductance only through a 1-in$^\times$-thicks 1-ft$^2$ area of homogeneous material per °F temperature difference from surface to surface. Unit for k is Btu/(in. $\times$ ft$^2$ $\times$ °F); The basic unit of heat flow, being the amount of heat energy conducted through a unit area of unit thickness in unit time with unit temperature difference between the faces. Expressed in watts (Joules per second) per square meters per meters thickness per degree Celsius temperature difference. The symbol is a small "k" referred to as k-value or k-factor and the units reduce to $W/(m^2 \cdot ^\circ C)$. $C = k/n$ where n is thickness in meters.

Thermal Insulation: A material applied to reduce the flow of heat.

Thermal Resistance ($R = 1/C$): Material's resistance to conductive heat flow, in $^\circ F/(\text{Btu} \times \text{ft}^2)$—that is, for a 5°F temperature difference surface to surface, 1 Btu would flow through a 1 ft$^2$ specimen with $R = 5$, an index of a material's resistance to heat flow; it is the reciprocal of thermal conductivity ($k$) or thermal conductance ($C$). The formula for thermal resistance is: $R = 1/C$ or $R = 1/k$ or $R = \text{THICKNESS IN INCHES}/k$; A measure of the resistance to heat flow of a material or component of construction of a particular thickness. The symbol "$R$" is used but is also used for the total resistance of a number of components of materials combined in a roof system. $R = 1/C$ for a particular material and the units are square meters degree Celsius per watt (m2$^\circ$C)/W.

Thermal Resistivity: The basic property of a material's resistance to heat flow through a unit area of unit thickness for unit temperature difference between the faces. It is $1/k$ and the units are meters degree Celsius per watt (m$^2$$^\circ$C)/W.

Thermal Shock: Stress-producing phenomenon resulting from sudden temperature change in a roof membrane when, for example, a rain shower follows brilliant, hot sunshine; A stress-producing phenomenon thought to result from sudden temperature changes to a roof membrane that takes place with rapid weather changes.

Thermal Shock Factor (TSF): Mathematical expression for calculating the theoretical temperature drop required to split a rigidly held membrane test sample under tensile contractive stress.

Thermal Transmittance: A measure of the heat conducted through a unit of a roof system (or other building element) in unit time with unit temperature difference between inside and outside. Also called the coefficient of heat transfer or "U" value for the roof. It is the time rate of heat flow under assumed steady-state conditions that enables one to calculate the heat loss and temperature conditions at any point in a roof system for some particular conditions. Its units are watts per square meters degree Celsius $W/(m^2 \cdot ^\circ C)$. It is the reciprocal of the total resistance for the system obtained by adding all the individual resistances of the components of the system including surface and air space resistances. $U = 1/R$ (total)

Tin Caps: Small flat metal discs used with nails for securing roofing felts to nailable decks.

Thermoplastic: Changing viscosity under thermal cycling (fluid when heated, solid when cooled).

Thermoplastic Membrane Roof Covering: A sheet membrane composed of polymers and other proprietary ingredients, in compliance with U.B.C. Standard No. 32-13, whose chemical composition allows the sheet to be welded together by either heat or solvent throughout its service life.
Thermoset Membrane Roof Covering: A sheet membrane composed of polymers and other proprietary ingredients, in compliance with U.B.C. Standard No. 32-13, whose chemical composition vulcanizes or crosslinks during manufacture or during its service life.

Thermosetting: Hardening permanently when heated, owing to cross-linking of Polymeric resins into a rigid matrix.

Through-Wall Flashing: Water-resistant membrane or material assembly extending through a wall's horizontal cross section and designed to direct water flow through the wall toward the exterior.

Trimmer: The beam or roof joist into which a header is framed in the formation of a roof opening.

Truss: A combination of members such as beams, bars and ties, usually arranged in triangular units, to form a rigid framework for supporting loads over relatively long spans as in wide span roof construction.

Truncated: A hip type of roof terminating in a flat roof.

Tuck Pointing: (1) Troweling mortar into a joint after masonry units are laid; (2) Final treatment of joints in cut stonework. Mortar or a putty-like filler is forced into the joint after the stone is set.

Underlay: A material, usually felt, used in covering a roof deck before the roofing materials are supplied.

Underlayment: One or more layers of felt, sheathing paper, nonbituminous saturated felt, or other approved material over which a roofing system is applied.

Underwriters Laboratories (UL): An organization that classifies roof assemblies for their fire characteristics and wind uplift resistance.

Valley: (1). The horizontal line formed along the depressed angle at the bottom of two inclined roof surfaces. (2). The sloping line of the depressed interior angle formed by two inclined roofs whose eaves meet at right angles.

Vapor: A substance in gaseous state. In relation to building it generally refers to water vapor.

Vapor Barrier: A material, usually in sheet form, used to retard the passage of water vapor into a wall or roof.

Vapor Migration: The movement of water molecules from a region of high to one of lower vapor pressure through the walls and roofs of buildings; Flow of water vapor from a region of high vapor pressure to a region of lower vapor pressure.

Vapor Permeability: The rate at which water vapor will diffuse or permeate through a unit area in unit time with unit vapor pressure difference across a unit thickness of a material. The units are nanograms per square meters per meters of thickness per second of time per pascal of pressure difference.

Vapor Permeance: The rate at which water vapor will diffuse through a material of a particular thickness. The symbol is M and the units nanograms per square meters per second per pascal vapor pressure difference.

Vapor Resistance: A measure of the resistance to water-vapour flow. Vapor resistance is the reciprocal of permeance = 1/M and the units are written (Pa*s*m²)/μg.
Vapor Retarder: Roof component designed to obstruct water vapor flow through a roof or wall; it is a layer of material or a laminate used to appreciably reduce the flow of water vapor into the roofing system; a material designed to restrict the passage of water vapor into the roofing system.

Vent: Opening designed to convey water vapor, or other gas, from inside a building or building component to the atmosphere.

Vermiculite: Aggregate used in lightweight insulating concrete, formed by heating and consequent expansion of mica rock.

Viscoelastic: Characterized by changing mechanical behavior, from nearly elastic at low temperature to plastic, like a viscous fluid, at high temperature.

Viscosity: Index of a fluid's internal resistance to flow, measured in centistokes (cSt) for bitumens. (Water has a viscosity of roughly 1 cSt; light cooking oil 100 cSt); the internal resistance offered by a fluid to change of shape or to relative motion or flow of its parts. The flow characteristics of bitumen measured in centistokes. Asphalt may vary from 30 to 500 centistokes when heated from 175°C to 260°C depending on the asphalt type.

Walking In: Manually forcing insulation boards against previously installed boards to lighten the joints.

Waterproofing: Waterproofing can be used in many applications. Though it will be understood from the context, in most cases waterproofing will mean roofing membrane; treatment of a surface or structure to prevent the passage of water under hydrostatic pressure; a material used to treat or cover a building element or component to prevent permeation of water. The act of making something impervious to water.

Wood Shakes: Tapered or nontapered pieces of approved durable wood of random widths ranging from 4 inches to 14 inches and of the following four types:
(a) Hand split and resawn: Tapered with one sawn and one split face; semisplit: tapered with partially sawn and split faces both sides, 15 inches, 18 inches or 24 inches in length.
(b) Taper split: Tapered with both split faces, 24 inches in length.
(c) Straight split: Nontapered with both split faces, either 18 inches or 24 inches in length.
(d) Tapersawn: Sawn both sides, edges sawn or split. Lengths 24 inches and longer.

Wood Shakes (treated): Taper-sawn pieces of southern pine, black gum/ sweetgum wood treated in accordance with U.B.C. Standard No. 25-12 of random widths ranging from 4 to 8 inches and lengths of 18 inches or 24 inches. Maximum weather exposure as shown in Table No. 32-C, Wood Shakes.

Wood Shingles: Tapered pieces of approved durable wood, sawed both sides, of random widths ranging from 3 inches to 14 inches and in lengths of 16 inches, 18 inches or 24 inches.

Wrinkling: Small ridges formed at the surface of roofing membranes similar to ridging. See Ridging

Wythe: A masonry wall, one masonry unit, a minimum of two inches thick.
Standard Terminology Relating to Roofing, Waterproofing, and Bituminous Materials

This standard is issued under the fixed designation D 1079; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

aggregate—(1) crushed stone, crushed slag, or water-worn gravel used for surfacing a built-up roof;
(2) any granular mineral material.
alligatoring—the cracking of the surfacing bitumen on a built-up roof, producing a pattern of cracks similar to an alligator's hide; the cracks may not extend through the surfacing bitumen.
ionic emulsion—an emulsion in which the emulsifying system establishes a predominance of negative charges on the discontinuous phase.
application rate—the quantity (mass, volume or thickness) of material applied per unit area.
asbestos—a group of natural fibrous impure silicate materials.
asphalt—a dark brown to black cementitious material in which the predominating constituents are bitumens which occur in nature or are obtained in petroleum processing.
ascphalt, air blown—an asphalt produced by blowing air through molten asphalt at an elevated temperature to raise its softening point and modify other properties.
asphaltene—a high molecular weight hydrocarbon fraction precipitated from asphalt by a designated paraffinic naphtha solvent at a specified temperature and solvent-asphalt ratio.

discussion—The asphaltene fraction should be identified by the temperature and solvent-asphalt ratio used.
asphalt felt—an asphalt-saturated felt.
asphalt, steam blown—an asphalt produced by blowing steam through molten asphalt to modify its properties.
asphaltite—a natural asphalt found below ground level.
asphalt mastic—a mixture of asphaltic material and graded mineral aggregate that can be poured when heated, but requires mechanical manipulation to apply.
asphalt rock (rock asphalt)—a naturally occurring rock formation, usually limestone or sandstone, containing throughout its mass a minor amount of asphalt.
backnailing—the practice of blind-nailing roofing felts to a substrate in addition to hot-mopping to prevent slippage.
bald roof—Smooth-surfaced roof.
base ply—the bottom or first ply in a built-up roofing membrane when additional plies are to be subsequently installed.
base sheet—a product intended to be used as a base ply in a built-up roofing system.

bitumen—(1) a class of amorphous, black or dark-colored, (solid, semi-solid, or viscous) cementitious substances, natural or manufactured, composed principally of high molecular weight hydrocarbons, soluble in carbon disulfide, and found in asphalts, tars, pitches, and asphaltites;
(2) a generic term used to denote any material composed principally of bitumen.
biter trap—See pitch pocket.
biteminized, adj—impregnated with bitumen. Example: bituminized fiber pipe.
biteminuous, adj—containing or treated with bitumen. Examples: bituminous concrete, bituminous felts and fabrics, bituminous pavement.
biteminuous emulsion—(1) a suspension of minute globules of bituminous material in water or in an aqueous solution;
(2) a suspension of minute globules of water or of an aqueous solution in a liquid bituminous material (invert emulsion).
biteminuous grout—a mixture of bituminous material and fine sand that will flow into place without mechanical manipulation when heated.
blast-furnace slag—the nonmetallic product, consisting essentially of silicates and alumino-silicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace.
blind nailing—the use of nails that are not exposed to the weather in the finished roofing.
blist—(1) a raised portion of a roofing membrane resulting from local internal pressure;
(2) the similarly formed protuberances in coated prepared roofing.
blocking—(1) wood built into a roofing system above the deck and below the membrane and flashing to (a) stiffen the deck around an opening, (b) act as a stop for insulation, (c) serve as a nailer for attachment of the membrane or flashing.
(2) wood cross-members installed between rafters or joists to provide support at cross-joints between deck panels.
(3) cohesion or adhesion between similar or dissimilar materials in roll or sheet form that may interfere with the satisfactory and efficient use of the material.
blueberry—See strawberry.
bond—the adhesive and cohesive forces holding two roofing components in intimate contact.
brooming—embedding a ply by using a broom to smooth it out and ensure contact with the adhesive under the ply.
built-up roofing—a continuous, semisimplex membrane consisting of plies of saturated felts, coated felts, fabrics or mats assembled in place with alternate layers of bitumen.
and surfaced with mineral aggregate, bituminous materials, or a granule surfaced sheet (abbreviation, BUR). cant strip—a beveled strip used under flashings to modify the angle at the point where the roofing or waterproofing membrane meets any vertical element.
cap flashing—See flashing.
cap sheet—a granule-surfaced coated felt used as the top ply of a built-up roofing membrane.
cationic emulsion—an emulsion in which the emulsifying system establishes a predominance of positive charges on the discontinuous phase.
caulk—A composition of vehicle and pigment, used at ambient temperatures for filling joints, that remains plastic for an extended time after application.
channel mopping—See mopping, (3) strip.
coal tar—a dark brown to black cementious material produced by the destructive distillation of coal.
coal-tar felt—a felt that has been saturated with refined coal tar.
coal-tar pitch—a dark brown to black, solid cementious material obtained as residue in the partial evaporation or distillation of coal tar.
coated sheet (or felt)—(1) an asphalt felt that has been coated on both sides with harder, more viscous asphalt; (2) a glass fiber felt that has been simultaneously impregnated and coated with asphalt on both sides.
coke-oven tar—See coal tar.
cold-process roofing—a continuous, semiflexible membrane consisting of plies of felts, mats, or fabrics laminated on a roof with alternate layers of roof cement and surfaced with a cold-applied coating.
condensation—the conversion of water vapor or other gas to liquid as the temperature drops or atmospheric pressures rises. (See also dew point.)
conductance, thermal—the thermal transmission in unit time through unit area of a particular body or assembly having defined surfaces, when unit average temperature difference is established between the surfaces. \[ C = \frac{W}{m^2 \cdot K} \quad (C = \text{Btu/h} \cdot \text{ft}^2 \cdot \text{°F}) \]
conductivity, thermal—the thermal transmission, by conduction only, in unit time through unit area between two isothermal surfaces of an infinite slab of a homogeneous material of unit thickness, in a direction perpendicular to the surface, when unit temperature difference is established between the surfaces. \[ k = \frac{W}{m \cdot K} \quad (k = \text{Btu} \cdot \text{in.} / \text{h} \cdot \text{ft}^2 \cdot \text{°F}) \]
cone penetration—See penetration.
coping—a covering on top of a wall exposed to the weather, usually sloped to carry off water.
counterflashing—formed metal or elastomeric sheeting secured on or into a wall, curb, pipe, roof-top unit, or other surface, to cover and protect the upper edge of a base flashing and its associated fasteners.
coverage—the surface area to be continuously covered by a specific quantity of a particular material.
creep—the time-dependent part of a strain resulting from stress.
cricket—a relatively small, elevated area of a roof constructed to divert water from a horizontal intersection of the roof with a chimney, wall, expansion joint, or other projection.
crushed stone—the product resulting from the artificial crushing of rocks, boulders, or large cobblestones, substantially all faces of which have resulted from the crushing operation.
cutback—solvent-thinned bitumen used in cold-process roofing adhesives, flashing cements, and roof coatings.
cutoff—a detail designed to prevent lateral water movement into the insulation where the membrane terminates at the end of a day’s work, or used to isolate sections of the roofing system. It is usually removed before the continuation of the work.
damp-proofing—treatment of a surface or structure to resist the passage of water in the absence of hydrostatic pressure.
dead level—absolutely horizontal, or zero slope (see also slope).
dead level asphalt—a roofing asphalt conforming to the requirements of Specification D 312, Type I.
dead level roofing—a roofing system applied on a surface with a 0 to 2% incline.
deck—the structural surface to which the roofing or waterproofing system (including insulation) is applied.
direction change—a change in the orientation of the principal dimension or of the support of adjoining units of the roofing system.
double pour—to apply two layers of aggregate and bitumen to a built-up roof.
dry felt—(1) see felt; (2) a felt which has not been saturated with bitumen.
edge stripping—application of felt strips cut to narrower widths than the normal felt-roll width to cover a joint between flashing and built-up roofing.
edge venting—the practice of providing regularly spaced protected openings at a roof perimeter to relieve water vapor pressure in the insulation.
elastomer—a macromolecular material that returns rapidly to its approximate initial dimensions and shape after substantial deformation by a weak stress and subsequent release of that stress.
embodiment—(1) the process of pressing a felt, aggregate, fabric, mat, or panel uniformly and completely into hot bitumen or adhesive to ensure intimate contact at all points; (2) the process of pressing granules into coating in the manufacture of factory-prepared roofing, such as shingles.
emulsion—an intimate mixture of bitumen and water, with uniform dispersion of the bitumen or water globules, usually stabilized by an emulsifying agent or system.
envelope—a continuous membrane edge seal formed at the perimeter and at penetrations by folding the base sheet or ply over the plies above and securing it to the top of the membrane. The envelope prevents bitumen seepage from the edge of the membrane.
equilibrium moisture content—(1) the moisture content of a material stabilized at a given temperature and relative humidity, expressed as percent moisture by weight; (2) the typical moisture content of a material in any given geographical area.
equiviscous temperature (EVT)—the temperature at which the viscosity of an asphalt is 125 mm²/s (125 cST); the recommended asphalt temperature ±14°C (25°F) at the time of application to the substrate.
**Glossary of Roofing/Waterproofing Terms**

**Discussion**—In England, EVT is the temperature corresponding to a standard efflux time from a road tar viscometer.

**expansion joint**—a structural separation between two building elements that allows free movement between the elements without damage to the roofing or waterproofing system.

**exposure**—(1) the transverse dimension of a roofing element not overlapped by an adjacent element in any roofing system. The exposure of any ply in a membrane may be computed by dividing the felt width minus 51 mm (2 in.), by the number of shingled plies; thus, the exposure of a 914-mm (36-in.) wide felt in a shingled, four-ply membrane should be 216 mm (8 1/2 in.); (2) the time during which a portion of a roofing element is exposed to the weather.

**extra-steep asphalt**—See super-steep asphalt.

**fabric**—a woven cloth of organic or inorganic filaments, threads, or yarns.

**factory square**—10 m² (108 ft²).

**fallback**—a reduction in bitumen softening point, sometimes caused by refluxing or overheating in a relatively closed container. (See also softening point drift).

**felt**—a flexible sheet manufactured by the interlocking of fibers with a binder or through a combination of mechanical work, moisture, and heat. Felts are manufactured principally from vegetable fibers (organic felts), asbestos fibers (asbestos felts) or glass fibers (glass fiber felts); other fibers may be present in each type.

**felt layer**—(1) a machine used for applying bitumen and built-up roofing felts; (2) See ply.

**felt roll**—the mass in pounds of 480 ft² of dry, unsaturated felt, also termed "point weight."

**fine mineral surfacing**—water-insoluble inorganic material, more than 50% of which passes the 500-μm (No. 35) sieve, used on the surface of roofing.

**finger blisters**—finger shaped blisters or wrinkles in the plies of a built-up roofing or waterproofing membrane.

**finger wrinkles**—See finger blisters.

**fishmouth**—(1) a half-cylindrical or half-conical opening formed by an edge wrinkle or failure to embed a roofing felt; (2) in shingles, a half-conical opening formed at a cut edge.

**flashing**—the system used to seal membrane edges at walls, expansion joints, drains, gravel stops, and other places where the membrane is interrupted or terminated. Base flashing covers the edges of the membrane. Cap or counterflashing shields the upper edges of the base flashing.

**flashing cement**—a trowelable mixture of cutback bitumen and mineral stabilizers including asbestos or other inorganic fibers.

**flat asphalt**—a roofing asphalt conforming to the requirements of Specification D 312, Type II.

**flood coat**—the top layer of bitumen used to hold the aggregate on an aggregate-surfaced, built-up roofing membrane.

**fluid-applied elastomer**—an elastomeric material, fluid at ambient temperature, that dries or cures after application to form a continuous membrane. Such systems normally do not incorporate reinforcement.

**flux**—a bituminous material used as a feed stock for further processing and as a material to soften other bituminous materials.

**free carbon** in tar— the hydrocarbon fraction that is precipitated from a tar by dilution with carbon disulfide.

**glass felt**—glass fibers bonded into a sheet with resin and suitable for impregnation in the manufacture of bituminous waterproofing, roofing membranes, and shingles.

**glass mat**—a thin mat of glass fibers with or without a binder.

**glaze coat**—(1) the top layer of asphalt in a smooth-surfaced built-up roof assembly; (2) a thin protective coating of bitumen applied to the lower plies or top ply of a built-up membrane, when application of additional felts, or the flood coat and aggregate surfacing are delayed.

**granule**—See mineral granules.

**gravel**—coarse, granular aggregate, with pieces larger than sand grains, resulting from the natural erosion of rock.

**gravel in**—to spread aggregate into hot bitumen on the surface of the roofing membrane.

**gravel stop**—a flanged device, frequently metallic, designed to prevent loose aggregate from washing off the roof and to provide a continuous finished edge for the roofing.

**headlap**—the minimum distance, measured at 90 deg to the eave along the face of a shingle or felt as applied to a roof, from the upper edge of the shingle or felt, to the nearest exposed surface.

**holliday**—an area where a liquid-applied material is missing. "hot stuff" or "hot"—a roofer's term for hot bitumen.

**hygroscopic**—attracting, absorbing, and retaining atmospheric moisture.

**ice dam**—a mass of ice formed at the transition from a warm to a cold roof surface. Frequently formed by refreezing meltwater at the overhang of a steep roof, an ice dam may cause ice and water to back up under shingles or other roofing materials.

**incline**—the slope of a roof expressed in percent or in the number of vertical units of rise per horizontal unit of run.

**inorganic**—being or composed of matter other than hydrocarbons and their derivatives, or matter that is not of plant or animal origin.

**insulation**—See thermal insulation.

**kerosine number**—the milliliters of kerosine held per 100 g of felt as determined by Test Method D 727. To obtain the percentage saturating capacity of the felt for any bituminous saturant, obtain the specific gravity of the saturant and multiply that figure by the kerosine number of the felt.

**knot**—an imperfection or nonhomogeneity in materials used in fabric construction, the presence of which causes surface irregularities.

**liquid bituminous material**—one having a definite volume but no definite form, except as provided by its container. It has a viscosity of 0.1 to 1 × 10² cSt (mm²/s) at 40°C. This does not include powders or granular materials.

**loose-laid membrane**—a ballasted roofing membrane that is attached to the substrate only at the edges and penetrations through the roof.
lot—in roofing, (1) production lot—all material produced in one eight-hour shift of the same type (and color when applicable); (2) delivery lot—all material of the same type delivered at one time by one truck or railroad car.

mastic—See flashing cement and asphalt mastic.
membrane—a flexible or semirigid roof covering or waterproofing, whose primary function is the exclusion of water.

mesh—the square opening of a sieve.

metal flashing—See flashing; frequently used as through-wall, cap-, or counter-flashing.
mixed fiber felt—a felt with rock wool as the principal component.

mineral granules—opaque, natural, or synthetically colored aggregate commonly used to surface cap sheets, granule-surfaced sheets, and roofing shingles.

mineral stabilizer—a fine, water-insoluble inorganic material, used in admixture with solid or semisolid bituminous materials.

mineral-surfaced roofing—built-up roofing whose top ply consists of a granule-surfaced sheet.

mineral-surfaced sheet—a felt that is coated on one or both sides with asphalt and surfaced with mineral granules.

mold run—a meandering ridge in a membrane not associated with insulation or deck joints.

mop-and-flop—a procedure in which roofing elements (insulation boards, felt plies, cap sheets, etc.) are initially placed upside down adjacent to their ultimate locations, are coated with adhesive, and are then turned over and adhered to the substrate.

mopping—the application of hot bitumen with a mop or mechanical applicator to the substrate or to the plies of a built-up roof. There are four types of mopping: (1) solid—a continuous coating; (2) spot—bitumen is applied in roughly circular areas, generally about 460 mm (18 in.) in diameter, leaving a grid of unmopped, perpendicular areas; (3) strip—bitumen is applied in parallel bands, generally 200 mm (8 in.) wide and 300 mm (12 in.) apart; (4) sprinkle—bitumen is shaken onto the substrate from a broom or mop in a random pattern.

mud cracking—surface cracking resembling a dried mud flat.

nailing—(1) exposed-nailing of roofing wherein nail heads are bare to the weather; (2) concealed-nailing of roofing wherein nail heads are concealed from the weather. (See also blind nailing).

negative side waterproofing, n—an application wherein the waterproofing system and the source of hydrostatic pressure are on opposite sides of the structural element.

neoprene—a synthetic rubber (polychloroprene) used in liquid- or sheet-applied elastomeric roofing membranes or flashing.

nineteen-inch selvage—a prepared roofing sheet with a 432-mm (17-in.) granule-surfaced exposure and a 483-mm (19-in.) selvage.

ninety-pound—a prepared roll roofing with a granule-surfaced exposure that has a mass of approximately 4400 g/m² (90 lb/108 ft²).

one-on-one—the application of a single ply of roofing over the substrate, followed by the application of a second single ply over the first (phased application).

organic, adj—being or composed of hydrocarbons or their derivatives, or matter of plant or animal origin.

parting agent—a material applied to one or both surfaces of a sheet to prevent blocking.

penetration—the consistency of a bituminous material expressed as the distance in tens of a millimetre (0.1 mm) that a standard needle penetrates vertically a sample of material under specified conditions of loading, time, and temperature. A cone is sometimes used for special purposes instead of a needle.

perlite—an aggregate used in lightweight insulating concrete and in preformed perlite insulating board; formed by heating and expanding siliceous volcanic glass.

permeance—the rate of water vapor transmission per unit area at a steady state through a membrane or assembly, expressed in ng/Pa·s·m² (grain/ft²·h·in. Hg).

phased application—the installation of a roofing or waterproofing system during two or more separate time intervals; a roofing system not installed in a continuous operation.

petroleum pitch—a dark brown to black, predominantly aromatic, solid cementitious material obtained by the processing of petroleum, petroleum fractions, or petroleum residuals.

picture framing—a rectangular pattern of ridges in a membrane over insulation or deck joints.

pinhole—a tiny hole in a film, foil, or laminate comparable in size to one made by a pin.

pitch—See incline; coal-tar pitch; or petroleum pitch.

pitch pocket—a flanged, open-bottomed metal container placed around a column or other roof penetration, and filled with hot bitumen or flashing cement to seal the joint.

plastic cement—See flashing cement.

ply—a layer of felt in a built-up roofing membrane; a four-ply membrane has at least four plies of felt at any vertical cross section cut through the membrane.

plying cement—any bituminous material used for adhering layers of felts, fabrics, or mats to structural surfaces and to each other.

point weight—See felt mill ream.

pond—a surface which is incompletely drained.

positive side waterproofing, n—an application wherein the waterproofing system and the source of hydrostatic pressure are on the same side of the structural element.

primer—a thin liquid bitumen applied to a surface to improve the adhesion of heavier applications of bitumen and to absorb dust.

rake—the sloped edge of a roof at the first or last rafter.

raspberry—See strawberry.

recovering—the process of covering an existing roofing system with a new roofing system.

reentrant corner—an inside corner of a surface, producing stress concentrations in the roofing or waterproofing membrane.

reglet—a groove in a wall or other surface adjoining a roof surface for the attachment of counterflashing.

reinforced membrane—a roofing or waterproofing membrane reinforced with felts, mats, fabrics, or chopped fibers.

relative humidity—the ratio of the mass per unit volume (or partial pressure) of water vapor in an air-vapor mixture to
the saturated mass per unit volume (or partial pressure) of the water vapor at the same temperature, expressed as a percentage.

release agent—See parting agent.

eroofing—the process of recovering or replacing an existing roofing system. See recovering.

resistance, thermal—the average temperature difference between two defined surfaces of a particular body or assembly when unit thermal transmission in unit time through unit area is established between the surfaces. \( R = \frac{K \cdot m^2}{W} (R = \frac{F \cdot h}{R^2 / Btu}) \)

riding—an upward, tenting displacement of a membrane, frequently over an insulation joint.

roll roofing—coated felts, either smooth or mineral-surfaced. roof cement—See flashing cement.

roofing system—an assembly of interacting components designed to weatherproof, and normally to insulate, a building's top surface.

rubber—a material that is capable of recovering from large deformations quickly and forcibly, and can be, or already is, modified to a state in which it is essentially insoluble (but can swell) in boiling solvent such as benzene, methyl ethyl ketone, and ethanol-toluene azeotrope.

Discussion—A rubber in its modified state, free of diluents, retracts within 1 min to less than 1.5 times its original length after being stretched at room temperature (18 to 29°C) to twice its length and held for 1 min before release.

saddle—in roofing, a small structure that helps to channel surface water to drains. Frequently located in a valley, a saddle is often constructed like a small hill roof, or like a pyramid with a diamond-shaped base. (See also cricket.)

sales square—the quantity of prepared roofing required to cover 9.3 m² (100 ft²) of deck.

saturated felt—a felt that has been immersed in hot bitumen; the felt absorbs and absorbs as much bitumen as it can retain under the processing conditions, but remains porous and contains voids.

screen—an apparatus with circular apertures for separating sizes of material.

scuttle—a hatch that provides access to the roof from the interior of the building.

sealant—a mixture of polymers, fillers, and pigments used to fill and seal joints where moderate movement is expected; unlike caulking, it cures to a resilient solid.

selvage—an edge or edging which differs from the main part of (1) a fabric; or (2) granule-surfaced roll roofing.

shark fin—an upward-curved felt sidelap or endlap.

shingle—(1) a small unit of prepared roofing designed for installation with similar units in overlapping rows on inclines normally exceeding 25°; (2) to cover with shingles; and (3) to apply any sheet material in overlapping rows like shingles.

shingling—(1) the procedure of laying parallel felts so that one longitudinal edge of each felt overlaps, and the other longitudinal edge underlaps, an adjacent felt. (See also ply). Normally, felts are shingled on a slope so that the water flows over rather than against each lap; (2) the application of shingles to a sloped roof.

sieve—an apparatus with square apertures for separating sizes of material.

skater's cracks—curvilinear cracks in a roofing membrane that appear to relate neither to the direction of application of the membrane components nor the substrate components.

slag—the fused agglomerate which separates in metal smelting and floats on the surface of the molten metal. (See also blast-furnace slag.)

slippage—relative lateral movement of adjacent components of a built-up membrane. It occurs mainly in roofing membranes on a slope, sometimes exposing the lower plies or even the base sheet to the weather.

slope—the tangent of the angle between the roof surface and the horizontal plane, expressed as a percentage, or in inches of rise per foot of horizontal distance. (See also incline).

smooth-surfaced roof—a built-up roof without mineral aggregate surfacing.

softening point—the temperature at which a bitumen becomes soft enough to flow as determined by an arbitrary, closely defined method.

softening point drift—a change in the softening point during storage or application. (See also fallback).

solid bituminous material—one having a viscosity of over 1 \( \times 10^8 \) cSt (mm²/s) at 40°C or an equivalent viscosity at an agreed-upon temperature. This includes powders and granular materials.

solid mopping—See mopping.

split—a membrane tear resulting from tensile stress.

split sheet—See nineteen-inch selvage.

spot mopping—See mopping.

sprinkle mopping—See mopping.

spud—to remove the roofing aggregate and most of the bituminous top coating by scraping and chipping.

square—a roof area of 9.29 m² (100 ft²), or enough material to cover 9.29 m² of deck.

stack vent—a vertical outlet in a built-up roofing system to relieve the pressure exerted by water vapor between the roofing membrane and the vapor retarder or deck.

steep asphalt—a roofing asphalt conforming to the requirements of Specification D 312, Type III.

strawberry—a small bubble or blister in the flood coating of a gravel-surfaced membrane.

strip mopping—See mopping.

stripping—strip flashing:

1) the technique of sealing a joint between metal and built-up membrane with one or two plies of felt or fabric and hot- or cold-applied bitumen;

2) the technique of tapping joints between insulation boards or deck panels.

substrate—the surface upon which the roofing or waterproofing membrane is placed (structural deck or insulation).

sump—a depression around a drain.

super-steep asphalt—a roofing asphalt conforming to the requirements of Specification D 312, Type IV.

susceptibility—when not otherwise qualified, the degree of change in viscosity with temperature.

system—See roofing system.

tapered edge strip—a tapered insulation strip used to elevate the roofing at the perimeter and at penetrations of the roof.
Glossary of Roofing/Waterproofing Terms

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Tar—a brown or black bituminous material, liquid or semi-solid in consistency, in which the predominating constituents are bitumens obtained as condensates in the processing of coal, petroleum, oil-shale, wood, or other organic materials.

Tear-off—to remove an existing roofing system down to the structural deck.

Thermal insulation—a material applied to reduce the flow of heat.

Thermal shock—the stress-producing phenomenon resulting from sudden temperature drops in a roof membrane when, for example, a rain shower follows brilliant sunshine.

Through-wall flashing—a water-resistant membrane or material assembly extending totally through a wall and its cavities, positioned to direct any water within the wall to the exterior.

Tie-off, n—in waterproofing, the transitional seal used to terminate a waterproofing application at the top or bottom of flashing or by forming a watertight seal with the substrate, membrane, or waterproofing system(s).

Vapor barrier—See vapor retarder.

Vapor migration—the movement of water vapor from a region of high vapor pressure to a region of lower vapor pressure.

Vapor retarder—a layer of material or a laminate used to appreciably reduce the flow of water vapor into the roofing system.

Vent—an opening designed to convey water vapor or other gas from inside a building or a building component to the atmosphere.

Vermiculite—an aggregate used in lightweight insulating concrete, formed by heating and expanding a micaceous mineral.

Viscoelasticity—a combination of viscous and elastic properties in a material, with the relative contribution of each dependent upon time, temperature, stress, and strain rate.

Walk-in—to embed insulation panels in hot bitumen or adhesive by walking on them immediately after application.

Water repellent system, n—an exterior coating system for above grade concrete or masonry which temporarily repels water but which is not intended to prevent the passage of moisture under hydrostatic pressure.

1. Film forming type—latex or oil based paints or similar materials that may require repair or renewal because of climatic action;

2. Pore penetrating type—types that fill or coat the interior of the surface pores of concrete or masonry and are temporarily retained in these surface pores thus providing water repelling action; periodic repair or renewal may be required because of climatic action.

Waterproofing—treatment of a surface or structure to prevent the passage of water under hydrostatic pressure.

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**NOMENCLATURE**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>W/M °C</td>
<td>Watt/Meter Degree Celsius</td>
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<tr>
<td>BUR</td>
<td>Built-Up Roofing</td>
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<tr>
<td>APP</td>
<td>Atactic Polypropylene</td>
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<tr>
<td>SBS</td>
<td>Styrene Butadiene Styrene</td>
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<tr>
<td>ASTM</td>
<td>American Society for Testing and Material</td>
</tr>
<tr>
<td>EPDM</td>
<td>Ethylene Propylene Diene Monomer</td>
</tr>
<tr>
<td>CR</td>
<td>Chloroprene Rubber</td>
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<tr>
<td>CPE</td>
<td>Chlorinated Polyethylene</td>
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<tr>
<td>CSPE</td>
<td>Chlorosulphonated Polyethylene</td>
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<tr>
<td>PIB</td>
<td>Polyisobutylene</td>
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<tr>
<td>NBP</td>
<td>Nitrile Alloy</td>
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<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
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<tr>
<td>EIP</td>
<td>Ethylene Interpolymer</td>
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<tr>
<td>PMBP</td>
<td>Polymer Modified Bituminous Membrane</td>
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<tr>
<td>BS</td>
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<tr>
<td>LT</td>
<td>Loose Tiles</td>
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<tr>
<td>LAC</td>
<td>Liquid Applied Acrylic</td>
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<td>F/L</td>
<td>Fixed or Loose tiles</td>
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<tr>
<td>LAPU</td>
<td>Liquid Applied Polyurethane</td>
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<tr>
<td>PUF</td>
<td>Polyurethane Foam</td>
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<td>Polyurethane Boards</td>
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<td>PWM</td>
<td>Plastic Wire Mesh/Fiber Mesh (FM)</td>
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<td>CCS</td>
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<td>CPL</td>
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