The Effects of Faulty Design and Construction of Building Maintenance

by

Mansoor Mohammad Al-Shiha

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

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DHAHRAN, SAUDI ARABIA

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This thesis, written by MANSOOR MOHAMMAD AL-SHIHA under the direction of his Thesis Committee and approved by all its members has been presented to and accepted by the Dean of College of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING AND MANAGEMENT.**

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Department Chairman

Dean, College of Graduate Studies

11-7-93

Date


بسم الله الرحمن الرحيم

I dedicate this work to my country, my beloved parents, my wife , and my brothers for their continuous support and encouragement.

ACKNOWLEDGMENTS

Acknowledgment is due to King Fahd University of Petroleum and Minerals for support of this research.

I wish to express my appreciation to Dr. Sadi Assaf who served as my major advisor. I also wish to thank the other members of my Thesis Committee : Dr. Abdul Mohsen Al Hammad and Dr. Kamal Al Harbi for their comments and suggestions.

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بســـم الله الرحمن الرحيـــم

الأخطاءالتي تحدث أثناء التصميم والتشييد ومدى تأثيرها على صيانة المباني

يستعرض هذا البحث الأخطاء التي تحدث أثناء تصميم المباني وانشائها من الناحية المدنية والمعمارية والتي تؤثر على صيانة المباني بعد التشغيل وتزيد من تكاليف صيانتها.

وتم تحديد هذه الأخطاء من خلال استفتاء ميداني؛ بالأضافة الى البحث في المراجع المتعلقة بموضوع صيانة المباني وتم حصرها في سبعة وستون خطأ.

ومن ثم تقسيمها الى احدى عشرة مجموعة ووضعها بصورة استبيان لأخذ آراء المقاولين والاستشاريين وأصحاب المباني. وقد شمل الاستبيان (٩٠) مقاول و (٣٠) استشاري و (٢٠) مالك للمباني في المنطقة الشرقية.

وقد رتبت هذه الأخطاء حسب أهميتها وطبقا للرؤية الجماعية للمقاول والاستشاري والمالك، وكذلك لكل منهم على حده. وقد حللت نتائج هذا البحث بواسطة الحاسب الآلي.

هذا وقد ركزت الدراسة على أهمية مدى التوافق في رؤية كل من المقاول والاستشاري والمالك في تقديره لمدى تأثير هذه الأخطاء على صيانة المباني.

واستنتج الباحث بعد البحث أن هنالك توافق في الآراء وأن عدم كفاءة التصميم الانشائي، واستخدام العمالة ذات الخبرة الرديئة، والاستعمال الخاطئ للمواد وعدم الالتزام بالمواصفات الانشائية والمعمارية هي من أهم الأخطاء التي تؤثر على صيانة المبنى وتزيد من تكاليف صيانتها.

كذلك يبين البحث أن العلاقة بين المقاول الانشائي والاستشاري هي من أقوى العلاقات مقارنة بعلاقة الأطراف المذكورة سابقا ببعضها البعض.

ABSTRACT

THE EFFECTS OF FAULTY DESIGN AND CONSTRUCTION ON BUILDING MAINTENANCE.

The thesis discusses the effects of faulty design and construction factors on maintenance. A survey of 90 construction and maintenance contractors, 30 designers and 20 owners was conducted.

The survey included 67 different faulty factors and their degree of importance. The severity factors of these factors were measured by their level of importance and were ranked according to the severity index for the combination of all respondents, contractors, consultants and owners.

The severity of the faulty factors were analyzed statistically using the SAS mainframe computer package. These defect factors were obtained from interviews and discussions with contractors, consultants and owners.

The research includes a hypothesis that "contractors, consultants and owners generally agree on the ranking of severity indices" which was tested and shown to hold true. It was concluded that Inadequate Structural Design , Unqualified Staff , Wrong Selection of Material, and Non Compliance with Specification , are the most severe factors. Also, it was noted that contractors gave the most actual responses, followed by consultants then the owner. This reflects their true involvement and awareness of faulty factors that increase maintenance.

Finally , in order to minimize maintenance defects and expenditure, a set of recommendations are made and topics for future research are suggested.

CHAPTER 1

INTRODUCTION

The scope of this chapter is to give the reader an idea about the maintenance industry world-wide and in Saudi Arabia and to make him aware of the effort and expenditure needed to maintain the buildings.

1.1 GENERAL :

Saudi Arabia is a rich developing country with huge capital resources. It is developing very fast in every area including building construction. Large and complex projects have been built due to the demands of both the public and private sectors. To meet the high demand of both private and public sectors needs in a short time, it is expected that many errors and defects will have occurred during the design and construction stages which resulted later in high maintenance costs. Under normal conditions all buildings start to deteriorate the moment they are constructed. Maintenance is needed to keep these buildings in good condition.

1.2 STATEMENT OF THE PROBLEM :

A large amount of the country's maintenance resources is being expended on corrective or remedial measures to buildings and their services due to design or constructional defects. In the UK. about 20% of the average annual expenditure on repairs in buildings arises from defects. Reducing the number of defects will end in the reduction of maintenance expenditure.

All defects create avoidable maintenance. Some defects can be corrected without recurring expenditure while the remainder require periodical attention. All work within these two spheres add to the ever increasing sum expended on maintenance per annum, (GIBSON,1979) .

FAULTY DESIGN :

"Increase of maintenance cost or effort can be attributed to faulty designs. Many of these maintenance problems arise where design is satisfactory in principle but has a low probability of achievement in practice. These are not to be regarded as defects in workmanship but rather as too high an expectation in design. For example, the detail for the placing of the reinforcement in cladding panels may appear to provide the necessary cover on an engineer's drawing but

would need a 'watch-making technique' to achieve this which would be quite impractical on a building site or even in factory prefabrication ", (LEE, 1987).

Maintenance problems can also arise where no attention was given at the design stage of a project to the materials and finishes chosen and whether they are capable of withstanding everyday wear and tear.

They can also arise from faulty design decisions. Faulty design decisions are the most common faults which may be grouped as follows (GIBSON , 1979) :

1. Failure to follow well established design criteria in the choice of structural system and selection of materials.

2. Ignorance of the basic physical properties of the materials. e.g. failing to make allowance for the differing thermal and moisture movements of materials used in combination.

3. Use of new materials or innovative forms of construction which have not been properly tested in use. This is often the result of uncritical reliance on manufacturer's literature quoting simulated laboratory tests.

4. Misjudgment of user and climatic conditions under which the material has to perform.

5. Impractical or very difficult to execute design .

6. Poor communication between different members of the design and construction teams.

FAULTY CONSTRUCTION :

Another source of maintenance expenditure is construction defects which happen during the construction stage and because of construction contractor performance or material used.

Faulty construction is one of the most common causes of early deterioration. Common construction faults include inadequate compaction and failure to position the reinforcement so that it has adequate concrete cover. Under almost any exposure conditions these faults will eventually reduce the service life of the structure as a result of reinforcement rusting after the concrete has become carbonated, (SEELEY ,1987).

Another source of fault is the construction method. "The conditions under which construction takes place are often far from ideal , and coupled with an emphasis on speedy completion, can result in careless and skimped work. The Building Research Establishment (BRE) study shows that only a small portion of defects are attributable to faulty materials . It is apparent that some manufacturers of so-called high technology components have little awareness of the rigours of a building site or the standards of accuracy achievable under such conditions. Thus, whilst the materials may be perfect on leaving the factory they can quite easily be damaged during loading handling, unloading, storing or placing in position. Many such defects can be avoided by ensuring greater care at all stages in the process, proper training of operatives, and closer supervision. To tackle this problem the construction industry is beginning to introduce the quality assurance techniques developed in other industries such as Quality Assurance (QA) groups and quality control (QC)" (BRE ,1983).

1.3 PREVIOUS STUDIES :

"BS 3811:1964 defines maintenance as :' a combination of any actions carried out to retain an item in, or restore it to, an acceptable condition'. The actions referred to are those associated with initiation, organization and implementation. There are two processes envisaged : retaining , i.e., work carried out in anticipation of failure, and restoring, i.e., work carried out after failure. The former is usually referred to as preventive maintenance and the later as corrective maintenance " (BRE, 1983).

Few studies have been conducted to find out the faults in design and construction that affect maintenance. Most of the available studies are developed in European countries where the building histories, type, material, workmanship and design methods are different. The Building Research Establishment in England conducted a survey of building failure patterns and their implications and the most common defects are shown in Table 1.1. In a sample of 510 buildings, 58% of the defects originated from faulty design, 35% from faulty execution, 12% from faulty materials, components or proprietary systems and 11% from unexpected user requirements, but there was some overlap between these categories (SEELEY,1987).

TABLE 1.1

MOST COMMON BUILDING DEFECTS IN UK.

Building Type	Defects percent				
	Condensat-ion	Rain Penetration	Cracking	Floors	Roofs
Council Houses	59	13			
Council Flats	38	33			
Private Houses	18	33	20		
Private Flats		64			
Factories		29	29		
Offices		28	19	28	23
Schools				32	39
Hospitals				35	26

"In the survey of housing under construction, reported by Quality in Traditional Housing : Vol. 1, just under 1000 different kinds of faults were identified. About half that number were related to the external envelope, including external walls, windows and doors, and roofs. Figure 1.1 shows the breakdown. It can be argued therefore that, for both design and site staff, where time is short, concentrating on the external envelope is likely to uncover the largest numbers of potential faults. This idea does not, however, mean that serious faults cannot and do not occur in other elements.

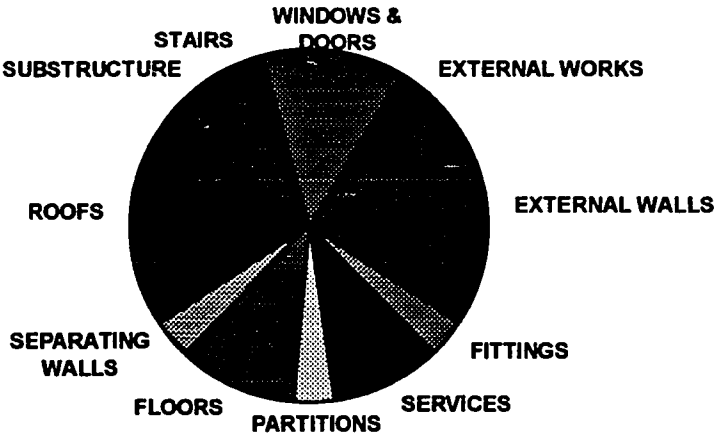


FIG 1.1

Design staff should be aware that by far the largest category of faults were attributed to performance,and related to durability and maintenance. This is the area above all others where much time and thought need to be devoted to predicting future performance. Fig. 1.2 shows the breakdown. Apart from the category of strength and stability, all other remaining categories produced much the same numbers of kind of faults.

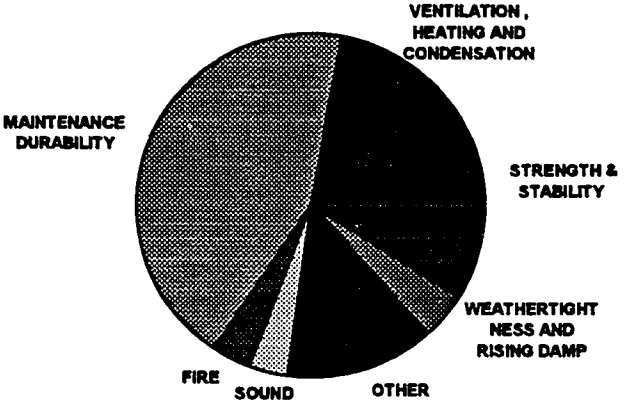


FIG 1.2

Over one quarter of all fault-types attributed to design were infringements of building regulations or codes and standards cited in building regulations. Another fifth infringed other codes and standards. Figure 1.3 shows the breakdown." (BRE,1983).

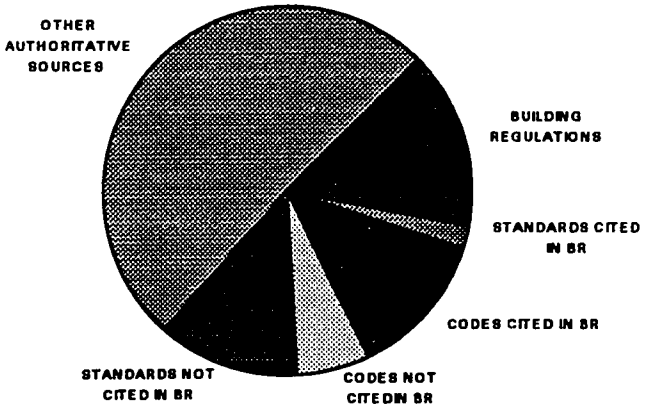


FIG 1.3

"A report that was developed to the Building Maintenance Committee (in Britain) suggests that about 20% of the average annual expenditure on repairs in a large number of buildings was abnormal and, in most cases, could be described as arising from defects. According to evidence from the insurance trade and from an analysis of the investigations into defects in buildings by the new Building Research Advisory Service, most defects come to light in the first 3 to 4 years of the lives of buildings. While most of these defects are associated with the structure, others are associated with such things as unsightly patterns of soiling of the elevations or lack of accessibility to services; such occurrences stem from the design of the building and are generally avoidable". (GIBSON , 1979)

"One analysis of maintenance costs in buildings not more than 25 years old showed fair wear and tear accounting for 56 percent, rectification of design or specification faults at 20%, repairs due to faulty materials or workmanship at 12.5% and the remaining 11.5% was attributed to sundry causes. The annual cost of maintenance is likely to increase in the future because of some new products, whose properties and problems are largely unknown, are still misused. Finally, correct diagnosis of building defect is essential to ensure that the cost of remedial work is not excessive and that it is successful". (RANSOM ,1981)

"In England the Building Research Establishment mounted a major research project with the National Building Agency, to examine the quality of construction

work in progress on a number of low-rise traditional housing schemes. The results of the three year investigation were published in 1982. They showed that just over one-half of the faults concerned the external envelope, with 20% in walls, 20% in roofs, and 13% in windows and doors. One quarter of all faults were infringements of Buildings Regulations. Out of the total number of faults, 50% were attributed to design, 41% to site, and 8% to materials. Figure 1.4 and 1.2 :

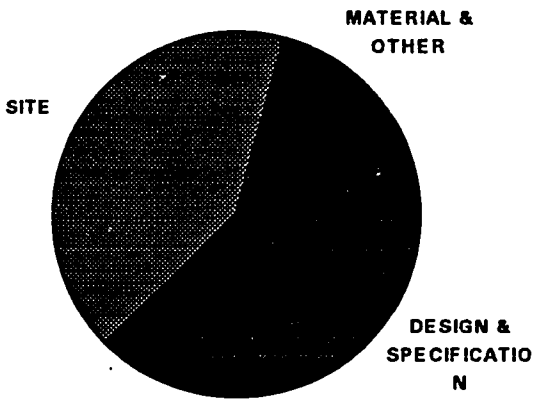


FIG 1.4

The importance of research in various aspects of building maintenance was recognized by the British former Minister of Public Building and Works when he established the Committee on Building Maintenance in 1965. Research and development problems in building maintenance spring essentially from the great diversity of the subjects. In the two decades after World War II, research in this field was mainly directed at properties of materials and few of the results were actually implemented. So much needs to be done concerning the relationship between design and maintenance, execution of maintenance, economic significance of maintenance and the actual performance of the materials and components under varying conditions. There is also a great need for a continuing dialogue between research and development workers on the one hand and architects, surveyors , maintenance personnel and contractors on the other, to ensure the relevance of research to the realities of construction and the implementation of the results of research in practice. The Government has initiated a large amount of research in this field and has assisted in its dissemination by conferences and publications, primarily through the Building Research Establishment.

Concern has been growing at the very substantial sums of money, amounting to several hundreds millions of pounds per annum in the public sector alone, which are being spent on correcting design and construction faults in housing". (RANSOM ,1981)

1.4 OBJECTIVES OF THE STUDY :

The main objectives of this research are to :

1. Undertake a comprehensive analysis of civil and architectural defects in design and construction that affect building maintenance.

2. Exclude electrical and mechanical defects .

3. Identify the most severe defects affecting maintenance.

4. Test hypothesis that contractors (construction & maintenance), consultants and owners generally agree on the severity ranks of the faulty factors.

5. Discuss the relation between all parties.

6. Make recommendations for further studies .

1.5 APPROACH TAKEN :

The initial phase of this research involved a comprehensive study of all types of defects in design and construction phases that affect maintenance. Then a literature search was focused on the identification of some of the relative defect factors in design and construction stages that affect maintenance.

The second phase involved gathering data through site visits, interviews and discussions with owners, consultants, maintenance contractors, and construction contractors. The result of the preliminary interviews with owners, consultants and contractors along with the information obtained from a literature search led to the formulation of the attached questionnaire. (See Appendix I).

In this study, the questionnaires was distributed to consultants, owners, and contractors to have feed back in a more standardized manner. For each question, the respondents had four options. These are strongly affects, moderately affects, slightly affects, and does not affect responses. The four options expressed the percent of degree of severity of the factors to the respondent.

Each factor has a severity index. The severity index is computed by the following equation :

$$\text{Severity Index (IS)} = [\sum_{i=1}^{4}(a_i \cdot x_i) / 3] \times 100\% \qquad \text{eq. 1.1(ALHAZMI,1987)}$$

Where :

a_i = constant, expressing the weight given to i th response , i = 1,2,3,4

x_i = the variable expressing the frequency of the i th responses, for i = 1,2,3,4 and illustrated as follows:

x_1 = the frequency of "strongly affects response "

x_2 = the frequency of "moderately affects response "

x_3 = the frequency of " slightly affects response "

x_4 = the frequency of "does not affects response "

Consequently, the design and construction factors are organized in their descending order according to their severity indices. As a result five lists will be obtained, namely an owner list, a maintenance contractor list, construction contractor list, and a consultant list. A fifth list will represent the opinion of the three parties together and is called a standard list.

Finally, the agreement between any two parties can be measured quantitatively using the rank correlation theory.

1.6 SCOPE & LIMITATION OF THE STUDY :

This research will be limited to civil and architectural defects in building design and construction that affect maintenance only. This research will be restricted to buildings in the Eastern Province of Saudi Arabia such as but not limited to industrial buildings, hospitals, houses, multistory buildings, airport buildings. Since, the large buildings and building complex owners are involved more in building maintenance and their opinion will be more objective, they will be taken as a representative sample for the building owners. Sample of other parties ,contractors and consultants will cover all types of buildings.

1.7 SIGNIFICANCE OF THE STUDY :

The efficiency, convenience, life span, economic viability and appearance of any building can be affected by decisions taken and actions performed at any time in the history of a building project, from its initial conception to its final demolition. (GIBSON ,1979)

"Most building defects are avoidable : they occur, in general, not through a lack of basic knowledge but by non- application or misapplication of it. Knowledge seems to become mislaid from time to time. Those with long memories, and those whose business it is to make a particular study of building defects, are often struck by the re-emergence of problems which have been well researched and documented. Certain basic properties of materials, such as their ability to move through changes in temperature and moisture, seems to be overlooked and a rash of difficulties occurs. A call goes out for more research but, in truth, all that is usually needed is a good system for the retrieval of information, a better procedure for its dissemination and most important, the realization that an information search is desirable." (SEELEY,1985).

Current training in design tends to concentrate on what to do rather than what not to do. A similar situation exits in training in constructional techniques, where the craftsman is instructed how best to undertake a particular operation , but only to a lesser extent in the dangers of deviation from an accepted technique.
Understanding of the likelihood of defects through inadequate design or construction is taught implicitly rather than explicitly. "The level and nature of defects in building construction currently encountered suggest that more guidance is required in the avoidance of failures". A need is seen , too, for such guidance to be a positive part of the training curriculum (SEELEY ,1987).

Defects in building design and construction increase and decrease according to the designer's and construction contractor's education, experience and compliance with the codes and standards. If these factors are not limited the owner will suffer the maintenance cost at the end. In some cases the law forces the contractor and the designers to share the maintenance and repair expense.

By conducting this research and identifying the faults and defects which are expected to occur in design and construction and identifying their severity index, for the public and private sector, the design firm and the contractor will benefit each according to his discipline.

In the meantime the owner will minimize maintenance expenditure and the substantial life of the building will increase. The designer will improve the quality

of the design by recognizing the faults and avoiding them, and as a result he will have better recognition and liabilities or losses to the owner. The contractor will improve the quality of work and minimize time delay and expenditure on repair work ; also , he will benefit and have a better recognition in the market.

1.8 THESIS ORGANIZATION :

The thesis discusses building maintenance and the associated civil architectural defects which happen during the design and construction phase and increase maintenance work. Defining these defects and their severity is considered to be an important field of study for future improvement in the design and construction industry. The thesis will be divided into five chapters and an appendix.

Chapter One is intended to give the reader an overview of the design and construction industry in Saudi Arabia, and present previous studies conducted on defining faults in design and construction that affect building maintenance.

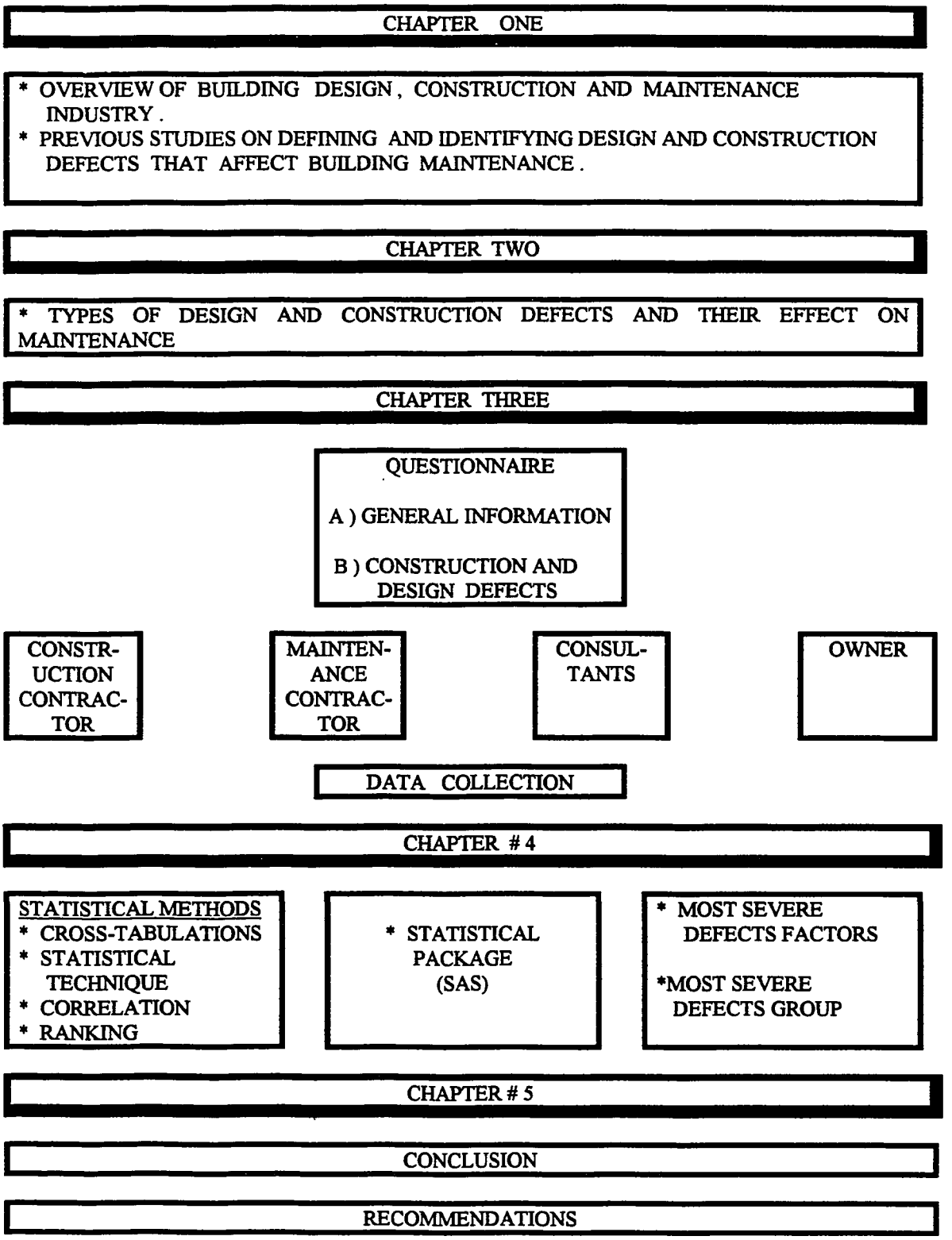
Chapter Two discusses design and construction fault types that increase the maintenance effort in buildings in the Eastern Province of Saudi Arabia.

Chapter Three presents a detailed survey of the opinions of building owners, construction and maintenance contractors, and consultants . It also includes the research methodology and sampling techniques used to measure the severity indices of faults which can occur in design and construction phases that affect and increase the maintenance effort.

Chapter Four is devoted to the statistical methods used, tables, information deduced from statistical analysis and the statistical results, and interpretation of these tables and information. It also contains the ranking by severity index of design faults and construction faults that affect maintenance. A hypothesis is set up and tested that the contractors, consultants and owners generally agree on the severity rank of design and construction faults.

Chapter Five is devoted to a summary, conclusions and recommendations for further studies. Fig. 1.5 shows a chart of the organization of the thesis.

FIG 1-5
THESIS ORGANIZATION CHART



CHAPTER 2

Construction and Design Faults which Affects Maintenance

This chapter discusses the types of design and construction faults which happen during the design and construction stages which could affect and increase building maintenance. This chapter focuses on the civil and architectural faults present in buildings in the Eastern Province of the Kingdom of Saudi Arabia.

2.1 GENERAL :

Defects in building design and construction increase and decrease according to the education and the practical and technical experience of the designer and construction contractor. Below are defects which are gathered from the literature search and the site interview. They are divided into eleven groups.

A. DEFECTS IN CIVIL DESIGN :

01. INADEQUATE PROVISIONS FOR MOVEMENT.

02. IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS.

03. IGNORING BIOLOGICAL EFFECTS.

04. INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION.

05. IGNORING VARIATION IN SOIL CONDITIONS.

06. IGNORING LOAD IMPACT ON STRUCTURE STABILITY.

07. EXCEEDING ALLOWABLE DEFLECTION.

08. IGNORING WIND EFFECTS ON THE STRUCTURE.

09. INADEQUATE CONCRETE COVER ON THE REINFORCEMENT.

10. IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS.

B. ARCHITECTURAL DEFECTS IN DESIGN :

01. NARROW STAIRS, PASSAGES & DOORS.

02. NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION.

03. SPECIFYING FINISHING WHICH NEED TO BE REPAIRED AS A WHOLE.

04. NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE.

05. INADEQUATE JOINTS BETWEEN FINISHED FACES.

C. DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY.

01 NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT.

02. DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE.

03. NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN.

04. NOT CONSIDERING THE MAINTENANCE REQUIREMENTS IN DESIGN

D. DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF :

01. LACK OF QA/QC PROGRAM DURING DESIGN.

02. POOR TECHNICAL UPDATING OR STAFF TRAINING.

03. HIRING UNQUALIFIED DESIGNERS.

04. LACK OF DESIGNER FIELD EXPERIENCE.

05. LACK OF DESIGNER TECHNICAL BACKGROUND.

06. DESIGNER IGNORANCE OF MATERIALS PROPERTIES.

07. MISJUDGMENT OF CLIMATIC CONDITIONS.

08. MISJUDGMENT OF USER'S INTENDED USE.

E. DEFECTS DUE TO CONSTRUCTION DRAWINGS :

01. LACK OF REFERENCES.

02. CONFLICTING DETAILS.

03. LACK OF DETAILS.

F. DEFECTS DUE TO CONSTRUCTION INSPECTION :

01. LACK OF INSPECTION.

02. UNQUALIFIED INSPECTOR.

03. PROPONENT (OWNER) NEGLIGENCE
OF THE IMPORTANCE OF INSPECTION.

04. WEAKNESS OF INSPECTION RULE IN IMPLEMENTING
CORRECTIVE ACTIONS DURING JOB EXECUTION.

G. DEFECTS DUE TO CIVIL CONSTRUCTION :

01. INACCURATE MEASUREMENT.

02. DAMAGED FORM WORK.

03. EXCAVATION TOO CLOSE TO THE BUILDING.

04. PAINTING IN UNSUITABLE CONDITIONS
OR ON UNSUITABLE SURFACE.

05. INADEQUATE WATER PROOFING AND DRAINAGE.

06. INSUFFICIENT REINFORCEMENT CONCRETE COVER.

07. COLD JOINTS.

08. LOSS IN ADHESION BETWEEN MATERIALS.

09. EARLY FORM WORK REMOVAL.

10. POOR SOIL COMPACTION.

11. INADEQUATE CURING.

12. LACK OF COMMUNICATION.

H. DEFECTS DUE TO CONTRACTOR ADMINISTRATION :

01. NOT COMPLYING WITH SPECIFICATION.

02. INABILITY TO READ THE DRAWINGS.

03. INSUFFICIENT SITE SUPERVISION.

04. POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER.

05. UNQUALIFIED SUPERVISION.

06. SPEEDY COMPLETION OR CHEAP QUALITY WORK.

07. UNQUALIFIED WORK FORCE.

08. MULTINATIONAL CONSTRUCTION EXPERIENCE.

I. DEFECTS DUE TO CONSTRUCTION MATERIALS :

01. DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIAL.

02. SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR THE EXISTING CLIMATIC CONDITIONS.

03. USE OF NONDURABLE MATERIAL.

04. USE OF EXPIRED MATERIAL.

05. POOR MATERIAL HANDLING & STORAGE.

J. DEFECTS DUE TO CONSTRUCTION EQUIPMENT :

01. WRONG USE OF EQUIPMENT.

02. INADEQUATE PERFORMANCE OF EQUIPMENT.

03. LACK OF REQUIRED AMOUNT OF EQUIPMENT'.

K. DEFECTS DUE TO SPECIFICATION :

01. UNCLEAR SPECIFICATION.

02. NOT DEFINING ADEQUATE MATERIAL TYPE.

03. NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE.

04. NOT SPECIFYING THE ALLOWABLE LOAD LIMITS.

05. SPECIFYING INADEQUATE CONCRETE MIX DESIGN.

2.2 DEFECTS IN CIVIL DESIGN :

Are defects caused during the early stage of design and particularly in the structural design such as :

2.2.1 INADEQUATE PROVISIONS FOR MOVEMENT :

This occurs when the designer ignores the spacing for contraction and expansion movement. Such movement causes cracking of the structure which will result in corrosion of the structural items (beams, columns and slabs) or cracking of the wall or will affect the look of the building.

2.2.2 IGNORING AGGRESSIVE ENVIRONMENT & WEATHER CONDITION EFFECTS:

In building design, the designer should always select and specify the right material to tolerate the existing weather which will result in less maintenance. Problems result when the designer is used to certain weather conditions and then moves to another place where the weather is different without giving consideration to the weather changes. This problem causes the material to deteriorate in a

shorter time and leads to defects in other parts of the building , e.g. the internal paint when the external paint does not protect the water from seeping through.

2.2.3 IGNORING BIOLOGICAL EFFECTS :

The designer should always have an idea about the building location and the type of plants and insects existing in that area and if any special treatment is needed against these biological factors to be specified in the design drawings . Ignoring biological factors could lead to continuous maintenance which can be avoided during the design and construction stage.

2.2.4 INADEQUATE STRUCTURAL DESIGN :

This results when the designer under designs the structural elements of the building. This will cause the building to settle or the building's structural elements to crack and further help initiation of steel bar corrosion or cracking of the walls or wall finishing.

2.2.5 IGNORING VARIATION IN SOIL CONDITIONS :

Most of the time the soil conditions do not vary in one place. But still there are cases where the soil structure varies in one area. Therefore, the designer should always make sure that the soil conditions are similar to the land built next to it. Such a problem will cause settling which will cause cracking of structural elements or exterior and interior walls of the building.

2.2.6 IGNORING LOAD IMPACT ON STRUCTURAL STABILITY :

This results when the building is subjected to physical or mechanical action such as elevators, the vibration of central air-conditioning units or wend load in high rise buildings. Such problem will result in continuous surface cracking and cannot be solved until the impact of movement is isolated.

2.2.7 EXCEEDING ALLOWABLE DEFLECTION :

This happens when the designer exceeds the allowable structural span length or does not evaluate the dead and life load effect correctly.

2.2.8 IGNORING WIND EFFECT ON THE STRUCTURE :

Usually, this happens in a medium size building where it is treated as a two story building. Such factor can cause continuous structural movement which can lead to failure of the structure.

2.2.9 INADEQUATE CONCRETE COVER ON THE REINFORCEMENT :

Corrodents reach the concrete reinforcement (steel bars) faster if the concrete cover on the steel bars is insufficient ,which will result in corrosion of the steel bars and cracking of the concrete element.

2.2.10 IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS :

This happens when the civil designer does not review the layout of the mechanical or electrical design, where the electrical or mechanical designer installs the conduits in a very critical structural area which will result in failure or continuous cracking of the structural elements or damage to the mechanical system of the building, e.g. breakage of water pipes or sewer leakage .

2.3 ARCHITECTURAL DEFECTS IN DESIGN :

These are defects caused during the architectural design stage such as :

2.3.1 NARROW STAIRS, PASSAGES & DOORS :

Buildings always need minor and preventive maintenance . Such maintenance requires some tools (ladder, cleaning equipment, etc.). If the designer does not allow enough clearance to get the tools in and out, these minor problems will get bigger and become major problems.

2.3.2 NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION :

The designer should always select the color and type of a building's exterior finishing material to suit the weather and environmental conditions of the building, e.g. not painting buildings with dark colors in a dusty area where they require a lot of cleaning , or using paints which cannot resist heat and humidity.

2.3.3 SPECIFYING FINISHING WHICH NEED TO BE REPAIRED AS A WHOLE :

Designers should specify finishings which require minimum maintenance and are always available in the market. If the finishing material is not available, the owner should keep a stock and if no stock is available, the owner may be forced to remove the whole surface , e.g. what happens to wall paper if one area is damaged leading to the replacement of the total area to maintain the color match .

2.3.4 NOT CONSIDERING THE LOCAL CLIMATIC CONDITIONS WHEN DESIGNING THE EXTERIOR SHAPE :

Buildings should be designed in such a way to avoid the collection of moisture , water or dust. Such design will help to reduce the maintenance effort required for continuous cleaning and repairing damages due to , e.g. water collection on building's roofs where moisture collection is always a problem.

2.3.5 INADEQUATE JOINTS BETWEEN FINISHED FACES :

Designers should specify the location of joints in floor slabs, walls, etc. Insufficient joints will cause cracking of the surface or overlapping of tiles or wall cracking due to thermal expansion .

2.4 DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY :

This section covers defects caused by improper planning and ignoring the requirements of preventive maintenance during the design stage such as:

2.4.1 NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT :

Buildings are designed so that the maintenance workers with their equipment can reach any place in the building to perform maintenance work. Ignoring such a factor will increase maintenance cost and efforts and obstruct preventive maintenance.

2.4.2 DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE :

Designers should always avoid permanent fixing of elements which need continuous maintenance, e.g. such as lamps, carpets,wash basin separator air filters and external windows .

2.4.3 NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN :

Designer should always design the building according to the available maintenance equipment in the market. The designer should be aware of the equipment available in the market so that he can consider it in his design. Such a problem arises during the cleaning of a building's exterior surface or windows or changing lamps in a very high area. Unavailability of the required equipment will increase the maintenance cost and obstruct preventive maintenance.

2.4.4 NOT CONSIDERING THE MAINTENANCE REQUIREMENTS IN DESIGN :

Designers should always consider the maintenance frequency of the building elements. Areas or elements to be maintained frequently should not be obstructed. And the designer should always consider in his design that the maintenance should be applied smoothly without interruption of the building's operation.

2.5 DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF:

Some of the defects are attributed to the consultant staff and administration such as:

2.5.1 LACK OF Q.A/Q.C. PROGRAM DURING DESIGN :

Qualified consultants usually implement Quality Assurance/Quality Control Programs on their design to reduce the number of defects and mistakes in the design. The Q.A/Q.C. Program requests that one group do the design and another group review it to highlight design defects.

2.5.2 POOR TECHNICAL UPDATING OR STAFF TRAINING :

Consultants should update and expose their staff to the latest construction material and methods in the market. In addition, they should maintain and keep track of the new materials redundant or construction methods and make sure that they perform adequately in the existing building environment .

2.5.3 HIRING UNQUALIFIED DESIGNERS :

To reduce overhead cost, consultantstend to hireunqualified (inexperienced) designers just because they are cheap and can perform the minimum standards of building design. In this case, the designer will produce poor design and specifications for the owner and contractor to follow.

2.5.4 DESIGNER FIELD EXPERIENCE :

Qualified designers should have office and field experience. If the designer has only office experience, he will not experience the faults happening at the construction site during the design implementation .

2.5.5 DESIGNER TECHNICAL BACKGROUND :

Efficient and cost effective building design depend to a great degree on the designer's technical background. The more the designer is exposed to the latest design technology , the better his output is and the less maintenance is required on the building.

2.5.6 DESIGNER IGNORANCE OF MATERIALS PROPERTIES :

The designer should always study the properties ofconstruction materials before they specify them in their design drawings.A material and proven to be good in one place or country, could be bad in another place because of the change of climatic conditions , or the poor experience of the construction contractor with this material. This leads to the improper installation or performance of the material .

2.5.7 MISJUDGMENT OF CLIMATIC CONDITIONS :

Most consultants require from the owner the land details only. They neglect to request more information on the land location to know if it is in a rainy area, where a good drainage system is required, or in a windy area, where some precaution is required. It is very important for the designer to be aware of all the

climatic details related to the design to avoid any maintenance problem that could arise from climatic conditions..

2.5.8 MISJUDGMENT OF USER IS INTENDED USE :

It is very important to know the building owner's intended use and plans, whether the building will be used publicly or privately, so the designer can decide the needed precautions to minimize maintenance cost and efforts. E.g. , public buildings need more maintenance precautions than private buildings.

2.6 DEFECTS DUE TO CONSTRUCTION DRAWING :

This section will discuss defects due to design faults in the drawings such as:

2.6.1 LACK OF REFERENCES :

Building design drawings should always show the cross section and detailed references clearly on the drawings. Lack of references will lead the contractor to construct the building according to his understanding and experience.

2.6.2 CONFLICTING DETAILS :

Most of the designs are performed separately for each section, for example civil drawings or mechanical drawings, without consulting other related parties. E.g. when the mechanical engineer makes some changes which will affect the civil work, this action can lead to conflicts which are usually left to the contractor to find and solve.

2.6.3 LACK OF DETAILS :

Most of the building designs lack cross sections, details of structural elements, joints, plumbing, drainage and electrical connections. These are left to the contractor's judgment and experience. As a result, the contractor may perform the job with poor quality and cause many maintenance defects which can only be discovered during building operation .

2.7 DEFECTS DUE TO LACK OF PERIODIC CONSTRUCTION INSPECTION :

This section discusses defects due to poor inspection practice, such as:

2.7.1 LACK OF INSPECTION :

It is well known that when construction inspection increases, quality increases. Therefore, the maintenance needed is reduced. Most of the building owners ignore this or reject it to save in building expenditure . As a result, cheap or unqualified contractors tend to cheat or perform poor workmanship which at the end affects the quality and increases maintenance cost.

2.7.2 UNQUALIFIED INSPECTOR :

Some owners insist on implementing the inspection program. But in some cases it could be that the inspector lacks experience, and the contractor performs the construction as per the inspector's guidance, resulting in poor construction.

2.7.3 PROPONENT NEGLIGENCE OF THE IMPORTANCE OF INSPECTION :

Most of the owners try to save money by selecting poor quality material, and avoiding inspection because of their ignorance of its importance. As a result, the contractor performs the job on his own without inspection .Some owners avoid inspection by performing the inspection themselves where they can improve little in the quality. But sometime they can affect the quality very badly .E.g. most of the owners ask contractors to add water to the concrete mix to make it more workable which will result into a very porous concrete and cause corrosion of steel bars

2.7.4 WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION :

Some owners insist on having an inspection program, but they make themselves the communication channel between the inspector and the contractor. This causes a lot of delays and any corrective action comes late, after the elements are already constructed with poor quality. In this case, the owner should make a direct communication channel with the assurance that the contractor performs the job as per the contract specification and with the approval of the inspector without the owner's full time involvement.

2.8 DEFECTS DUE TO CIVIL CONSTRUCTION :

2.8.1 INACCURATE MEASUREMENT :

Inaccurate measurement occurs where the contractor undermeasures or overmeasures the sizes of building elements, the location and the material ratios, for example increasing the gap between door and door frame or window and window frame, which causes water and dust leakage. Another case is where the contractor increases the water content in the concrete mix which causes porous concrete and at the end corrosion of steel bars and cracking of the concrete structure.

2.8.2 DAMAGED FORM WORK :

Damaged form work affects the quality by producing a honeycomb or porous concrete surface or surface cracks which will allow for moisture penetration and cause corrosion of steel bars.

2.8.3 EXCAVATION TOO CLOSE TO THE BUILDING :

Excavation next to an existing building usually causes soil settlement or vibration to the building's foundation .This action causes continuous wall cracking and requires continuous surface treatment.

2.8.4 PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE :

Painting is considered a continuous maintenance item either for redecoration or renewal purposes . But sometimes it can become a major maintenance item if it is performed improperly, such as painting on a wet surface or a salty surface or painting in humid weather which will result in the peeling of some of the paint and necessiate complete removal of the original paint and cleaning of the surface.

2.8.5 INADEQUATE WATER PROOFING AND DRAINAGE :

Water proofing and drainage are two of the items where contractors lack experience. Most of the time are performed wrongly or inadequately, specially at the joints, which results in water seepage through the roof ceiling, or block wall. Most buildings lack proper roof drainage or sewer drainage system.

2.8.6 INSUFFICIENT REINFORCEMENT CONCRETE COVER :

Most of the standards recommend the increase of concrete cover, for example ACI 301 specifies a concrete cover of 2" on beams and columns and 3" in foundations. Most of the contractors perform the job and ignore the importance of concrete cover and even perform the job with less than drawings requirement of one inch, which expedites the rate of reinforcement corrosion and causes concrete cracking.

2.8.7 COLD JOINTS :

Cold joints usually happen between new and old concrete or between new cement plastering or old plastering. Such joints if not treated properly will cause surface cracking and water seepage , e.g. in concrete water tanks or on basement walls.

2.8.8 LOSS IN ADHESION BETWEEN MATERIALS :

Loss in adhesion results when the material shel-life has expired,e.g. for paints, glue for tiles and PVC fittings, or when the material is used in the wrong place or for the wrong temperature such as using indoor sealants or indoor glue out doors.

2.8.9 EARLY FORM WORK REMOVAL :

Most contractors if not all would like to remove the form work as soon as possible and some of them even before the allowable time . This can cause permanent deflection and cracking of the structure. These cracks will cause the moisture to reach the steel and cause continuous corrosion and cracking of the building structural elements .

2.8.10 POOR SOIL COMPACTION :

Most contractors back-fill the soil in one rather than several layers. Therefore, they only compact the top layer. Since, the bottom soil is not compacted, it will settle at a later stage and cause settlement in the building which will cause continuous cracking in the building walls.

2.8.11 INADEQUATE CURING :

Contractors do not spend time and money on concrete curing. It is proven that curing is needed specially in a hot climate to reduce water loss in the

concrete ,the surface cracking in the concrete elements .Both defects could be a good source for steel bar corrosion. Even if they cure the concrete, they use salty water which will allow the salt to penetrate the concrete elements and cause corrosion of steel bars or cause loss of adhesion between cement plastering and the concrete or block surface .

2.8.12 LACK OF COMMUNICATION :

In Saudi Arabia, the construction industry recruits workers from different nations. Such a problem causes a communication barrier between the Construction Engineer and the Foremen and between the Forman and workers who at the end perform the actual job . Site workers will always perform the job as per their understanding. So, if they understand wrong, they will perform it wrong , e.g. use the wrong material or wrong fittings. Such a problem will not be discovered until the building is in use and operation .

2.9 DEFECTS DUE TO CONTRACTOR ADMINISTRATION :

Some of the defects are attributed to the contractor staff and administration such as:

2.9.1 NOT COMPLYING WITH SPECIFICATION :

Contractors tend to do things their own way and few of them follow the construction specification. As a result all the effort spent during the design stage is ignored. Such a problem will increase the maintenance work required during the operation of the building depending on the contractor's experience. If the contractor is well experienced, the maintenance effort needed will be less.

2.9.2 UNABLE TO READ DRAWINGS :

The owner should always make sure that the contractor engineer can read the drawings. Most of the design drawings usually are made in Arabic which the construction engineer is sometimes unable to read. . And if he can understand the steel and concrete schedules, he may not be able to read the details or the construction specification or references. Again such a problem depends on the construction engineer's experience. The more experienced he is , the fewer the defects will arise during building operation.

2.9.3 INSUFFICIENT SITE SUPERVISION :

Having multinational construction workers who speak different languages and vary in experience requires the site engineer to pay a great attention to his workers and direct them to avoid any problem on time. Insufficient site supervision can cause a lot of problems during the construction stage which will require a lot of maintenance during the building operation.

2.9.4 POOR COMMUNICATION WITH THE CONSULTANT AND THE OWNER :

If the contractor does not communicate with the owner and the designer for consultation or understanding of the specification, he will depend on his experience in performing the job . This can cause a lot of maintenance defects depending on his experience.

2.9.5 UNQUALIFIED SUPERVISION :

The Contractor Engineer is the main controller of the construction quality. A qualified technical and administrative engineer can reduce the maintenance cost and time dramatically. Problems are obvious in buildings built with poor management and unqualified engineers.

2.9.6 SPEEDY COMPLETION OR CHEAP QUALITY WORK :

Contractors tend to do the job which needs tools or equipment quickly to reduce rental time . In addition they always tend to select cheap quality material to save money. This problem affects maintenance dramatically. If the contractor selects the right material or performs the job correctly the maintenance required in the future will be reduced.

2.9.7 UNQUALIFIED WORK FORCE :

Contractor quality is affected by the site engineer and the work force. Both parties have to be well experienced. If the supervision is good but the implementation is poor because of poor workmanship, the maintenance defects will increase during the building operation. Therefore, both the construction supervision and construction workers should be qualified.

2.9.8 MULTINATIONAL CONSTRUCTION EXPERIENCE :

One of the items that affects construction quality is the difference in the contractor's workers experience. Workers perform the job according to their past experience. Some of the workers can utilize the available equipment but others cannot. Therefore, having the right tool does not mean the job will be performed properly. Both the right tool and the trained workers should be available to perform the job properly.

2.10 DEFECTS DUE TO CONSTRUCTION MATERIALS :

Maintenance defects could be caused by the wrong selection or use of material such as:

2.10.1 DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIALS :

One of the maintenance problems comes from combining materials with different thermal expansion, such as tile glue where the cement thermal expansion is different than the glue. This defect will cause the two materials to separate or dis-bond .

2.10.2 SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR EXISTING CLIMATIC CONDITIONS :

Using material suitable for cold climatic conditions for hot climatic conditions or indoor materials for out door conditions, will cause the material to perform inadequately and require replacement in a short time

2.10.3 USE OF NONDURABLE MATERIAL :

Cheap or low quality material needs continuous repair and maintenance. Maintenance expenditure and efforts can be reduced by selecting good durable materials.

2.10.4 USE OF EXPIRED MATERIAL :

Use of expired material at the construction stage will require the owner to replace it at the operation stage, e.g. expired tile glue or paints.

2.10.5 POOR MATERIAL HANDLING & STORAGE :

Poor handling and storage of material affect the material's quality which will affect the building quality and increase maintenance defects. For example storing building paints outside in the sun will affect paint quality and require replacement in a short time after the building is in operation.

2.11 DEFECTS DUE TO CONSTRUCTION EQUIPMENT :

In addition equipment can be a source of building defects through :

2.11.1 WRONG USE OF EQUIPMENT :

Good equipment is the means to perform a good quality job. Therefore, if the equipment is used for the wrong job or misused to perform a job, the quality of construction will be affected, as, for example, when using a wood saw for plastic pipe cutting or a brush instead of a roller for texture paints.

2.11.2 INADEQUATE PERFORMANCE OF EQUIPMENT :

Equipment performance affects building quality. If the equipment or tools are performing poorly, the job will be done poorly and accordingly the building maintenance defects will increase.

2.11.3 LACK OF REQUIRED AMOUNT OF EQUIPMENT :

Having enough equipment will help in performing the job properly. Lackof enough equipment will cause the contractor to perform his work by hand where a special tool is required, as when a level hose is used where a thedolite is needed for leveling roof slab for drainage. As a result, the job will be done poorly and requires continuous maintenance after some time of operation.

2.12 DEFECTS DUE TO CONSTRUCTION SPECIFICATION :

In addition to clear construction drawings ,the construction specification should be clear also. Maintenance defects can be caused.

2.12.1 UNCLEAR SPECIFICATION :

Poor specification will cause the contractor to perform the job to his own standard and interpretation. For an unqualified contractor it means poor quality work and more maintenance defects.

2.12.2 NOT DEFINING ADEQUATE MATERIAL TYPES :

Weak or inadequate designs specify the materials in general without detailed specifications. Such a problem will allow the contractor to provide the material to meet the general guidelines, where it will not serve the job correctly. For example, if the design specifies only sealant without specifying the type ,the contractor will select the cheapest. Another example is when the design specify the strength of concrete as 3,500 psi without specifying the w/c ratio and the allowable dissolved salts in the concrete to prevent steel bar corrosion . As a result, continuous maintenance and replacement of material will be required at the operation stage.

2.12.3 NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE :

Most construction specifications do not specify the relationship between the owner, the inspector and the contractor ,and how to communicate properly to avoid any defect or solve any problem . In addition it does not specify the responsibility of each party . Therefore, the system becomes loose and many defects can happen during the construction stage without correction.

2.12.4 NOT SPECIFYING THE ALLOWABLE LOAD LIMITS :

This can cause the building to be overloaded either with dead or live loads. For example as using a normal activity room for storage or filing cabinets will cause the load to exceed the allowable limits and cause structural cracks or failures.

2.12.5 SPECIFYING INADEQUATE MIX DESIGN :

Most designers design the concrete mix to meet the strength requirements and ignore the quality and durability side. The concrete durability is affected highly by the salt content in the sand, water ,and aggregate. If the salt content exceeds the allowable limit, the concrete is contaminated and considered as a corrosion environment. In addition, the w/c ratio should be minimized without affecting the workability of the concrete to increase the impermeability.

2.13 SUMMARY :

The first part of the chapter demonstrated the types of civil and architectural defects that can happen during the design and construction stages and affect maintenance. There are sixty seven defects grouped into eleven major areas .Thirty five of the defects are related to the design stage and the other thirty two defects are related to the construction stage. The second part of the chapter discussed each defect in detail and explained how each defect can affect or increase building maintenance. The following chapter is devoted to a detailed survey of the three main parties in building construction :contractors, consultants and owners. It also includes research methodology and sampling techniques used to measure the severity index of the major maintenance defect factors.

CHAPTER 3

THE SURVEY

3.1 INTRODUCTION :

The main objective of this research is to investigate the civil and architectural faults that happen during the design and construction stages and that affect maintenance in the Eastern Province. In addition it will :

1) Determine the severity index of all factors for all parties, classify the factors by severity and recommend corrective action for the most severe factors.

2) Determine the severity index of all parties for each factor within the group and classify them by severity .

3) Determine one severity index for each main group and classify them by severity.

4) Determine the severity index of all factors by owner, consultant, maintenance contractor, construction contractor, and construction maintenance contractor individually.

This chapter includes the research methodology , and the sampling and statistical techniques used to perform this investigation .

3.2 QUESTIONNAIRE DESIGN :

The investigation to determine the defects (factors) that might affect maintenance and their degree of effectiveness was made in three stages.

STAGE - I :

Since there is no one reference to determine the design and construction factors that affect maintenance and since owners, designers, and contractor engineers have different views, the following methodology was followed to identify all the defects that affect building maintenance :

Step 1 : A literature search was made on the factors that affect maintenance.

Step 2 : In addition, data was gathered through site visits, interviews and discussions with owners, designers , and contractors .

Step 3 : From the preliminary interviews and the literature review, a questionnaire was formulated .

The questionnaire is mainly categorized as follows :

01. DEFECTS IN CIVIL DESIGN.

02. ARCHITECTURAL DEFECTS IN DESIGN.

03. DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY.

04. DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF.

05. DEFECTS DUE TO CONSTRUCTION DRAWINGS.

06. DEFECTS DUE TO CONSTRUCTION INSPECTION.

07. DEFECTS DUE TO CIVIL CONSTRUCTION.

08. DEFECTS DUE TO CONTRACTOR ADMINISTRATION.

09. DEFECTS DUE TO CONSTRUCTION MATERIALS.

10. DEFECTS DUE TO CONSTRUCTION EQUIPMENT.

11. DEFECTS DUE TO SPECIFICATION .

Since some factors could have more effect than others , a weight was established for each factor in the questionnaire. Each factor was measured with four measures: "Does not affect" rated 0, "Slightly affects" rated 1, "Moderately affects" rated 2 and "Strongly affects" rated 3.In addition each section was subcategorized as shown in Appendix (I).

STAGE - 2 :

A pilot study was performed just before the final questionnaire draft had been approved. A sample of Engineers involved in the building construction

activities was selected from the Dhahran and Dammam area. They were asked to fill out the questionnaire. This pilot study served to:

- Test the adequacy of the questions;

- point out places of ambiguities;

- incorporate more possible answers and increase the lists of choices;

- review the adequacy of provided space for each question, and estimate the time needed to fill out the questionnaire .

STAGE - 3 :

Then the questionnaire was distributed by hand to the concerned respondents (evaluators) questionaires with all the questions answered were collected , and uncompleted questionnaires were excluded.

The questionnaires were distributed to 20 owners, 30 consultants , and 90 building contractors (30 maintenance contractors, 60 construction contractors).

Respondents were asked to give their opinion of the presented factors that affect maintenance and in addition to measure the degree of importance of each. Their comments are presented in Chapter - 4.

STAGE - 4 :

The fourth stage consists of examining the questionnaire collected from the evaluators and obtaining the weighted overall factors affecting building maintenance using the weights obtained from the responses to the questionnaires.

3.3 Sample Size :

In this research, the questionnaire will be distributed to random selection of contractors, consultants and owners.

In the selection process, there are four restrictions, namely,

1. To building contractors who are registered and categorized in the Dammam Chamber of Commerce including the third degree.

2. To any building projects in the Eastern Province of Saudi Arabia.

3. To owners of tall buildings and buildings complexes .

4. To Eastern Province consultant .

In this research, the population will be divided into three strata :

Stratum I. Owners

Stratum II. Consultants

Stratum III. Building Contractors (construction & maintenance).

For Stratum I, the available number of owners owning large buildings or building complexes in the Eastern Province is estimated to be 300 . The sample size of owners to be surveyed will be calculated by the following formula :

$$n = [(ts_1 / d) **2)] \ / \ [1 + 1/N* (ts_1 / d) **2)]$$ e.q. 3.1 (KENDALL,1960)

where

n = Sample size

N = Sample Population

t : $t\alpha /2$ is the abscissa of the normal curve that cuts off an area of $\alpha = 0.05$ at the tails, $t\alpha / 2 = 1.960$

d : the expected error in the estimate. The amount of accuracy $(1 - \alpha)\% = 0.95$

S = pq , p: is the proportion of the characteristic under investigation. the maximum value of p = 1/2 ; q = (1-p) = 1/2

$$n_1 = [(2.02 X 0.5/ 0.05) ** 2] / [1 + (1 /300)(2.02 X 0.5/ 0.05)**2]$$

n_1 = 172	n_6 = 44	n_{11} = 23
n_2 = 109	n_7 = 38	n_{12} = 20
n_3 = 80	n_8 = 33	n_{13} = 19
n_4 = 63	n_9 = 29	
n_5 = 52	n_{10} = 26	

It is better to stop here because the difference becomes smaller. So the total owners sample is 20.

For Stratum II, there are 60 consultants in the Eastern Province of Saudi Arabia. Using Formula 3.1 :

$$n_1 = [(2.02 \times 0.5/ 0.05) ** 2] / [1 + (1 /60)(2.02 \times 0.5/ 0.05)**2]$$

$n_1 = 52$	$n_4 = 14$
$n_2 = 27$	$n_5 = 11$
$n_3 = 19$	$n_6 = 9$

It is better to stop here and since the opinion of the consultant will be more precise and related to the subject studied , a sample size of 30 will be selected.

For Stratum III, the number of available building contractors in the Eastern Province is 900 , contractors from Mumtazazah to the 3rd degree at the Chamber of Commerce.This includes construction and maintenance contractors.
The contractor sample size is calculated by using Equation 3.1 :

$$n_1 = [(2.02 \times 0.5/ 0.05) ** 2] / [1 + (1 /900)(2.02 \times 0.5/ 0.05)**2]$$

$n_1 = 281$	$n_6 = 108$
$n_2 = 214$	$n_7 = 96$
$n_3 = 172$	$n_8 = 86$
$n_4 = 144$	$n_9 = 78$
$n_5 = 124$	$n_{10} = 71$

It is better to stop here because the difference becomes smaller and since the output of the contractors will be more actual, a sample size of 90 will be selected.

3.4 SCORING SYSTEM :

For the first part of the questions, no scoring was used since these consist of general information related to respondents. For the second part of the questions, the importance of the faulty factors are considered. The option given for each question is on a four-point scale.

As mentioned earlier (Section 1.5), each factor has a severity index and the severity index is controlled by Equation 1.1. The equation contains the constant a_i.

This constant attempts to determine quantitative measures as an indicator of comparable responses. This simply means that the respondent keeps in mind a four-point scale while answering.

The importance index could be obtained for each factor as follows :

$$\text{Severity Index (IS)} = [\ \sum_{i=1}^{4}(a_i \ X \ x_i) / 4\ ] \ X \ 100\%$$

Where :

a_i = constant expressing the weight given to (i th) response.

i = 1,2,3,4 where

a_1 = 0 is equivalent to " Does not affect ".

a_2 = 1 is equivalent to " Slightly affects ".

a_3 = 2 is equivalent to " Moderately affects ".

a_4 = 3 is equivalent to " Strongly affects ".

x_i = the variable expressing the degree of importance of each factor.

x_1 = the frequency of " Does not affect " responses.

x_2 = the frequency of " Moderately affects " responses.

x_3 = the frequency of " Moderately affects " responses.

x_4 = the frequency of " Strongly affects " responses.

For illustration, consider the following example. Consider the E3 factor "Lack of Detail". The frequency of this factor is :

Strongly Affects	=	47	=	33.57 %
Moderately Affects	=	79	=	56.42 %
Slightly Affects	=	11	=	7.85 %
Does Not Affect	=	3	=	2.14 %

The severity index is

$$Is = [(3 * 33.57 + 2 * 56.42 + 1 * 7.85 + 0 * 2.14) / 3] \times 100\%$$

$$= 73.81$$

Accordingly, if all parties answer any factor by "Does not affect" then the severity index is = 0, which means that this factor is not relevant and the last in the rank. On the other hand, if all answers are "Strongly affects", then the severity index is = 1 and means that it is the most important factor and the first in the rank. Consequently, this will give a scale from 0 to 1 or from 0% to 100%.

3.5 SUMMARY :

This chapter has explained the approach used to develop the final questionnaire and the way data are collected . Questionnaires were distributed and collected by the researcher. A random sample of 90 building contractors (construction & maintenance contractors), 30 consultants and 20 owners were surveyed. Out of the 90 contractors 30 were maintenance contractors, and the rest were building contractors. The sampling and scoring techniques were presented. The next chapter is devoted to the analysis and discussion of the survey results.

CHAPTER 4

FINDINGS AND RESULTS

Chapter four presents the survey data and discusses the results obtained from these data.

4.1 Statistical Methods :

The following statistical methods were used in this report :

1. Tabulation and Cross Tabulation
2. Statistical Techniques
3. Correlation
4. Ranking

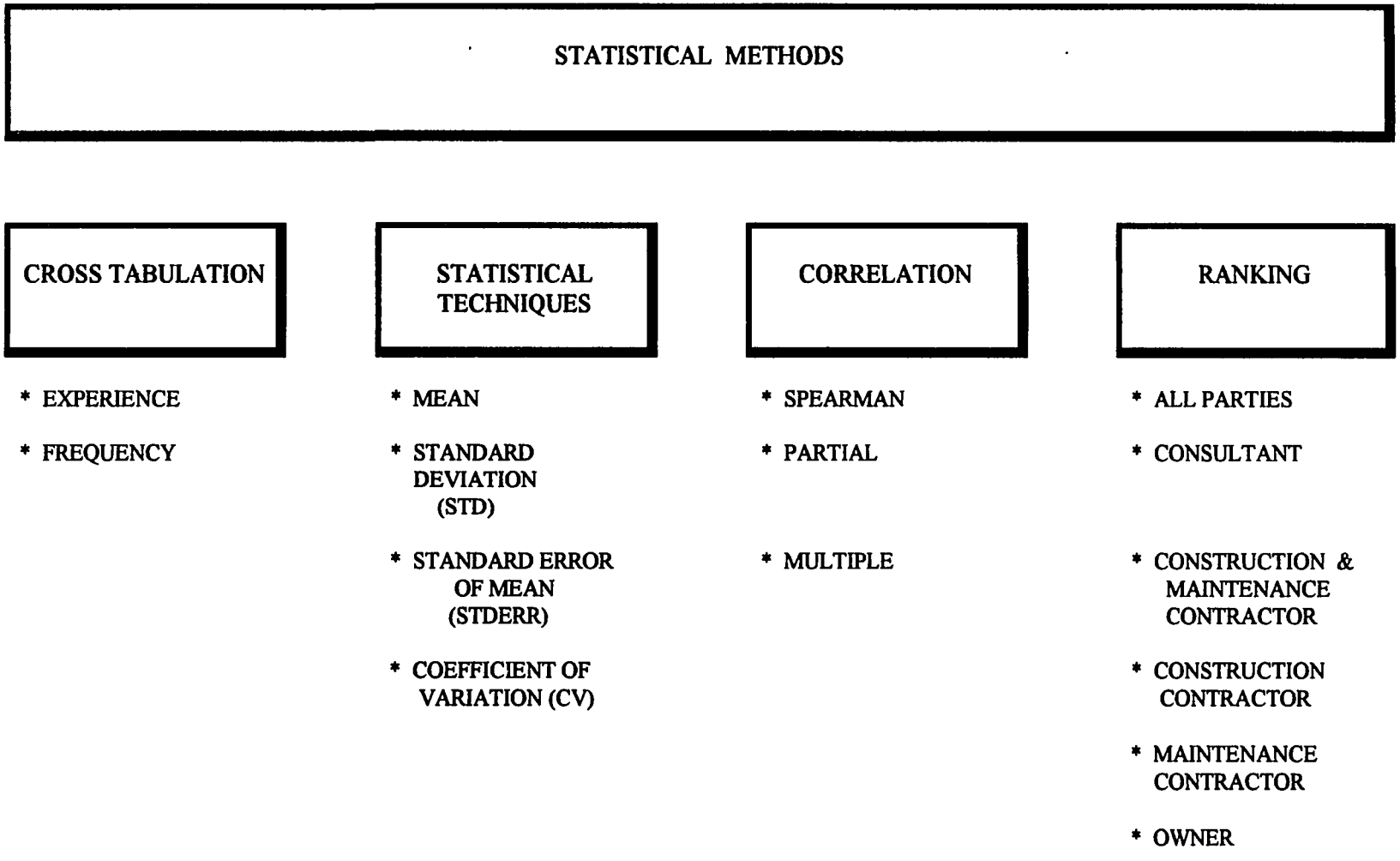
Figure 4.1 shows these statistical methods.

The data resulting from this study were analyzed and are presented in 18 tables using these methods. An explanation of each of these methods follows this section.

4.1.1 TABULATION AND CROSS-TABULATION :

Cross tabulation involves placing the survey data into tabular form (a two-way table) so that the functional relation of these data can be described. Question 1 in the questionnaire (Part A) is crossed with Question 2. The results are shown in Table 4-1. Additionally, Part B was crossed with the maintenance defects frequency of all parties ,the results are shown in appendix II .

FIG 4 - 1


STATISTICAL METHODS
CROSS TABULATION
* EXPERIENCE
* FREQUENCY
STATISTICAL TECHNIQUES
* MEAN
* STANDARD DEVIATION (STD)
* STANDARD ERROR OF MEAN (STDERR)
* COEFFICIENT OF VARIATION (CV)
CORRELATION
* SPEARMAN
* PARTIAL
* MULTIPLE
RANKING
* ALL PARTIES
* CONSULTANT
* CONSTRUCTION & MAINTENANCE CONTRACTOR
* CONSTRUCTION CONTRACTOR
* MAINTENANCE CONTRACTOR
* OWNER

4.1.2 STATISTICAL TECHNIQUES :

Table 4.2 shows the statistical techniques used to analyze the collected data. The purpose of this table is to present the techniques that aid the researcher in interpretation of the existing information. This table contains the computation of of the following statistics.

1. Mean $= X = \sum_{h=1}^{3} W_h * \overline{X}_h$ (Eq. 4.1) (AL-HAZMI,1987)

$W_h = n_h / N$, $h = 1,2,3$

2. Standard Deviation =

$$S_x = [\sum_{h=1}^{3} W_h^2 * S_{hx}^2]^{1/2}$$ (Eq.4.2) (AL-HAZMI,1987)

3. Standard Error of Mean =

$$S_x = S_x / N^{1/2}$$ (Eq.4.3) (AL-HAZMI,1987)

The standard error of mean is used to describe the deviation of sample means around their population means.

4. 95% confidence interval = $\overline{X} \pm 1.9 \; SE \; (\overline{X})$ (Eq. 4.4) (AL-HAZMI,1987)

Samples usually are not perfect replicas of the population from which they were drawn, which means that the researcher is never sure how close the sample value is to the population value. While sample data would not determine the exact population value, this data can be used to estimate a value or an interval which is considered to contain the population value .The sample value is called a point estimate , and this interval is called a confidence interval and its size depends upon the degree of confidence desired in the sample's results by the researcher. The confidence coefficient used in this thesis is 95% unless otherwise mentioned. This means that if a large number of probability samples were taken, 95% of these samples would contain the actual mean of the universe within an interval of[+

TABLE 4 - 1

CROSS TABULATION OF THE EXPERIENCE OF EACH OF THE TEST PARTIES

FREQUENCY PERCENT ROW PCT COL. PCT	EXP< 5 YEARS	5 < EXP < 10 YEARS	10 < EXP YEARS	TOTAL
CONSTRUCTION CONTRACTOR	1 0.71 1.67 11.11	42 30.00 70.00 54.55	17 12.14 28.33 31.48	60 42.86
MAINTENANCE CONTRACTOR	0 0.00 0.00 0.00	14 10.00 46.67 18.18	16 11.43 53.33 29.63	30 21.43
CONSULTANT	3 2.14 10.00 33.33	16 11.43 53.33 20.78	11 7.86 36.67 20.37	30 21.43
OWNER	5 3.57 25.00 55.56	5 3.57 25.00 6.49	10 7.14 50.00 18.52	20 14.29
TOTAL	9 6.43	77 55.00	54 38.57	140 100.00

TABLE 4-2

STATISTICAL TECHNIQUES USED IN THE ANALYSIS OF DATA

Q #	FACTORS	MEAN	STD	STD ERROR OF MEAN	VAR	COEF. OF VARIA-TION CV	95% CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT
A	DEFECTS IN CIVIL DESIGN							
1	INADEQUATE PROVISIONS FOR MOVEMENT	1.85	0.79	0.07	0.62	42.48	1.72	1.98
2	IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS	2.25	0.58	0.05	0.33	25.64	2.16	2.34
3	IGNORING BIOLOGICAL EFFECTS	1.76	0.79	0.07	0.63	45.22	1.63	1.88
4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	2.39	0.81	0.07	0.66	33.89	2.26	2.52
5	IGNORING VARIATION IN SOIL CONDITIONS	2.24	0.79	0.07	0.62	35.02	2.12	2.37
6	IGNORING LOAD IMPACT ON STRUCTURE STABILITY	1.98	0.82	0.07	0.67	41.33	1.85	2.11
7	EXCEEDING ALLOWABLE DEFLECTION	1.93.	0.84	0.07	0.70	43.38	1.79	2.06
8	IGNORING WIND EFFECTS ON THE STRUCTURE	1.87	0.76	0.06	0.57	40.46	1.75	1.99
9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	2.21	0.82	0.07	0.67	37.05	2.08	2.35
10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	1.99	0.85	0.07	0.72	42.71	1.85	2.12

TABLE 4-2
(Contd.)

STATISTICAL TECHNIQUES USED IN THE ANALYSIS OF DATA

Q #	FACTORS	MEAN	STD	STD ERROR OF MEAN	VAR	COEF. OF VARIA-TION CV	95% CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT
B	ARCHITECTURAL DEFECTS IN DESIGN							
1	NARROW STAIRS, PASSAGES & DOORS	2.16	0.77	0.07	0.59	35.72	2.03	2.28
2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	2.29	0.65	0.06	0.42	28.41	2.19	2.40
3	SPECIFYING FINISHINGS WHICH NEED TO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	1.49	0.84	0.07	0.70	55.96	1.36	1.63
4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	1.92	0.73	0.06	0.53	38.01	1.80	2.04
5	INADEQUATE JOINTS BETWEEN FINISHED FACES	1.99	0.64	0.05	0.41	32.13	1.89	2.10
C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY							
1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	2.16	0.66	0.06	0.44	30.66	2.06	2.27
2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	1.86	0.78	0.07	0.61	41.80	1.74	1.99
3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	2.04	0.57	0.05	0.32	27.89	1.94	2.13
4	NOT CONSIDERING THE MAINTENANCE	1.97	0.76	0.06	0.57	38.45	1.85	2.09

TABLE 4-2
(Contd.)

STATISTICAL TECHNIQUES USED IN THE ANALYSIS OF DATA

Q #	FACTORS	MEAN	STD	STD ERROR OF MEAN	VAR	COEF. OF VARIA-TION CV	95% CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT
D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF							
1	LACK OF QA/QC PROGRAM DURING DESIGN	1.94	0.87	0.07	0.76	32.48	1.80	2.08
2	POOR TECHNICAL UPDATING OR STAFF TRAINING	2.19	0.74	0.06	0.54	33.65	2.07	2.30
3	HIRING UNQUALIFIED DESIGNERS	2.39	0.76	0.06	0.57	31.58	2.27	2.51
4	DESIGNER FIELD EXPERIENCE	2.14	0.71	0.06	0.50	32.91	2.03	2.26
5	DESIGNER TECHNICAL BACKGROUND	2.03	0.84	0.07	0.70	41.37	1.89	2.16
6	DESIGNER IGNORANCE OF MATERIALS PROPERTIES	2.21	0.80	0.07	0.64	36.25	2.08	2.34
7	MISJUDGEMENT OF CLIMATIC CONDITIONS	2.02	0.73	0.06	0.54	36.32	1.90	2.14
8	MISJUDGEMENT OF USER'S INTENDED USE	1.74	0.87	0.07	0.75	49.81	1.60	1.88

TABLE 42
(Contd.)

STATISTICAL TECHNIQUES USED IN THE ANALYSIS OF DATA

Q #	FACTORS	MEAN	STD	STD ERROR OF MEAN	VAR	COEF. OF VARIA-TION CV	95% CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT
E	DEFECTS DUE TO CONSTRUCTION DRAWINGS							
1	LACK OF REFERENCES	1.91	0.66	0.06	0.43	34.39	1.80	2.01
2	CONFLICTING DETAILS	2.20	0.64	0.05	0.41	28.95	2.10	2.30
3	LACK OF DETAILS	2.21	0.68	0.06	0.46	30.54	2.11	2.32
F	DEFECTS DUE TO CONSTRUCTION INSPECTION							
1	LACK OF INSPECTION	2.20	0.75	0.06	0.56	34.14	2.08	2.32
2	UNQUALIFIED INSPECTOR	2.16	0.80	0.07	0.64	37.02	2.04	2.29
3	PROPONENT (OWNER) NEGLIGENCE OF THE IMPORTANCE OF INSPECTION	2.14	0.73	0.06	0.54	34.26	2.02	2.25
4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	2.07	0.80	0.07	0.64	38.69	1.94	2.20

TABLE 4-2
(Contd.)

STATISTICAL TECHNIQUES USED IN THE ANALYSIS OF DATA

Q #	FACTORS	MEAN	STD	STD ERROR OF MEAN	VAR	COEF. OF VARIA-TION CV	95% CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT
G	DEFECTS DUE TO CIVIL CONSTRUCTION							
1	INACCURATE MEASUREMENT	2.09	0.89	0.08	0.79	42.47	1.95	2.24
2	DAMAGED FORMWORK	2.00	0.74	0.06	0.55	36.97	1.88	3.12
3	EXCAVATION TOOL CLOSE TO THE BUILDING	2.03	0.81	0.07	0.66	40.08	1.90	2.16
4	PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE	2.04	0.76	0.06	0.58	37.46	1.91	2.16
5	INADEQUATE WATER PROOFING AND DRAINAGE	2.29	0.75	0.06	0.57	32.89	2.16	2.41
6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	2.24	0.79	0.07	0.63	35.43	2.11	2.36
7	COLD JOINTS	1.79	0.77	0.06	0.59	42.90	1.66	1.91
8	LOSS IN ADHESION BETWEEN MATERIALS	2.03	0.81	0.07	0.66	40.08	1.90	2.16
9	EARLY FORMWORK REMOVAL	1.95	0.81	0.07	0.65	41.41	1.82	2.08

TABLE 4-2
(Contd.)
STATISTICAL TECHNIQUES USED IN THE ANALYSIS OF DATA

Q #	FACTORS	MEAN	STD	STD ERROR OF MEAN	VAR	COEF. OF VARIA-TION CV	95% CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT
0	POOR SOIL COMPACTION	2.12	0.76	0.06	0.58	35.97	2.00	2.24
1	INADEQUATE CURING	2.10	0.80	0.07	0.64	38.02	1.97	2.23
2	LACK OF COMMUNICATION	2.02	0.72	0.06	0.52	35.83	1.91	2.14
H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION							
1	NOT COMPLYING WITH SPECIFICATION	2.34	0.63	0.05	0.40	26.98	2.24	2.44
2	INABILITY TO READ THE DRAWINGS	2.28	0.75	0.06	0.56	32.90	2.16	2.40
3	INSUFFICIENT SITE SUPERVISION	2.24	0.63	0.05	0.40	28.23	2.14	2.34
4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	2.11	0.69	0.06	0.47	32.55	2.00	2.22
5	UNQUALIFIED SUPERVISION	2.14	0.73	0.06	0.53	33.85	2.03	2.26
6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	2.15	0.78	0.07	0.60	36.12	2.03	2.27
7	UNQUALIFIED WORK FORCE	2.29	0.78	0.07	0.61	34.13	2.16	2.41
8	MULTINATIONAL CONSTRUCTION EXPERIENCE	1.52	0.79	0.07	0.63	51.98	1.39	1.65

TABLE 4-2
(Contd.)

STATISTICAL TECHNIQUES USED IN THE ANALYSIS OF DATA

Q #	FACTORS	MEAN	STD	STD ERROR OF MEAN	VAR	COEF. OF VARIA-TION CV	95% CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT
I	DEFECTS DUE TO CONSTRUCTION MATERIALS							
1	DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIAL	1.96	0.69	0.06	0.47	35.14	1.85	2.07
2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR EXISTING CLIMATIC CONDITIONS	2.22	0.76	0.06	0.58	34.18	2.10	2.34
3	USE OF NONDURABLE MATERIAL	2.19	0.77	0.06	0.59	34.98	2.07	2.32
4	USE OF EXPIRED MATERIAL	2.08	0.87	0.07	0.76	42.04	1.94	2.22
5	POOR MATERIAL HANDLING & STORAGE							
J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT							
1	WRONG USE OF EQUIPMENT	1.81	0.75	0.06	0.57	41.60	1.69	1.94
2	INADEQUATE PERFORMANCE OF EQUIPMENT	1.78	0.72	0.06	0.52	40.50	1.66	1.89
3	LACK OF REQUIRED AMOUNT OF EQUIPMENT	1.61	0.72	0.06	0.51	44.59	1.49	1.72

TABLE 4-2
(Contd.)

STATISTICAL TECHNIQUES USED IN THE ANALYSIS OF DATA

Q #	FACTORS	MEAN	STD	STD ERROR OF MEAN	VAR	COEF. OF VARIA-TION CV	95% CONFIDENCE INTERVAL LOWER LIMIT	UPPER LIMIT
K	DEFECTS DUE TO SPECIFICATION							
1	UNCLEARED SPECIFICATION	1.94	0.78	0.07	0.62	40.38	1.82	2.07
2	NOT DEFINING ADEQUATE MATERIALS	2.07	0.76	0.06	0.57	36.46	1.95	2.19
3	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	1.66	0.89	0.07	0.79	53.26	1.52	1.81
4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	1.82	0.87	0.07	0.75	47.61	1.68	1.96
5	SPECIFYING INADEQUATE CONCRETE MIX DESIGN	2.13	0.83	0.07	0.69	38.98	2.00	2.26

1.96 SE (X)]. For example, Question B1 has the following 95% confidence interval :

The Lower Limit (LL) = 2.03

The Upper Limit (UL) = 2.28

According to the scale used in the analysis of data (see Figure 4.2), if the total population 900 + 300 + 60 were taken; 95% of these samples would contain the actual mean of the Universe (2.00) which is the "Moderately Affects" response :

Fig 4-2
Scoring Scale

1	2	3	4
Strongly Affects	Moderately Affects	Slightly Affects	Does Not Affect

5. Coefficient of Variation (C.V.) :

$$C.V. = (Sx / \overline{X}) * 100 \qquad \text{(Eq. 4.5)}$$

(AL-HAZMI,1987)

4.1.3 CORRELATION :

Correlation (r) is used to find the relationship existing among different factors or parties (consultants, contractors and owners) and the degree of this relationship. There are three methods suitable for determining association among the parties included in this study. They are the Spearmen correlation, the Partial correlation, and the Multiple correlation

Spearmen correlation :

The Spearmen correlation is used to find and compare how well any two parties agree while ignoring the third party completely. Table 4.3 shows the calculations used to find the agreement between any two parties. For example, the agreement between the contractor and the consultant (r_{12}) is 82.80% when the owner is not considered. This confirms that there is a substantial correlation between the two parties.

Partial correlation :

Partial correlation is used to find and compare how well any two parties agree while holding the third party constant .The following equations are used for the calculations, namely :

1. $$r_{12.3} = [r_{12} - (r_{13} x r_{23})] / [(1- r_{13}^2) (1 - r_{23}^2)]^{1/2}$$ (Eq.4.6) (KENDALL,1960)

2. $$r_{13.2} = [r_{13} - (r_{23} x r_{12})] / [(1- r_{23}^2) (1 - r_{12}^2)]^{1/2}$$

3 $$r_{23.1} = [r_{23} - (r_{12} x r_{13})] / [(1- r_{12}^2) (1 - r_{13}^2)]^{1/2}$$

Where :

$r_{12.3}$ = The agreement between the Construction & Maintenance Contractors & the Consultant when the Owner's rank is held constant.

$r_{13.2}$ = The agreement between the Construction & Maintenance Contractors and the Owner when the Consultant is rank is held constant.

$r_{23.1}$ = The agreement between the Consultant and owner when the Maintenance & Construction Contractor rank is held constant.

TABLE 4-3

SPEARMAN RANK CORRELATION

	RANK BY					DIFFERENCE BETWEEN (D/D^2)							
Q #	CONTR CM 1	CONSL CS 2	Owner O 3	Construction Contr. C 4	Maintenance Contr. M 5	CM-CS D_{12}	(CM-CS)^2 D^2_{12}	CM-O D_{13}	(CM-O)^2 D^2_{13}	CS-O D_{23}	(CS-O)^2 D^2_{23}	C-M D_{45}	(C-M)^2 D^2_{45}
A1	58.5	59.5	50	55	48	3.5	12.25	10.5	110.25	7	49	9.5	90.25
A2	75	15	2.5	28	7.5	20.5	420.25	0	0	20.5	420.25	12.5	156.25
A3	52	54	50	65	67	13	169	15	225	2	4	4	16
A4	1	1	19.5	3	2.5	2	4	1.5	2.25	0.5	0.25	18.5	342.25
A5	9	6	19.5	5	34	4	16	25	625	29	841	13.5	182.25
A6	44.5	51.5	24.5	40	48	4.5	20.25	3.5	12.25	8	64	27	729
A7	56.5	51.5	58.5	40	34	16.5	272.25	22.5	506.25	6	36	7	49
A8	52	56	46	55	54	3	9	2	4	1	1	10	100
A9	13.5	18.5	9.5	14	21.5	0.5	0.25	8	64	7.5	56.25	9	81
A10	42.5	40	46	43.5	48	1	1	5.5	30.25	4.5	20.25	6	36
B1	20.5	9	40	31	16	10.5	110.25	4.5	20.25	15	225	31	961
B2	2	3	6.5	25	21.5	23	529	19.5	380.25	3.5	12.25	3.5	12.25
B3	65	63	66	67	61	2	4	4	16	6	36	3	9
B4	46.5	40	58.5	60	38	13.5	182.25	8.5	72.25	22	484	18.5	342.25
B5	41	32.5	50	51.5	38	10.5	110.25	3	9	13.5	182.25	17.5	306.25
C1	24.5	18.5	35	28	7.5	3.5	12.25	17	289	20.5	420.25	16.5	272.25
C2	58.5	51.5	61.5	55	38	3.5	12.25	20.5	420.25	17	289	10	100
C3	46.5	49	35	28	21.5	18.5	342.25	25	625	6.5	42.25	14	196
C4	56.5	61	30.5	36	12	20.5	420.25	44.5	1980.25	24	576	30.5	930.25
D1	49	56	27.5	43.5	54	5.5	30.25	5	25	10.5	110.25	28.5	812.25

TABLE 4-3
(Contd.)

SPEARMAN RANK CORRELATION

	RANK BY					DIFFERENCE BETWEEN (D/D^2)							
Q #	CONTR CM 1	CONSL CS 2	Owner O 3	Construction Contr. C 4	Maintenance Contr. M 5	CM-CS D_{12}	(CM-CS)^2 D^2_{12}	CM-O D_{13}	(CM-O)^2 D^2_{13}	CS-O D_{23}	(CS-O)^2 D^2_{23}	C-M D_{45}	(C-M)^2 D^2_{45}
D2	19	23.5	19.5	3	38	16	256	19	361	35	1225	4	16
D3	3	2	14.5	1	7.5	2	4	4.5	20.25	6.5	42.25	12.5	156.25
D4	24.5	18.5	35	20	30.5	4.5	20.25	6	36	10.5	110.25	16.5	272.25
D5	44.5	46.5	40	36	16	8.5	72.25	28.5	812.25	20	400	6.5	42.25
D6	13.5	30	4.5	20	21.5	6.5	42.25	8	64	1.5	2.25	25.5	650.25
D7	35.5	31	43.5	36	58.5	0.5	0.25	23	529	22.5	506.25	12.5	156.25
D8	63	65.5	53.5	57.5	42.5	5.5	30.25	20.5	420.25	15	225	12	144
E1	49	37.5	61.5	53	58.5	4	16	9.5	90.25	5.5	30.25	24	576
E2	16	9	24.5	20	21.5	4	16	5.5	30.25	1.5	2.25	15.5	240.25
E3	17.5	7	35	9.5	12	8	64	5.5	30.25	2.5	6.25	28	784
F1	13.5	18.5	9.5	6.5	38	7	49	24.5	600.25	31.5	992.25	9	81
F2	20.5	23.5	24.5	14	30.5	6.5	42.25	10	100	16.5	272.25	1	1
F3	22.5	23.5	27.5	6.5	54	16	256	31.5	992.25	45.5	2070.25	4	16
F4	37.5	48	9.5	31	30.5	6.5	42.25	7	49	0.5	0.25	38.5	1482.25
G1	27	32.5	19.5	48.5	16	21.5	462.25	11	121	32.5	1056.25	13	169
G2	32.5	28	50	46	58.5	10.5	110.25	23	529	12.5	156.25	22	484
G3	33.5	15	56	43.5	48	10	100	14.5	210.25	4.5	20.25	41	1681
G4	29.5	23.5	40	48.5	48	19	361	18.5	342.25	0.5	0.25	16.5	272.25
G5	6	9	4.5	20	2.5	14	196	3.5	12.25	17.5	306.25	4.5	20.25
G6	10.5	28	2.5	14	16	3.5	12.25	5.5	30.25	2	4	25.5	650.25

TABLE 4-3
(Contd.)

SPEARMAN CORRELATION

	RANK BY					DIFFERENCE BETWEEN (D/D^2)							
Q #	CONTR CM 1	CONSL CS 2	Owner O 3	Construction Contr. C 4	Maintenance Contr. M 5	CM-CS D_{12}	(CM-CS)^2 D^2_{12}	CM-O D_{13}	(CM-O)^2 D^2_{13}	CS-O D_{23}	(CS-O)^2 D^2_{23}	C-M D_{45}	(C-M)^2 D^2_{45}
G7	54.5	51.5	56	64	65	9.5	90.25	10.5	110.25	1	1	4.5	20.25
G8	27	28	30.5	48.5	58.5	20.5	462.25	31.5	992.25	10	100	2.5	6.25
G9	49	44	53.5	43.5	48	5.5	30.25	1	1	4.5	20.25	9.5	90.25
G10	31.5	40	19.5	20	26.5	11.5	132.25	5	25	6.5	42.25	20.5	420.25
G11	22.5	12	40	31	48	8.5	72.25	25.5	650.25	17	289	28	784
G12	39.5	35	43.5	40	42.5	0.5	0.25	3	9	2.5	6.25	8.5	72.25
H1	4	4	14.5	3	1	1	1	3	9	2	4	10.5	110.25
H2	2.7	5	19.5	9.5	7.5	2	4	0	0	2	4	14.5	210.25
H3	13.5	15	12	9.5	7.5	4	16	6	36	2	4	3	9
H4	39.5	37.5	40	9.5	26.5	30	900	13	169	17	289	2.5	6.25
H5	29.5	42.5	6.5	14	26.5	15.5	240.25	3	9	12.5	156.25	36	1296
H6	27	35	14.5	14	26.5	13	169	0.5	0.25	12.5	156.25	20.5	420.25
H7	5	12	1	20	4	15	225	1	1	16	256	11	121
H8	67	64	67	66	66	1	1	1	1	0	0	3	9
I1	42.5	45	30.5	51.5	54	9	81	11.5	132.25	2.5	6.25	14.5	210.25
I2	10.5	12	9.5	25	16	14.5	210.25	5.5	30.25	9	81	2.5	6.25
I3	17.5	23.5	14.5	25	12	7.5	56.25	5.5	30.25	13	169	9	81
I4	31.5	23.5	46	36	30.5	4.5	20.25	1	1	5.5	30.25	22.5	506.25
I5	61	46.5	64	57.5	54	3.5	12.25	7	49	3.5	12.25	17.5	306.25
J1	54.5	56	50	60	63	5.5	30.25	8.5	72.25	3	9	6	36

TABLE 4-3
(Contd.)

SPEARMAN RANK CORRELATION

	RANK BY					DIFFERENCE BETWEEN (D/D^2)							
Q #	CONTR CM 1	CONSL CS 2	Owner O 3	Constru-ction Contr. C 4	Mainte-nance Contr. M 5	CM-CS D_{12}	(CM-CS)^2 D^2_{12}	CM-O D_{13}	(CM-O)^2 D^2_{13}	CS-O D_{23}	(CS-O)^2 D^2_{23}	C-M D_{45}	(C-M)^2 D^2_{45}
J2	60	58	56	62	63	2	4	3	9	1	1	2	4
J3	66	65.5	65	60	63	6	36	3	9	3	9	0.5	0.25
K1	52	59.5	35	48.5	21.5	3.5	12.25	30.5	930.25	27	729	24.5	600.25
K2	33.5	35	30.5	33	34	0.5	0.25	0.5	0.25	1	1	4.5	20.25
K3	64	67	61.5	63	42.5	1	1	21.5	462.25	20.5	420.25	5.5	30.25
K4	62	62	61.5	36	42.5	26	676	19.5	380.25	6.5	42.25	0.5	0.25
K5	37.5	42.5	24.5	20	7.5	17.5	306.25	30	900	12.5	156.25	18	324

$\Sigma D^{**}2 =$	8619.5	815.515	14292	19318.5
$6^* [\Sigma D^{**}2] / [N^{**}3 - N] =$	0.172	0.316	0.285	0.385
$r_s = 1-[6 *\Sigma D^{**}2] / [N^{**}3 - N] =$	0.828	0.684	0.715	0.615

TABLE 4-3
(Contd.)

SPEARMAN RANK CORRELATION

	RANK BY					DIFFERENCE BETWEEN (D/D^2)							
Q #	CONTR CM 1	CONSL CS 2	Owner O 3	Construction Contr. C 4	Maintenance Contr. M 5	CS-C D_{24}	(CS-C)^2 D^2_{24}	O-C D_{34}	(O-C)^2 D^2_{34}	CS-M D_{25}	(CS-M)^2 D^2_{25}	O-M D_{35}	(O-M)^2 D^2_{35}
A1	58.5	59.5	50	55	48	4.5	20.25	11.5	132.25	5	25	2	4
A2	75	15	2.5	28	7.5	13	169	7.5	56.25	25.5	650.25	5	25
A3	52	54	50	65	67	11	121	13	169	15	225	17	289
A4	1	1	19.5	3	2.5	2	4	1.5	2.25	16.5	272.25	17	289
A5	9	6	19.5	5	34	1	1	28	784	14.5	210.25	14.5	210.25
A6	44.5	51.5	24.5	40	48	11.5	132.25	3.5	12.25	15.5	240.25	23.5	552.25
A7	56.5	51.5	58.5	40	34	11.5	132.25	17.5	306.25	18.5	342.25	24.5	600.25
A8	52	56	46	55	54	1	1	2	4	9	81	8	64
A9	13.5	18.5	9.5	14	21.5	4.5	20.25	3	9	4.5	20.25	12	144
A10	42.5	40	46	43.5	48	3.5	12.25	8	64	2.5	6.25	2	4
B1	20.5	9	40	31	16	22	484	5	25	9	81	24	576
B2	2	3	6.5	25	21.5	22	484	18.5	342.25	18.5	342.25	15	225
B3	65	63	66	67	61	4	16	2	4	1	1	5	25
B4	46.5	40	58.5	60	38	20	400	2	4	1.5	2.25	20.5	420.25`
B5	41	32.5	50	51.5	38	19	361	5.5	30.25	1.5	2.25	12	144
C1	24.5	18.5	35	28	7.5	9.5	90.25	11	121	7	49	27.5	756.25
C2	58.5	51.5	61.5	55	38	3.5	12.25	13.5	182.5	6.5	24.25	23.5	55.25
C3	46.5	49	35	28	21.5	21	441	27.5	756	7	49	13.5	182.25
C4	56.5	61	30.5	36	12	25	625	49	2401	5.5	30.5	18.5	342.25
D1	49	56	27.5	43.5	54	12.5	156.25	2	4	16	256	26.5	702.25

TABLE 4-3
(Contd.)

SPEARMAN RANK CORRELATION

	RANK BY					DIFFERENCE BETWEEN (D/D^2)							
Q #	CONTR CM 1	CONSL CS 2	Owner O 3	Construction Contr. C 4	Maintenance Contr. M 5	CS-C D_{24}	(CS-C)^2 D^2_{24}	O-C D_{34}	(O-C)^2 D^2_{34}	CS-M D_{25}	(CS-M)^2 D^2_{25}	O-M D_{35}	(O-M)^2 D^2_{35}
D2	19	23.5	19.5	3	38	20.5	420.25	14.5	210.25	16.5	272.25	18.5	342.25
D3	3	2	14.5	1	7.5	1	1	5.5	30.25	13.25	182.25	7	49
D4	24.5	18.5	35	20	30.5	1.5	2.25	12	144	15	225	4.5	20.25
D5	44.5	46.5	40	36	16	10.5	110.25	30.5	930.25	4	16	24	576
D6	13.5	30	4.5	20	21.5	10	100	9.5	90.25	15.5	240.25	17	289
D7	35.5	31	43.5	36	58.5	5	25	27.5	756.25	7.5	56.25	15	225
D8	63	65.5	53.5	57.5	42.5	8	64	23	529	4	16	11	121
E1	49	37.5	61.5	53	58.5	15.5	240.25	21	441	8.5	72.25	3	9
E2	16	9	24.5	20	21.5	11	121	12.5	156.25	4.5	20.25	3	9
E3	17.5	7	35	9.5	12	2.5	6.25	5	25	25.5	650.25	23	529
F1	13.5	18.5	9.5	6.5	38	12	144	20.5	420.25	3	9	28.5	812.25
F2	20.5	23.5	24.5	14	30.5	9.5	90.25	7	49	10.5	110.25	6	36
F3	22.5	23.5	27.5	6.5	54	17	289	30.5	930.25	21	441	26.5	702
F4	37.5	48	9.5	31	30.5	17	289	17.5	306.25	21.5	462.25	21	441
G1	27	32.5	19.5	48.5	16	16	256	16.5	272.25	29	841	3.5	12.25
G2	35.5	28	50	46	58.5	18	324	30.5	930.25	4	16	8.5	72.25
G3	33.5	15	56	43.5	48	28.5	812.25	33	1089	12.5	156.25	8	64
G4	29.5	23.5	40	48.5	48	25	625	42.25	600.25	8.5	72.25	8	64
G5	6	9	4.5	20	2.5	11	121	6.5	42.25	15.5	240.25	2	4
G6	10.5	28	2.5	14	16	14	196	12	144	11.5	132.25	13.5	182.25

TABLE 4-3
(Contd.)

SPEARMAN RANK CORRELATION

	RANK BY					DIFFERENCE BETWEEN (D/D^2)							
Q #	CONTR CM 1	CONSL CS 2	Owner O 3	Construction Contr. C 4	Maintenance Contr. M 5	CS-C D_{24}	(CS-C)^2 D^2_{24}	O-C D_{34}	(O-C)^2 D^2_{34}	CS-M D_{25}	(CS-M)^2 D^2_{25}	O-M D_{35}	(O-M)^2 D^2_{35}
G7	54.5	51.5	56	64	65	12.5	156.25	13.5	182.25	8	64	9	81
G8	27	28	30.5	48.5	58.5	20.5	420.25	30.5	930.25	18	324	28	784
G9	49	44	53.5	43.5	48	0.5	0.25	4	16	10	100	5.5	30.25
G10	31.5	40	19.5	20	26.5	20	400	13.5	182.25	0.5	0.25	7	49
G11	22.5	12	40	31	48	19	361	36	1296	9	81	8	64
G12	39.5	35	43.5	40	42.5	5	25	7.5	56.25	3.5	12.25	1	1
H1	4	4	14.5	3	1	1	1	3	9	11.5	132.25	13.5	182.25
H2	2.7	5	19.5	9.5	7.5	4.5	20.5	2.5	6.25	10	100	12	144
H3	13.5	15	12	9.5	7.5	5.5	30.25	7.5	56.25	2.5	6.25	4.5	20.25
H4	39.5	37.5	40	9.5	26.5	28	784	11	121	30.5	930.25	13.5	182.25
H5	29.5	42.5	6.5	14	26.5	28.5	812.25	16	256	7.5	56.25	20	400
H6	27	35	14.5	14	26.5	21	441	9.5	90.25	0.5	0.25	12	144
H7	5	12	1	20	4	8	64	8	64	19	361	3	9
H8	67	64	67	66	66	2	4	2	4	1	1	1	1
I1	42.5	45	30.5	51.5	54	6.5	12.25	9	81	21	441	23.5	552.25
I2	10.5	12	9.5	25	16	13	169	4	16	15.5	240.25	6.5	42.25
I3	17.5	23.5	14.5	25	12	1.5	2.25	11.5	132.25	10.5	110.25	12.5	156.25
I4	31.5	23.5	46	36	30.5	12.5	156.25	7	49	10	100	15.5	240.25
I5	61	46.5	64	57.5	54	11	121	7.5	56.25	6.5	42.25	10	100
J1	54.5	56	50	60	63	4.00	16	7	49	10	100	13	169

TABLE 4-3
(Contd.)

SPEARMAN RANK CORRELATION

	RANK BY					DIFFERENCE BETWEEN (D/D^2)							
Q #	CONTR CM 1	CONSL CS 2	Owner O 3	Construction Contr. C 4	Maintenance Contr. M 5	CS-C D_{24}	(CS-C)^2 D^2_{24}	O-C D_{34}	(O-C)^2 D^2_{34}	CS-M D_{25}	(CS-M)^2 D^2_{25}	O-M D_{35}	(O-M)^2 D^2_{35}
J2	60	58	56	62	63	4	16	5	25	6	36	7	49
J3	66	65.5	65	60	63	5.5	30.25	2.5	6.25	5	25	2	4
K1	52	59.5	35	48.5	21.5	11	121	38	1444	13.5	182.25	13.5	182.25
K2	33.5	35	30.5	33	34	2	4	1	1	2.5	6.25	3.5	12.25
K3	64	67	61.5	63	42.5	4	16	24.5	600.25	2.5	6.25	19	361
K4	62	62	61.5	36	42.5	26	676	19.5	380.25	25.5	650.25	19	361
K5	37.5	42.5	24.5	20	7.5	22.5	506.25	35	1225	4.5	20.25	17	289

Σ D **2 =	9237.5	20840.5	11288.25	15277.25
6* [ΣD**2] / [N **3 –N] =	0.0.184	0.416	0.225	0.305
r_s = 1–[6 *Σ D**2] / [N **3 –N] =	0.816	0.584	0.775	0.695

MULTIPLE CORRELATION :

Multiple correlation is used to describe the extent of association between the parties when considering one main party with the others.

The following equations are used in calculations :

1 $$r_{1.23} = \{ [r_{12}^2 + r_{13}^2 - 2(r_{12} \times r_{13} \times r_{23})] / (1 - r_{23}^2)] \}^{1/2}$$ (Eq.4.6)

(KENDALL,1960)

2 $$r_{2.13} = \{ [r_{12}^2 + r_{23}^2 - 2(r_{12} \times r_{13} \times r_{23})] / (1 - r_{13}^2)] \}^{1/2}$$

3 $$r_{3.12} = \{ [r_{13}^2 + r_{23}^2 - 2(r_{12} \times r_{13} \times r_{23})] / (1 - r_{12}^2)] \}^{1/2}$$

Where :

$r_{1.23}$ = The agreement between the contractors and the other two parties (consultant and owner).

$r_{2.13}$ = The agreement between the consultant and the other two parties (owners and contractors).

$r_{3.12}$ = The agreement between the Owner and the other two parties (consultants and contractors).

Table 4.4 shows the results of these correlations in a table format.

4.1.4 RANKING :

As mentioned in the previous chapter (3.4) the use of a percentage and severity index (weighted average) will simplify and reduce all numbers to a range from 0 to 100. Consequently, the data will be translated into standard form, with a base of 100, for relative comparisions.

TABLE 4.4

RANK CORRELATION VALUES

SPEARMAN	PARTIAL	MULTIPLE
$r_{(12)} = 0.828$	$r_{(12.3)} = 0.666$	$r_{(1.23)} = 0.838$
$r_{(13)} = 0.684$	$r_{(13.2)} = 0.234$	$r_{(2.13)} = 0.856$
$r_{(23)} = 0.715$	$r_{(23.1)} = 0.363$	$r_{(3.12)} = 0.733$
$r_{(24)} = 0.816$	NA	NA
$r_{(25)} = 0.775$	NA	NA
$r_{(34)} = 0.584$	NA	NA
$r_{(35)} = 0.695$	NA	NA
$r_{(45)} = 0.614$	NA	NA

This chapter includes six rank tables ranked by factor, six rank tables ranked by main categories, and one All Parties rank table ranked by factor within each category.

Table 4.5 expresses the opinion of the three parties (contractors, consultants, and owners) together , and the factors are ranked according to the opinions of all parties collectively. Table 4.6 expresses the opinion of all the three parties and ranks the factors within each category. Table 4.8 expresses the opinion of all the three parties and rank the eleven categories according to their importance. The other ten tables (from 4.8 to 4.17) express the opinion of each party (construction & maintenance contractor, consultant, owner, construction contractor and maintenance contractor), individually.

4.2 SATISFACTION OF RESTRICTIONS :

This research is restricted to studying the architectural and civil defects that happen during the design and construction stage which affect and increase maintenance. The area of research is limited to the Eastern Province of Saudi Arabia where the climatic condition and soil vary from other parts of the country. The study is limited to civil and architectural defects because it is difficult to find an evaluator who is experienced in all areas; to avoid getting faulty answers the study was restricted to the above mentioned defects. The study covers large buildings and complexes , and is limited to respondents selected in Section 3.3.

4.3 STATISTICAL RESULTS :

There are three main statistical results :

4.3.1 COEFFICIENT OF VARIATION :

The data is considered to be homogenous when the coefficient of variation (C.V.) is less than 10%; however, the variation in the responses in this set is somewhat large. Thus, predictive values should be considered with care. Consequently, the results are applied only to civil and architectural defects in building design and construction; otherwise, care should be taken when using the figures included in this study for other type of defects such as electrical or mechanical. The questions might be answered by other related divisions, but their responses might also differ by reflecting their existing situations.

TABLE 4-5

ALL PARTIES RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
1	A4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	2.39	79.76
2	D3	HIRING UNQUALIFIED DESIGNERS	2.39	79.76
3	H1	NOT COMPLYING WITH SPECIFICATION	2.34	78.10
4	B2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	2.29	76.43
5	G5	INADEQUATE WATER PROOFING AND DRAINAGE	2.29	76.19
6	H7	UNQUALIFIED WORK FORCE	2.29	76.19
7	H2	INABILITY TO READ THE DRAWINGS	2.28	75.95
8	A2	IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS	2.25	75.00
9	A5	IGNORING VARIATION IN SOIL CONDITIONS	2.24	74.76
10	H3	INSUFFICIENT SITE SUPERVISION	2.24	74.76
11	G6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	2.24	74.52
12	I2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR THE EXISTING CLIMATIC CONDITIONS	2.22	74.05
13	A9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	2.21	73.81
14	E3	LACK OF DETAILS	2.21	73.81
15	D6	DESIGNER IGNORANCE OF MATERIALS PROPERTIES	2.21	73.57
16	E2	CONFLICTING DETAILS	2.20	73.33
17	F1	LACK OF INSPECTION	2.20	73.33
18	I3	USE OF NONDURABLE MATERIAL	2.19	73.10
19	D2	POOR TECHNICAL UPDATING OR STAFF TRAINING	2.19	72.86
20	C1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	2.16	72.14
21	F2	UNQUALIFIED INSPECTOR	2.16	72.14
22	B1	NARROW STAIRS, PASSAGES & DOORS	2.16	71.90
23	H6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	2.15	71.67

TABLE 4-5
(Contd.)

ALL PARTIES RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
24	D4	DESIGNER FIELD EXPERIENCE	2.14	71.43
25	H5	UNQUALIFIED SUPERVISION	2.14	71.43
26	F3	PROPONENT (OWNER) NEGLIGENCE OF THE IMPORTANCE OF INSPECTION	2.14	71.19
27	K5	SPECIFYING INADEQUATE CONCRETE MIX DESIGN	2.13	70.95
28	G10	POOR SOIL COMPACTION	2.12	70.71
29	H4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	2.11	70.23
30	G11	INADEQUATE CURING	2.10	70.00
31	G1	INACCURATE MEASUREMENT	2.09	69.76
32	I4	USE OF EXPIRED MATERIAL	2.08	69.29
33	F4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	2.07	69.05
34	K2	NOT DEFINING ADEQUATE MATERIAL TYPE	2.07	69.05
35	C3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	2.04	67.86
36	G4	PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE	2.04	67.86
37	D5	DESIGNER TECHNICAL BACKGROUND	2.03	67.62
38	G3	EXCAVATION TOO CLOSE TO THE BUILDING	2.03	67.62
39	G8	LOSS IN ADHESION BETWEEN MATERIALS	2.03	67.62
40	D7	MISJUDGEMENT OF CLIMATIC CONDITIONS	2.02	67.38
41	G12	LACK OF COMMUNICATION	2.02	67.38
42	G2	DAMAGED FORMWORK	2.00	66.67
43	B5	INADEQUATE JOINTS BETWEEN FINISHED FACES	1.99	66.43
44	A10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	1.99	66.19
45	A6	IGNORING LOAD IMPACT ON STRUCTURE STABILITY	1.98	65.95
46	C4	NOT CONSIDERING THE MAINTENANCE REQUIREMENTS IN DESIGN	1.97	65.71

TABLE 4-5
(Contd.)

ALL PARTIES RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
47	I1	DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIAL	1.96	65.24
48	G9	EARLY FORMWORK REMOVAL	1.95	65.00
49	D1	LACK OF QA/QC PROGRAM DURING DESIGN	1.94	64.76
50	K1	UNCLEAR SPECIFICATION	1.94	64.76
51	A7	EXCEEDING ALLOWABLE DEFLECTION	1.93	64.29
52	B4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	1.92	64.05
53	E1	LACK OF REFERENCES	1.91	63.57
54	A8	IGNORING WIND EFFECTS ON THE STRUCTURE	1.87	62.38
55	C2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	1.86	62.14
56	A1	INADEQUATE PROVISIONS FOR MOVEMENT	1.85	61.66
57	K4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	1.82	60.71
58	I5	POOR MATERIAL HANDLING & STORAGE	1.81	60.48
59	J1	WRONG USE OF EQUIPMENT	1.81	60.48
60	G7	COLD JOINTS	1.79	69.52
61	J2	INADEQUATE PERFORMANCE OF EQUIPMENT	1.78	59.29
62	A3	IGNORING BIOLOGICAL EFFECTS	1.76	58.57
63	D8	MISJUDGEMENT OF USER'S INTENDED USE	1.74	58.10
64	K3	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	1.66	55.48
65	J3	LACK OF REQUIRED AMOUNT OF EQUIPMENT	1.61	53.57
66	H8	MULTINATIONAL CONSTRUCTION EXPERIENCE	1.52	50.71
67	B3	SPECIFYING FINISHINGS WHICH NEED TO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	1.49	49.76

TABLE 4 -6

DEFECTS RANKED BY ALL PARTIES WITH IN EACH DEFECTS GROUP

Q #	DEFECTS	RANK
	A DEFECTS IN CIVIL DESIGN	
A4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	1
A2	IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS	2
A5	IGNORING VARIATION IN SOIL CONDITIONS	3
A9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	4
A10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	5
A6	IGNORING LOAD IMPACT ON STRUCTURE STABILITY	6
A7	EXCEEDING ALLOWABLE DEFLECTION	7
A8	IGNORING WIND EFFECTS ON THE STRUCTURE	8
A1	INADEQUATE PROVISIONS FOR MOVEMENT	9
A3	IGNORING BIOLOGICAL EFFECTS	10
	B ARCHITECTURAL DEFECTS IN DESIGN	
B2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	11
B1	NARROW STAIRS, PASSAGES & DOORS	12
B5	INADEQUATE JOINTS BETWEEN FINISHED FACES	13
B4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	14
B3	SPECIFYING FINISHINGS WHICH NEED TO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	15
	C DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY	
C1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	16
C3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	17
C4	NOT CONSIDERING THE MAINTENANCE	18

TABLE 4 -6
(Contd.)
DEFECTS RANKED BY ALL PARTIES WITH IN EACH DEFECTS GROUP

Q #	DEFECTS	RANK
C2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	19
	D DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF	
D3	HIRING UNQUALIFIED DESIGNERS	20
D6	DESIGNER IGNORANCE OF MATERIALS PROPERTIES	21
D2	POOR TECHNICAL UPDATING OR STAFF TRAINING	22
D4	DESIGNER FIELD EXPERIENCE	23
D5	DESIGNER TECHNICAL BACKGROUND	24
D7	MISJUDGEMENT OF CLIMATIC CONDITIONS	25
D1	LACK OF QA/QC PROGRAM DURING DESIGN	26
D8	MISJUDGEMENT OF USER'S INTENDED USE	27
	E DEFECTS DUE TO CONSTRUCTION DRAWINGS	
E3	LACK OF DETAILS	28
E2	CONFLICTING DETAILS	29
E1	LACK OF REFERENCES	30
	F DEFECTS DUE TO CONSTRUCTION INSPECTION	
F1	LACK OF INSPECTION	31
F2	UNQUALIFIED INSPECTOR	32
F3	PROPONENTS (OWNER) NEGLIGENCE TO THE IMPORTANCE OF INSPECTION	33
F4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	34

TABLE 4 -6
(Contd.)
DEFECTS RANKED BY ALL PARTIES WITH IN EACH DEFECTS GROUP

Q #	DEFECTS	RANK
	G DEFECTS DUE TO CIVIL CONSTRUCTION	
G5	INADEQUATE WATER PROOFING AND DRAINAGE	35
G6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	36
G10	POOR SOIL COMPACTION	37
G11	INADEQUATE CURING	38
G1	INACCURATE MEASUREMENT	39
G4	PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE	40
G3	EXCAVATION TOOL CLOSE TO THE BUILDING	41
G8	LOSS IN ADHESION BETWEEN MATERIALS	42
G12	LACK OF COMMUNICATION	43
G2	DAMAGED FORMWORK	44
G9	EARLY FORMWORK REMOVAL	45
G7	COLD JOINTS	46
	H DEFECTS DUE TO CONTRACTOR ADMINISTRATION	
H1	NOT COMPLYING WITH SPECIFICATION	47
H7	UNQUALIFIED WORK FORCE	48
H2	INABILITYTO READ THE DRAWINGS	49
H3	INSUFFICIENT SITE SUPERVISION	50
H6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	51
H5	UNQUALIFIED SUPERVISION	52
H4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	53
H8	MULTINATIONAL CONSTRUCTION EXPERIENCE	54

TABLE 4 - 6
(Contd.)

DEFECTS RANKED BY ALL PARTIES WITH IN EACH DEFECTS GROUP

Q #	DEFECTS	RANK
	I DEFECTS DUE TO CONSTRUCTION MATERIALS	
I2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR EXISTING CLIMATIC CONDITIONS	55
I3	USE OF NONDURABLE MATERIAL	56
I4	USE OF EXPIRED MATERIAL	57
I1	DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIAL	58
I5	POOR MATERIAL HANDLING & STORAGE	59
	J DEFECTS DUE TO CONSTRUCTION EQUIPMENT	
J1	WRONG USE OF EQUIPMENT	60
J2	INADEQUATE PERFORMANCE OF EQUIPMENT	61
J3	LACK OF REQUIRED AMOUNT OF EQUIPMENTS	62
	K DEFECTS DUE TO SPECIFICATION	
K5	SPECIFYING INADEQUATE CONCRETE MIX DESIGN	63
K2	NOT DEFINING ADEQUATE MATERIALS	64
K1	UNCLEAR SPECIFICATION	65
K4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	66
K3	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	67

TABLE 4-7

ALL PARTIES RANK BY DEFECTS GROUP

Rank	GROUP	DEFECTS GROUP	SEVE-RITY INDEX
1	F	DEFECTS DUE TO CONSTRUCTION INSPECTION	71.42
2	H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION	71.13
3	E	DEFECTS DUE TO CONSTRUCTION DRAWINGS	70.28
4	D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF	69.43
5	G	DEFECTS DUE TO CIVIL CONSTRUCTION	68.57
6	I	DEFECTS DUE TO CONSTRUCTION MATERIALS	68.42
7	A	DEFECTS IN CIVIL DESIGN	68.23
8	C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY	66.97
9	B	ARCHITECTURAL DEFECTS IN DESIGN	65.71
10	K	DEFECTS DUE TO SPECIFICATION	64.19
11	J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT	57.78

TABLE 4-8

CONSTRUCTION & MAINTENANCE CONTRACTOR RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
1	A4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	2.38	79.26
2	B2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	2.34	78.14
3	D3	HIRING UNQUALIFIED DESIGNERS	2.33	77.78
4	H1	NOT COMPLYING WITH SPECIFICATION	2.29	76.30
5	H7	UNQUALIFIED WORK FORCE	2.28	75.92
6	G5	INADEQUATE WATER PROOFING AND DRAINAGE	2.27	75.56
7	A2	IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS	2.26	75.19
8	H2	INABILITY TO READ THE DRAWINGS	2.26	75.19
9	A5	IGNORING VARIATION IN SOIL CONDITIONS	2.24	74.81
10	G6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	2.22	74.07
11	I2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR THE EXISTING CLIMATIC CONDITIONS	2.22	74.07
12	A9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	2.20	73.33
13	D6	DESIGNER IGNORANCE OF MATERIALS PROPERTIES	2.20	73.33
14	F1	LACK OF INSPECTION	2.20	73.33
15	H3	INSUFFICIENT SITE SUPERVISION	2.20	73.33
16	E2	CONFLICTING DETAILS	2.19	72.96
17	E3	LACK OF DETAILS	2.17	72.22
18	I3	USE OF UNDURABLE MATERIAL	2.17	72.22
19	D2	POOR TECHNICAL UPDATING OR STAFF TRAINING	2.16	71.85
20	B1	NORROW STAIRS, PASSAGES & DOORS	2.14	71.48
21	F2	UNQUALIFIED INSPECTOR	2.14	71.48
22	F3	PROPONENT (OWNER) NEGLIGENCE OF THE IMPORTANCE OF INSPECTION	2.13	71.11
23	G11	INADEQUATE CURING	2.13	71.11

TABLE 4-8
(Contd.)

CONSTRUCTION & MAINTENANCE CONTRACTOR RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
24	C1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	2.12	70.74
25	D4	DESIGNER FIELD EXPERIENCE	2.12	70.74
26	G1	INACCURATE MEASUREMENT	2.11	70.37
27	G8	LOSS IN ADHESION BETWEEN MATERIALS	2.11	70.37
28	H6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	2.11	70.37
29	G4	PAINTING IN UNSUITABLE CONDITIONS OR ONUNSUITABLE SURFACE	2.10	70.00
30	H5	UNQUALIFIED SUPERVISION	2.10	70.00
31	G10	POOR SOIL COMPACTION	2.08	69.26
32	I4	USE OF EXPIRED MATERIAL	2.08	69.26
33	G3	EXCAVATION TOO CLOSE TO THE BUILDING	2.07	68.89
34	K2	NOT DEFINING ADEQUATE MATERIAL TYPE	2.07	68.89
35	D7	MISJUDGEMENT OF CLIMATIC CONDITIONS	2.06	68.52
36	G2	DAMAGED FORMWORK	2.06	68.52
37	F4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	2.04	68.15
38	K5	SPECIFYING INADEQUATE CONCRETE MIX DESIGN	2.04	68.15
39	G12	LACK OF COMMUNICATION	2.03	67.78
40	H4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	2.03	67.78
41	B5	INADEQUATE JOINTS BETWEEN FINISHED FACES	2.02	67.41
42	A10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	2.00	66.67
43	I1	DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIAL	2.00	66.67
44	A6	IGNORING LOAD IMPACT ON STRUCTURE STABILITY	1.98	65.93
45	D5	DESIGNER TECHNICAL BACKGROUND	1.97	65.56
46	B4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	1.96	65.19

TABLE 4-8
(Contd.)

CONSTRUCTION & MAINTENANCE CONTRACTOR RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
47	C3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	1.96	65.19
48	D1	LACK OF QA/QC PROGRAM DURING DESIGN	1.94	64.81
49	E1	LACK OF REFERENCES	1.94	64.81
50	G9	EARLY FORMWORK REMOVAL	1.94	64.81
51	A3	IGNORING BIOLOGICAL EFFECTS	1.89	62.96
52	A8	IGNORING WIND EFFECTS ON THE STRUCTURE	1.89	62.96
53	K1	UNCLEAR SPECIFICATION	1.89	62.96
54	G7	COLD JOINTS	1.88	62.59
55	J1	WRONG USE OF EQUIPMENT	1.88	62.59
56	A7	EXCEEDING ALLOWABLE DEFLECTION	1.87	62.22
57	C4	NOT CONSIDERING THE MAINTENANCE REQUIREMENTS IN DESIGN	1.87	62.22
58	A1	INADEQUATE PROVISIONS FOR MOVEMENT	1.84	61.48
59	C2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	1.84	61.48
60	J2	INADEQUATE PERFORMANCE OF EQUIPMENT	1.83	61.11
61	I5	POOR MATERIAL HANDLING & STORAGE	1.81	60.37
62	K4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	1.71	57.04
63	D8	MISJUDGEMENT OF USER'S INTENDED USE	1.68	55.93
64	K3	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	1.59	52.96
65	B3	SPECIFYING FINISHINGS WHICH NEEDTO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	1.58	52.59
66	J3	LACK OF REQUIRED AMOUNT OF EQUIPMENTS	1.56	51.85
67	H8	MULTINATIONAL CONSTRUCTION EXPERIENCE	1.51	50.37

TABLE 4-9

CONSTRICTION & MAINTENANCE RANK BY DEFECTS GROUP

Rank	GROUP	DEFECTS GROUP	SEVE-RITY INDEX
1	F	DEFECTS DUE TO CONSTRUCTION INSPECTION	71.01
2	E	DEFECTS DUE TO CONSTRUCTION DRAWINGS	70.00
3	H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION	69.90
4	G	DEFECTS DUE TO CIVIL CONSTRUCTION	69.44
5	D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF	69.67
6	I	DEFECTS DUE TO CONSTRUCTION MATERIALS	68.51
7	A	DEFECTS IN CIVIL DESIGN	68.48
8	B	ARCHITECTURAL DEFECTS IN DESIGN	66.97
9	C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY	64.90
10	K	DEFECTS DUE TO SPECIFICATION	62.00
11	J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT	68.51

TABLE 4-10

CONSULTANT RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
1	D3	HIRING UNQUALIFIED DESIGNERS	2.50	83.33
2	A4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	2.30	76.67
3	D2	POOR TECHNICAL UPDATING OR STAFF TRAINING	2.30	76.67
4	H1	NOT COMPLYING WITH SPECIFICATION	2.30	76.67
5	A5	IGNORING VARIATION IN SOIL CONDITIONS	2.27	75.56
6	F1	LACK OF INSPECTION	2.23	74.44
7	F3	PROPONENT(OWNER) NEGLIGENCE OF THE IMPORTANCE OF INSPECTION	2.23	74.44
8	E3	LACK OF DETAIL	2.20	73.33
9	H2	INABILITY TO READ THE DRAWINGS	2.20	73.33
10	H3	INSUFFICIENT SITE SUPERVISION	2.20	73.33
11	H4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	2.20	73.33
12	A9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	2.16	72.22
13	F2	UNQUALIFIED INSPECTOR	2.16	72.22
14	G6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	2.16	72.22
15	H5	UNQUALIFIED SUPERVISION	2.16	72.22
16	H6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	2.16	72.22
17	D4	DESIGNER FIELD EXPERIENCE	2.13	71.11
18	D6	DESIGNER IGNORANCE OF MATERIALS PROPERTIES	2.13	71.11
19	E2	CONFLICTING DETAILS	2.13	71.11
20	G10	POOR SOIL COMPACTION	2.13	71.11
21	G5	INADEQUATE WATER PROOFING AND DRAINAGE	2.13	71.11
22	H7	UNQUALIFIED WORK FORCE	2.13	71.11
23	K5	SPECIFYING INADEQUATE CONCRETE MIX DESIGN	2.13	71.11

TABLE 4-10
(Contd.)
CONSULTANT RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
24	B2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	2.10	70.00
25	I2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR THE EXISTING CLIMATIC CONDITIONS	2.10	70.00
26	I3	USE OF NONDURABLE MATERIAL	2.10	70.00
27	A2	IGNORING AGGRESSIVE ENVIRONMENT	2.07	68.89
28	C1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	2.07	68.89
29	C3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	2.07	68.89
30	B1	NARROW STAIRS, PASSAGES & DOORS	2.03	67.78
31	F4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	2.03	67.78
32	G11	INADEQUATE CURING	2.03	67.78
33	K2	NOT DEFINING ADEQUATE MATERIALS TYPE	2.00	66.67
34	C4	NOT CONSIDERING THE MAINTENANCE REQUIREMENTS IN DESIGN	1.97	65.56
35	D5	DESIGNER TECHNICAL BACKGROUND	1.97	65.56
36	D7	MISJUDGEMENT OF CLIMATIC CONDITIONS	1.97	65.56
37	I4	USE OF EXPIRED MATERIAL	1.97	65.56
38	K4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	1.97	65.56
39	A6	IGNORING LOADIMPACT ON STRUCTURE STABILITY	1.93	64.44
40	A7	EXCEEDING ALLOWABLE DEFLECTION	1.93	64.44
41	G12	LACK OF COMMUNICATION	1.93	64.44
42	A10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	1.90	63.33
43	D1	LACK OF QA/QC PROGRAM DURING DESIGN	1.90	63.33
44	G3	EXCAVATION TOO CLOSE TO THE BUILDING	1.90	63.33
45	G9	EARLY FORMWORK REMOVAL	1.90	63.33
46	G2	DAMAGED FORMWORK	1.87	62.22

TABLE 4-10
(Contd.)

CONSULTANT RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
47	G1	INACCURATE MEASUREMENT	1.83	61.11
48	G4	PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE	1.83	61.11
49	G8	LOSS IN ADHESION BETWEEN MATERIALS	1.83	61.11
50	K1	UNCLEAR SPECIFICATION	1.83	61.11
51	B5	INADEQUATE JOINTS BETWEEN FINISHED FACES	1.80	60.00
52	I1	DIFFERENTIAL THERMAL MOVEMENTS IN DISSIMILAR MATERIAL	1.80	60.00
53	E1	LACK OF REFERENCES	1.77	58.89
54	A1	INADEQUATE PROVISIONS FOR MOVEMENTS	1.73	57.78
55	A8	IGNORING WIND EFFECTS ON THE STRUCTURE	1.73	57.78
56	C2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	1.73	57.78
57	D8	MISJUDGEMENT OF USER INTENDED USE	1.70	56.67
58	I5	POOR MATERIAL HANDLING & STORAGE	1.70	56.67
59	B4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	1.67	55.56
60	J1	WRONG USE OF EQUIPMENT	1.67	55.56
61	J3	LACK OF REQUIRED NUMBER OF EQUIPMENTS	1.67	55.56
62	J2	INADEQUATE PERFORMANCE OF EQUIPMENT	1.63	54.44
63	H7	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	1.60	53.33
64	A2	COLD JOINTS	1.57	52.22
65	A3	IGNORING BIOLOGICAL EFFECTS	1.53	51.11
66	H8	MULTINATIONAL CONSTRUCTION	1.50	50.00
67	B3	SPECIFYING FINISHINGS WHICH ARE TO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	1.03	34.44

TABLE 4-11

CONSULTANT RANK BY DEFECTS GROUP

Rank	GROUP	DEFECTS GROUP	SEVE-RITY INDEX
1	F	DEFECTS DUE TO CONSTRUCTION INSPECTION	72.22
2	H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION	70.28
3	D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF	69.17
4	E	DEFECTS DUE TO CONSTRUCTION DRAWINGS	67.78
5	C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY	65.28
6	A	DEFECTS IN CIVIL DESIGN	65.22
7	I	DEFECTS DUE TO CONSTRUCTION MATERIALS	64.44
8	G	DEFECTS DUE TO CIVIL CONSTRUCTION	64.25
9	K	DEFECTS DUE TO SPECIFICATION	63.56
10	B	ARCHITECTURAL DEFECTS IN DESIGN	57.56
11	J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT	55.19

TABLE 4-12

OWNER RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
1	H1	NOT COMPLYING WITH SPECIFICATION	2.65	88.33
2	A4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	2.60	86.67
3	G5	INADEQUATE WATER PROOFING AND DRAINAGE	2.60	86.67
4	H7	UNQUALIFIED WORK FORCE	2.55	85.00
5	A2	IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS	2.50	83.33
6	C1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	2.50	83.33
7	D3	HIRING UNQUALIFIED DESIGNERS	2.50	83.33
8	H2	INABILITY TO READ THE DRAWINGS	2.50	83.33
9	H3	INSUFFICIENT SITE SUPERVISION	2.50	83.33
10	K5	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS-	2.50	83.33
11	C4	NOT CONSIDERING THE MAINTENANCE REQUIREMENTS IN DESIGN	2.45	81.67
12	E3	LACK OF DETAILS	2.45	81.67
13	I3	USE OF NONDURABLE MATERIAL	2.45	81.67
14	B1	NARROW STAIRS, PASSAGES & DOORS	2.40	80.00
15	D5	DESIGNER TECHNICAL BACKGROUND	2.40	80.00
16	G1	INACCURATE MEASUREMENT	2.40	80.00
17	G6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	2.40	80.00
18	I2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR THE EXISTING CLIMATIC CONDITIONS	2.40	80.00
19	A9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	2.35	78.33
20	B2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	2.35	78.33
21	C3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	2.35	78.33
22	D6	DESIGNER IGNORANCE OF MATERIALS PROPERTIES	2.35	78.33
23	E2	CONFLICTING DETAILS	2.35	78.33

TABLE 4-12
(Contd.)

OWNER RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
24	K1	UNCLEAR SPECIFICATION	2.35	78.33
25	G10	POOR SOIL COMPACTION	2.30	76.67
26	H4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	2.30	76.67
27	H5	UNQUALIFIED SUPERVISION	2.30	76.67
28	H6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	2.30	76.67
29	D4	DESIGNER FIELD EXPERIENCE	2.25	75.00
30	F2	UNQUALIFIED INSPECTOR	2.25	75.00
31	F4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	2.25	75.00
32	I4	USE OF EXPIRED MATERIAL	2.25	75.00
33	A5	IGNORING VARIATION IN SOIL CONDITIONS	2.20	73.33
34	A7	EXCEEDING ALLOWABLE DEFLECTION	2.20	73.33
35	K2	NOT DEFINING ADEQUATE MATERIALS TYPE	2.20	73.33
36	B4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	2.15	71.67
37	B5	INADEQUATE JOINTS BETWEEN FINISHED FACES	2.15	71.67
38	C2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	2.15	71.67
39	D2	POOR TECHNICAL UPDATING OR STAFF TRAINING	2.15	71.67
40	F1	LACK OF INSPECTION	2.15	71.67
41	D8	MISJUDGEMENT OF USER'S INTENDED USE	2.10	70.00
42	G12	LACK OF COMMUNICATION	2.10	70.00
43	K3	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	2.10	70.00
44	K4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	2.10	70.00
45	A1	INADEQUATE PROVISIONS FOR MOVEMENT	2.05	68.33
46	A10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	2.05	68.33

TABLE 4-12
(Contd.)

OWNER RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
47	A6	IGNORING LOAD IMPACT ON STRUCTURE STABILITY	2.05	68.33
48	G11	INADEQUATE CURING	2.05	68.33
49	G3	EXCAVATION TOO CLOSE TO THE BUILDING	2.05	68.33
50	G4	PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE	2.05	68.33
51	G9	EARLY FORMWORK REMOVAL	2.05	68.33
52	A8	IGNORING WIND EFFECTS ON THE STRUCTURE	2.00	66.67
53	D1	LACK OF QA/QC PROGRAM DURING DESIGN	2.00	66.67
54	F3	PROPONENT (OWNER) NEGLIGENCE OF THE IMPORTANCE OF INSPECTION	2.00	66.67
55	I1	DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIAL	2.00	66.67
56	I5	POOR MATERIAL HANDLING & STORAGE	2.00	66.67
57	D7	MISJUDGEMENT OF CLIMATIC CONDITIONS	1.95	65.00
58	E1	LACK OF REFERENCES	1.95	65.00
59	G2	DAMAGED FORMWORK	1.95	65.00
60	G8	LOSS IN ADHESION BETWEEN MATERIALS	1.95	65.00
61	B3	SPECIFYING FINISHINGS WHICH NEED TO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	1.80	60.00
62	J1	WRONG USE OF EQUIPMENT	1.75	58.33
63	J2	INADEQUATE PERFORMANCE OF EQUIPMENT	1.75	58.33
64	J3	LACK OF REQUIREDAMOUNT OF EQUIPMENT	1.75	58.33
65	G7	COLD JOINTS	1.70	56.67
66	H8	MULTINATIONAL CONSTRUCTION EXPERIENCE	1.60	53.33
67	A3	IGNORING BIOLOGICAL EFFECTS	1.50	50.00

TABLE 4-13

OWNER RANK BY DEFECTS GROUP

Rank	GROUP	DEFECTS BY GROUP	SEVE-RITY INDEX
1	C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY	78.75
2	H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION	77.91
3	E	DEFECTS DUE TO CONSTRUCTION DRAWINGS	75.00
4	K	DEFECTS DUE TO SPECIFICATION	75.00
5	I	DEFECTS DUE TO CONSTRUCTION MATERIALS	74.00
6	D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF	73.75
7	B	ARCHITECTURAL DEFECTS IN DESIGN	72.33
8	F	DEFECTS DUE TO CONSTRUCTION INSPECTION	72.08
9	A	DEFECTS IN CIVIL DESIGN	71.66
10	G	DEFECTS DUE TO CIVIL CONSTRUCTION	71.11
11	J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT	58.33

TABLE 4-14

CONSTRUCTION CONTRACTOR RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
1	A4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	2.45	81.67
2	D3	HIRING UNQUALIFIED DESIGNERS	2.37	78.89
3	B2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	2.33	77.78
4	H1	NOT COMPLYING WITH SPECIFICATION	2.30	76.67
5	H2	INABILITYTO READ THE DRAWINGS	2.27	75.56
6	A5	IGNORING VARIATION IN SOIL CONDITIONS	2.25	75.00
7	E3	LACK OF DETAILS	2.20	73.33
8	B1	NARROW STAIRS, PASSAGES & DOORS	2.18	72.78
9	E2	CONFLICTING DETAILS	2.18	72.78
10	G5	INADEQUATE WATER PROOFING AND DRAINAGE	2.18	72.78
11	G11	INADEQUATE CURING	2.17	72.22
12	H7	UNQUALIFIED WORK FORCE	2.17	72.22
13	I2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR THE EXISTING CLIMATIC CONDITIONS	2.17	72.22
14	A2	IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS	2.15	71.67
15	G3	EXCAVATION TOO CLOSE TO THE BUILDING	2.15	71.67
16	H3	INSUFFICIENT SITE SUPERVISION	2.15	71.67
17	A9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	2.13	71.11
18	C1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	2.13	71.11
19	D4	DESIGNER FIELD EXPERIENCE	2.13	71.11
20	F1	LACK OF INSPECTION	2.13	71.11
21	D2	POOR TECHNICAL UPDATING OR STAFF TRAINING	2.12	70.56
22	F2	UNQUALIFIED INSPECTOR	2.12	70.56
23	F3	PROPONENT (OWNER) NEGLIGENCE OF THE IMPORTANCE OF INSPECTION	2.12	70.56

TABLE 4-14
(Contd.)

CONSTRUCTION CONTRACTOR RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
24	G4	PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE	2.12	70.56
25	I3	USE OF NONDURABLE MATERIAL	2.12	70.56
26	I4	USE OF EXPIRED MATERIAL	2.12	70.56
27	G2	DAMAGED FORMWORK	2.10	70.00
28	G6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	2.10	70.00
29	G8	LOSS IN ADHESION BETWEEN MATERIALS	2.10	70.00
30	D6	DESIGNER IGNORANCE OF MATERIALS	2.08	69.44
31	D7	MISJUDGEMENT OF CLIMATIC CONDITIONS	2.07	68.89
32	B5	INADEQUATE JOINTS BETWEEN FINISHED FACES	2.05	68.33
33	G1	INACCURATE MEASUREMENT	2.05	68.33
34	G12	LACK OF COMMUNICATION	2.03	67.78
35	H6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	2.03	67.78
36	K2	NOT DEFINING ADEQUATE MATERIALS TYPE	2.03	67.78
37	E1	LACK OF REFERENCES	2.02	67.22
38	H4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	2.02	67.22
39	A10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	2.00	66.67
40	B4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	2.00	66.67
41	G10	POOR SOIL COMPACTION	2.00	66.67
42	H5	UNQUALIFIED SUPERVISION	1.97	65.56
43	K5	SPECIFYING INADEQUATE CONCRETE MIX DESIGN	1.97	65.56
44	G9	EARLY FORMWORK REMOVAL	1.95	65.00
45	I1	DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIAL	1.93	64.44
46	D5	DESIGNER TECHNICAL BACKGROUND	1.92	63.89

TABLE 4-14
(Contd.)

CONSTRUCTION CONTRACTOR RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
47	I5	POOR MATERIAL HANDLING & STORAGE	1.92	63.89
48	F4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	1.90	63.33
49	C3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	1.88	62.78
50	A6	IGNORING LOAD IMPACT ON STRUCTURE STABILITY	1.87	62.22
51	A7	EXCEEDING ALLOWABLE DEFLECTION	1.87	62.22
52	C2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	1.87	62.22
53	G7	COLD JOINTS	1.87	62.22
54	A3	IGNORING BIOLOGICAL EFFECTS	1.85	61.67
55	A8	IGNORING WIND EFFECTS ON THE STRUCTURE	1.83	61.11
56	D1	LACK OF QA/QC PROGRAM DURING DESIGN	1.83	61.11
57	J1	WRONG USE OF EQUIPMENT	1.83	61.11
58	J2	INADEQUATE PERFORMANCE OF EQUIPMENT	1.83	60.00
59	A1	INADEQUATE PROVISIONS FOR MOVEMENT	1.78	59.44
60	K1	UNCLEAR SPECIFICATION	1.78	59.44
61	C4	NOT CONSIDERING THE MAINTENANCE REQUIREMENTS IN DESIGN	1.73	57.78
62	K4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	1.67	55.56
63	B3	SPECIFYING FINISHINGS WHICH NEED TO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	1.65	55.00
64	H8	MULTINATIONAL CONSTRUCTION	1.57	52.22
65	D8	MISJUDGEMENT OF USER INTENDED USE	1.55	51.67
66	J3	LACK OF REQUIRED AMOUNT OF EQUIPMENT	1.55	51.67
67	K3	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	1.48	49.44

TABLE 4-15

CONSTRUCTION CONTRACTOR RANK BY DEFECTS GROUP

Rank	GROUP	DEFECTS GROUP	SEVE-RITY INDEX
1	E	DEFECTS DUE TO CONSTRUCTION DRAWINGS	71.11
2	G	DEFECTS DUE TO CIVIL CONSTRUCTION	68.93
3	F	DEFECTS DUE TO CONSTRUCTION INSPECTION	68.89
4	H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION	68.61
5	I	DEFECTS DUE TO CONSTRUCTION MATERIALS	68.33
6	B	ARCHITECTURAL DEFECTS IN DESIGN	68.11
7	A	DEFECTS IN CIVIL DESIGN	67.28
8	D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF	66.94
9	C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY	63.47
10	K	DEFECTS DUE TO SPECIFICATION	59.56
11	J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT	57.59

TABLE 4-16

MAINTENANCE CONTRACTOR RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
1	H7	UNQUALIFIED WORK FORCE	2.50	83.33
2	A2	IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS	2.47	82.22
3	G6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	2.47	82.22
4	D6	DESIGNER IGNORANCE OF MATERIALS PROPERTIES	2.43	81.11
5	G5	INADEQUATE WATER PROOFING AND DRAINAGE	2.43	81.11
6	B2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	2.37	78.89
7	H5	UNQUALIFIED SUPERVISION	2.37	78.89
8	A9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	2.33	77.78
9	F1	LACK OF INSPECTION	2.33	77.78
10	F4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	2.33	77.78
11	I2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR THE EXISTING CLIMATIC CONDITIONS	2.33	77.78
12	H3	INSUFFICIENT SITE SUPERVISION	2.30	76.67
13	D3	HIRING UNQUALIFIED DESIGNERS	2.27	75.56
14	H1	NOT COMPLYING WITH SPECIFICATION	2.27	75.56
15	H6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	2.27	75.56
16	I3	USE OF NONDURABLE MATERIAL	2.27	75.56
17	A4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	2.23	74.44
18	A5	IGNORING VARIATION IN SOIL CONDITIONS	2.23	74.44
19	D2	POOR TECHNICAL UPDATING OR STAFF TRAINING	2.23	74.44
20	G1	INACCURATE MEASUREMENT	2.23	74.44
21	G10	POOR SOIL COMPACTION	2.23	74.44
22	H2	INABILITYTO READ THE DRAWINGS	2.23	74.44
23	A6	IGNORING LOAD IMPACT ON STRUCTURE STABILITY	2.20	73.33

TABLE 4-16
(Contd.)

MAINTENANCE CONTRACTOR RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
24	E2	CONFLICTING DETAILS	2.20	73.33
25	F2	UNQUALIFIED INSPECTOR	2.20	73.33
26	K5	SPECIFYING INADEQUATE CONCRETE MIX DESIGN	2.20	73.33
27	D1	LACK OF QA/QC PROGRAM DURING DESIGN	2.16	72.22
28	F3	PROPONENT (OWNER) NEGLIGENCE OF THE IMPORTANCE OF INSPECTION	2.16	72.22
29	C4	NOT CONSIDERING THE MAINTENANCE REQUIREMENTS IN DESIGN	2.13	71.11
30	G8	LOSS IN ADHESION BETWEEN MATERIALS	2.13	71.11
31	I1	DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIALS	2.13	71.11
32	K2	NOT DEFINING ADEQUATE MATERIALS TYPE	2.13	71.11
33	C1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	2.10	70.00
34	C3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	2.10	70.00
35	D4	DESIGNER FIELD EXPERIENCE	2.10	70.00
36	E3	LACK OF DETAILS	2.10	70.00
37	K1	UNCLEAR SPECIFICATION	2.10	70.00
38	B1	NARROW STAIRS, PASSAGES & DOORS	2.07	68.89
39	D5	DESIGNER TECHNICAL BACKGROUND	2.07	68.89
40	G11	INADEQUATE CURING	2.07	68.89
41	G4	PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE	2.07	68.89
42	H4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	2.07	68.89
43	D7	MISJUDGEMENT OF CLIMATIC CONDITIONS	2.03	67.78
44	G12	LACK OF COMMUNICATION	2.03	67.78
45	A10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	2.00	66.67
46	A8	IGNORING WIND EFFECTS ON THE STRUCTURE	2.00	66.67

TABLE 4-16
(Contd.)

MAINTENANCE CONTRACTOR RANK

Rank	Q#	DEFECTS FACTOR	MEAN	SEVE-RITY INDEX
47	I4	USE OF EXPIRED MATERIAL	2.00	66.67
48	A1	INADEQUATE PROVISIONS FOR MOVEMENT	1.97	65.56
49	A3	IGNORING BIOLOGICAL EFFECTS	1.97	65.56
50	B5	INADEQUATE JOINTS BETWEEN FINISHED FACES	1.97	65.56
51	G2	DAMAGED FORMWORK	1.97	65.56
52	J1	WRONG USE OF EQUIPMENT	1.97	65.56
53	D8	MISJUDGEMENT OF USER'S INTENDED USE	1.93	64.44
54	G9	EARLY FORMWORK REMOVAL	1.93	64.44
55	G3	EXCAVATION TOO CLOSE TO THE BUILDING	1.90	63.33
56	G7	COLD JOINTS	1.90	63.33
57	J2	INADEQUATE PERFORMANCE OF EQUIPMENT	1.90	63.33
58	A7	EXCEEDING ALLOWABLE DEFLECTION	1.87	62.22
59	B4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	1.87	62.22
60	C2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	1.80	60.00
61	E1	LACK OF REFERENCES	1.80	60.00
62	K3	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	1.80	60.00
63	K4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	1.80	60.00
64	I5	POOR MATERIAL HANDLING & STORAGE	1.60	53.33
65	J3	LACK OF REQUIRED AMOUNT OF EQUIPMENT	1.57	52.22
66	B3	SPECIFYING FINISHINGS WHICH NEED TO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	1.43	47.78
67	H8	MULTINATIONAL CONSTRUCTION EXPERIENCE	1.40	46.67

TABLE 4-17

MAINTENANCE CONTRACTOR RANK BY DEFECTS GROUP

Rank	GROUP	DEFECTS GROUP	SEVE-RITY INDEX
1	F	DEFECTS DUE TO CONSTRUCTION INSPECTION	75.28
2	H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION	72.50
3	D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF	71.80
4	A	DEFECTS IN CIVIL DESIGN	70.89
5	G	DEFECTS DUE TO CIVIL CONSTRUCTION	70.46
6	I	DEFECTS DUE TO CONSTRUCTION MATERIALS	68.89
7	C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY	67.78
8	E	DEFECTS DUE TO CONSTRUCTION DRAWINGS	67.78
9	K	DEFECTS DUE TO SPECIFICATION	66.89
10	B	ARCHITECTURAL DEFECTS IN DESIGN	64.67
11	J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT	60.37

4.3.2 CORRELATION :

The correlation table shows that the contractor is the party who most reflects the actual defects existing in buildings. The consultant is the second and the owner is the third. This is because of the contractors and consultants direct involvement in design and construction activities , and their experience in the repair of various defects . The owner involvement during the construction stage is little , but it is noticed that his experience in maintenance is more, if limited to his own building defects , and it increases during the operation of the building .

The correlation table (4-4) identifies the relation between the owner, the construction contractor, the maintenance contractor, and the consultant and can be stated briefly as follows:

1) The strongest agreement is between the contractor and the consultant (r_{12} = 0.828); this is expected because of their involvement in all types of building construction . Then between the consultant and the construction contractor (r_{24} = 0.816), Next strongest agreement is between the consultant and the maintenance contractor (r_{25} = 0.775), then between the owner and the consultant (r_{23} = 0.715) .

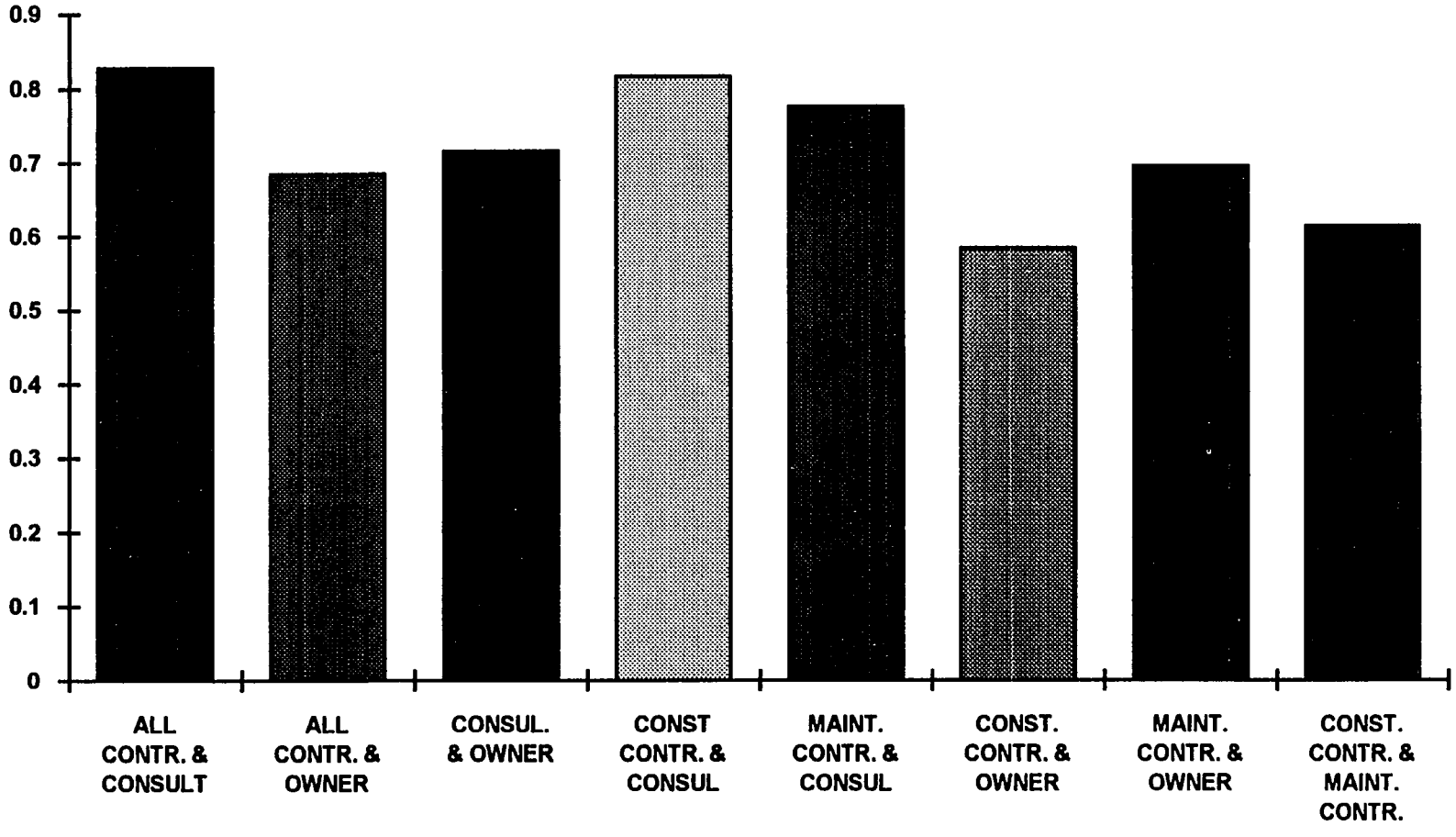
2) The correlation between the construction contractor and the maintenance contractor is low (r_{45} = 0.6145) compared to the others . This is expected because of the difference between the construction and maintenance activities .

3) The correlation between the consultant and the construction contractor (r_{24} = 0.816) is stronger than between the consultant and the maintenance contractor (r_{25} = 0.775) . This confirms the strong relation between the construction contractor and consultant . This is expected because most of the consultants are interested and involved more in new projects rather than repair and maintenance projects .

4) The study confirms that the owner is involved more in building maintenance than construction . The correlation table shows that the agreement between the owner and the maintenance contractor (r_{35} = 0.695) is stronger than between the owner and construction contractor (r_{34} = 0.584) .

FIG 4 -3

SPEARMAN RANK CORRELATION



5) The study also confirms that the owner is involved more in the building design ($r_{23} = 0.715$) than the construction ($r_{13} = 0.684$) . This demonstrates that the owner participates more during the design and maintenance stages .

6) The partial correlation shows that when the owner is kept constant, the agreement between the contractor and consultant is the highest ($r_{12.3} = 0.666$). On the other hand, when the consultant is kept constant, the agreement between the contractor and the owner is lowest ($r_{13.2} = 0.234$). This indicates that the consultant's responses are more important than the owner's in reflecting the existing situations. The agreement between the consultant and the owner when keeping the contractor constant, is ($r_{23.1} = 0.363$) .

This leads to the conclusion that the contractor's responses are the most important in reflecting the existing situations. These results are emphasized by the multiple correlation where the highest is when the consultant is considered with the other two parties ($r_{2.13} = 0.856$), as opposed to when the contractor is considered with the other parties. ($r_{1.23} = 0.838$). The least is when considering the owner with the other two parties ($r_{3.12} = 0.733$).This reflects the owner low knowledge and participation in construction and maintenance .

4.3.3. CROSS-TABULATION :

The cross tabulation (Table 4.1) shows that :

* 28% of the construction contractors have 10 years of experience or more, 70% have 5 to 10 years. 2% have less than 5 years.

* 53% of the maintenance contractors have 10 years of experience or more, 46% have 5 to 10 years .

* 37% of the consultants have 10 years of experience or more, 53% have 5 to 10 years, 10% have less than 5 years of experience, and 0% have less than 5 years of experience.

* 50% of the owners have 10 years of experience or more, 25% have 5 to 10 years, 25% have less than 5 years of experience.

These figures show that both the consultants and contractors have more experience than owners . Consequently, their responses to the problems reflect

the existing situations. Thus, the agreement between these two parties is expected to be the highest. Finally, the Spearman rank correlation emphasizes that the highest agreement is between these two parties (r_{12} = 0.83).

4.3.4 TEST OF HYPOTHESIS :

The researcher wants to test the hypothesis that contractors, consultants and owners generally agree on the severity ranking of maintenance defects . The 't' test is suitable and used in this study.

TEST OF CORRELATION :

This section tests the agreement between the parties . The null hypothesis (section a) below is tested by comparing the calculated value of t with the critical test value in the result given in Section (d) below :

a) The null hypothesis Ho : r = o

The null hypothesis says that the parties do not agree on the severity rank of maintenance defects and they differ in their responses with a correlation of zero among them.

b) The calculated value of t

$$t = [(n - 2) * r^2 / (1- r^2)]^{1/2} \quad \text{(Eq. 4.9)}$$

(KENDALL,1960)

Where :

r = the spearman correlation, partial correlation and multiple correlation found in Table 4.4

n = the number of observations (the number of questions in this study). It is taken as ∞ to include any number of questions .

By substituting the r values present in Table 4.4, the t values can be determined. The results are shown in Table 4.18.

c. The critical test value :

$$t_{0.05}, \infty - = 1.645$$

d. Decision :

In this case, the calculated values (Table 4.18) are greater than the critical value(1.645). Therefore, the null hypothesis is rejected and it is concluded that all the parties agree on the severity rank of maintenance defects and these parties are reliable in their responses.

4.4 MAJOR FINDINGS :

The sixty seven significant defects affecting maintenance were combined into eleven groups which were discussed in Chapter 2. The discussion in this section follows the organization used in Chapter 2 with focus on the results obtained and presented in the ranking tables (4.4 to 4.17).

4.4.1 FACTOR SEVERITY :

The severity index in the rank tables (4.4 to 4.17) range from Is lowest = 34 to Is highest = 89. Therefore, to identify the most severe factors, the scale is set between 30 and 90. Using the four point scale, the above mentioned range will be divided into four categories :

"Most Severe" defect	$75 \subset Is \subseteq 90$
"Moderately Severe" defect	$60 \subset Is \subseteq 75$
"Slightly Severe" defect	$45 \subset Is \subseteq 60$
"Non Severe" defect	$30 \subset Is \subseteq 45$

Based on the above, the all parties rank table (4-5) shows that :

7	Defects are "Most Severe"
52	Defects are "Moderately Severe"
8	Defects are "Severe"
0	Defects are "Non Severe"

The Most Severe Defects Are :

1 INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION

2 HIRING UNQUALIFIED DESIGNERS

3 NOT COMPLYING WITH SPECIFICATION

4 NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION

5 INADEQUATE WATER PROOFING AND DRAINAGE

6 UNQUALIFIED WORK FORCE

7 INABILITY TO READ THE DRAWINGS

Whereas, the contractor rank table (4-8) shows that :

8 Defects are "Most Severe"
52 Defects are "Moderately Severe"
7 Defects are "Severe"
0 Defects are "Non Severe"

The Most Severe Defects Are :

1 INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION

2 NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION

3 HIRING UNQUALIFIED DESIGNERS

4 NOT COMPLYING WITH SPECIFICATION

5 UNQUALIFIED WORK FORCE

6 INADEQUATE WATER PROOFING AND DRAINAGE

7 IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS

8 INABILITY TO READ THE DRAWINGS

While the Consultant Rank Table (4-10) shows that :

5 Defects are "Most Severe"
45 Defects are "Moderately Severe"
16 Defects are "Severe"
1 Defects are "Non Severe"

The Most Severe Defects Are :

1 HIRING UNQUALIFIED DESIGNERS

2 INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION

3 POOR TECHNICAL UPDATING OR STAFF TRAINING

4 NOT COMPLYING WITH SPECIFICATION

5 IGNORING VARIATION IN SOIL CONDITIONS

In the meantime, the owner rank table (4-12) shows that :

28 Defects are "Most Severe"
32 Defects are "Moderately Severe"
7 Defects are "Severe"
0 Defects are "Non Severe"

The Most Severe Defects Are :

1 NOT COMPLYING WITH SPECIFICATION

2 INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION

3 INADEQUATE WATER PROOFING AND DRAINAGE

4 UNQUALIFIED WORK FORCE

5 IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS

6 NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT

7 HIRING UNQUALIFIED DESIGNERS

8 INABILITY TO READ THE DRAWINGS

9 INSUFFICIENT SITE SUPERVISION

10 NOT SPECIFYING THE ALLOWABLE LOAD LIMITS

11 NOT CONSIDERING THE MAINTENANCE REQUIREMENTS IN DESIGN

12 LACK OF DETAILS

13 USE OF NONDURABLE MATERIAL

14 NARROW STAIRS, PASSAGES & DOORS

15 DESIGNER TECHNICAL BACKGROUND

16 INACCURATE MEASUREMENT

17 INSUFFICIENT REINFORCEMENT CONCRETE COVER

18 SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR THE EXISTING CLIMATIC CONDITIONS

19 INADEQUATE CONCRETE COVER ON THE REINFORCEMENT

20 NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION

21 NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN

TABLE 4.18

t-- VALUES FOR TESTING Ho

$t_{(12)} = 11.92$	$t_{(12.3)} = 7.20$	$t_{(1.23)} = 12.37$
$t_{(13)} = 7.56$	$t_{(13.2)} = 1.95$	$t_{(2.13)} = 13.35$
$t_{(23)} = 8.24$	$t_{(23.1)} = 3.14$	$t_{(3.12)} = 8.68$

22 DESIGNER IGNORANCE OF MATERIALS PROPERTIES

23 CONFLICTING DETAILS

24 UNCLEARED SPECIFICATION

25 POOR SOIL COMPACTION

26 POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER

27 UNQUALIFIED SUPERVISION

28 SPEEDY COMPLETION OR CHEAP QUALITY WORK

4.4.2 GROUPS SEVERITY :

Implementing the severity scale in section 4.4.1 on the defect main group severity index rank tables (4-6, 4-9, 4-11, 4-13) will give the results shown below :

The Defects group ranked by ALL PARTIES Table (4-6) shows that :

0 Groups considered as "Most Severe"
9 Groups considered as "Moderately Severe"
2 Groups considered as "Severe"
0 Groups considered as "Non Severe"

The Moderately Severe Groups Are :

1 DEFECTS DUE TO CONSTRUCTION INSPECTION

2 DEFECTS DUE TO CONTRACTOR ADMINISTRATION

3 DEFECTS DUE TO CONSTRUCTION DRAWINGS

4 DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF

5 DEFECTS DUE TO CIVIL CONSTRUCTION

6 DEFECTS DUE TO CONSTRUCTION MATERIALS

7 DEFECTS IN CIVIL DESIGN

8 DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY

9 ARCHITECTURAL DEFECTS IN DESIGN

The Defect groups ranked by Contractor Table (4-9) shows :

0	Groups considered as "Most Severe"
10	Groups considered as "Moderately Severe"
1	Groups considered as "Severe"
0	Groups considered as "Non Severe"

The Moderately Severe Groups are :

1 DEFECTS DUE TO CONSTRUCTION INSPECTION

2 DEFECTS DUE TO CONSTRUCTION DRAWINGS

3 DEFECTS DUE TO CONTRACTOR ADMINISTRATION

4 DEFECTS DUE TO CIVIL CONSTRUCTION

5 DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF

6 DEFECTS DUE TO CONSTRUCTION MATERIALS

7 DEFECTS IN CIVIL DESIGN

8 ARCHITECTURAL DEFECTS IN DESIGN

9 DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY

10 DEFECTS DUE TO SPECIFICATION

The Defects groups ranked by Consultant Table (4-11) shows :

0 Groups considered as "Most Severe"
6 Groups considered as "Moderately Severe"
5 Groups considered as "Severe"
0 Groups considered as "Non Severe"

The Moderately Severe Groups are :

1 DEFECTS DUE TO CONSTRUCTION INSPECTION

2 DEFECTS DUE TO CONTRACTOR ADMINISTRATION

3 DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF

4 DEFECTS DUE TO CONSTRUCTION DRAWINGS

5 DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY

6 DEFECTS IN CIVIL DESIGN

And the Defects main groups Owner Rank Table (4-13) shows :

2 Groups considered as "Most Severe"
8 Groups considered as "Moderately Severe"
1 Groups considered as "Severe"
0 Groups considered as "Non Severe"

The Most Severe Groups are :

1 DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY

2 DEFECTS DUE TO CONTRACTOR ADMINISTRATION

The Moderately Severe Groups Are :

1 DEFECTS DUE TO CONSTRUCTION DRAWINGS

2 DEFECTS DUE TO SPECIFICATION

3 DEFECTS DUE TO CONSTRUCTION MATERIALS

4 DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF

5 ARCHITECTURAL DEFECTS IN DESIGN

6 DEFECTS DUE TO CONSTRUCTION INSPECTION

7 DEFECTS IN CIVIL DESIGN

8 DEFECTS DUE TO CIVIL CONSTRUCTION

9 DEFECTS DUE TO CONSTRUCTION EQUIPMENT

4.4.3 THE COMMON MOST SEVERE DEFECTS :

Below are the most severe defects which are common in the response of the three parties.

- A 4. INADEQAUATE STRUCTURAL DESIGN
- D 3. HIRING UNQUALIFIED DESIGNERS
- H 1. NOT COMPLYING WITH SPECIFICATIONS

4.4.4. RESPONDENTS EXTRA COMMENTS:

Below are the comments which were mentioned in the respondent questionaire as extra comments:

- NO SPECIFICATION FOLLOWED
- QUICK RESPONSE

- PROPER RESPONSE
- PROJECT MANAGER LEADERSHIP
- REPORTING & DOCUMENTATION
- LAND SCAPING AND IRRIGATION SYSTEM SHOULD BE AWAY FROM BUILDING
- PERIODIC MAINTENANCE
- MAINTENANCE PROCEDURE
- USING UNCOATED REBAR
- STEEL BAR CORROSION
- CEMENT SPECIFICATIONS TYPE I AND V FOR EACH APPLICATION
- CURING
- TEMPERATURE OF CONCRETE PLACEMENT
- UNCLEAR TENDER DOCUMENTATION
- IGNORANCE OF SAFETY IN DESIGN
- NOT COMPLYING WITH GENERAL ENGINEERING SPECIFICATIONS
- POOR CONSTRUCTION MANAGEMENT
- NEEDS OF BUILDING CODE & STANDARD
- EXPERIENCE
- ORGANISATION
- SPARE PARTS
- PROMT & EFFECTIVE ACTIONS

- POOR TRAINING OF MAINTENANCE PERSONNEL
- USING WRONG CHEMICAL FOR MAINTENANCE PURPOSES
- DESIGNING SYSTEMS THAT ARE TOO COMPLICATED FOR MAINTENANCE
- DEFFECT DUE TO PRODUCT COMPETITION
- DEFFECTS DUE TO FEE COMPITITION
- DEFFECTS DUE TO BUILDING BUDGET CONSTRAINT
- CONSTRUCION JOINTS
- ACCESSIBILITY FOR INSPECTION
- PROPER DESIGN OF "P" TRAPS
- DRAINAGE OF SEWERAGE
- AS BUILT DRAWING
- PERFORMANCE SPECIFICATION OF MAINTENANCE EQUIPMENT
- LACK OF REGULER PREVENTIVE MAINTENANCE
- LACK OF SPARE PARTS
- REBAR DETAILING
- JOINTING OF NEW BUILDING WITH EXISTING
- UNSKILLED WORKERS
- CO-OPERATION, COMMUNICATION AND COORDINATION BETWEEN THE VARIOUS AGENCIES INVOLVED
- PROPER MATERIALS
- WRONG USE OF BUILDING

- CONSIDERATION OF MAINTENANCE REQUIREMENTS IN DESIGN
- MAINTENANCE BUDGET
- LACK OF AS BUILT DRAWINGS
- LACK OF MAINTENANCE EXPERIENCE
- LESS ATTENTION TO DAMAGED AREAS
- LACK OF MAINTENANCE EQUIPMENT
- SAFETY CONSIDERATIONS (ELECTRICAL FIREPROTECTION, ETC.)
- OWNER USE
- PROPER MAINTENANCE
- IMPROPER MANAGEMENT
- POOR COORDINATIONAMONG WORKERS
- INEXPERIENCED CREW
- SAFETY ITEMS
- TYPE OF WATER, AGGREGATE IN THE CONCRETE MIX
- CONCRETE TEMPERATURE AND MIXING TIME
- UNDERGROUND WATER PROOFING
- HUMAN ENVIRONMENT

4.5 SUMMARY :

This chapter is intended to give the reader an idea of how the data was collected and placed into a format that could be analyzed. This included the analysis of the raw data and a look at each group of the collected data separately, finding the major points they contain. The chapter contains the statistical results,

the statistical methods used, tables and information induced from statistical analysis and an interpretation of the tables and information. As part of this analysis, ranking by a severity index of the maintenance defects by contractors, consultants, and owners is given in a formatted table. A hypothesis was offered and tested that the contractors, consultants and owners generally agree on the severity rank of maintenance defects and it was proved that the hypothesis is true. And the last section discusses and identifies the most severe defects in the standard rank table and all the three parties separately .

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

This chapter is devoted to a summary, conclusion and recommendations.

5.1 SUMMARY OF THESIS :

Chapter 1 discussed the buildings maintenance industry and introduced objectives, previous studies done, and the approaches and the significance of this study. It was decided that building maintenance increases as the design and construction defects increases. Therefore, by identifying and evaluating the defects, the consultant, contractor and the owner can minimize them. The need for this research was discussed in detail in this chapter.

Chapter 2 discussed the types of design and construction defects that affect building maintenance and focused on problems present in the Eastern Province of the Kingdom of Saudi Arabia. The first part of the chapter demonstrated the types of defects. There are sixty seven defects which can affect building maintenance. They are grouped into eleven groups :

1 DEFECTS IN CIVIL DESIGN

2 ARCHITECTURAL DEFECTS IN DESIGN

3 DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY

4 DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF

5 DEFECTS DUE TO CONSTRUCTION DRAWINGS

6 DEFECTS DUE TO CONSTRUCTION INSPECTION

7 DEFECTS DUE TO CIVIL CONSTRUCTION

8 DEFECTS DUE TO CONTRACTOR ADMINISTRATION

9 DEFECTS DUE TO CONSTRUCTION MATERIALS

10 DEFECTS DUE TO CONSTRUCTION EQUIPMENT

11 DEFECTS DUE TO SPECIFICATION

The second part discussed these defect factors in more detail.

Chapter 3 demonstrated the means for collection of the raw data and then an approach was developed which resulted in the final questionnaire. Statistical sample size and scoring techniques were presented in this chapter. The total number of the respondents were 140, 65% of them are building contractors, 21% are consultants and 14% are building owners. 67% of the building contractors are construction contractors and the remaining 33% are maintenance contractors.

Chapter 4 included the analysis of the raw data and the study of each defect factor of the collected data separately . Mainly, it contained the statistical methods used, tables and information induced from the statistical analysis and the statistical results and an interpretation of the tables and information.

The hypothesis of the agreement for the rank of the maintenance defect factors was tested and it was proven that all parties (owners, contractors, and consultants) generally agree. In addition three correlation methods , Spearmen correlation, Partial correlation, and Multiple correlation , were used to determine the association among the parties included in this chapter. The correlation shows that the strongest agreement is between the construction contractor and the consultant .

5.2 CONCLUSIONS :

Based on the above information, the following conclusions seem justified.

1) There are sixty seven defect factors identified to have effect on building maintenance. Thirty-five of them are related to the Design stage and the remaining thirty-two are related to the Construction stage. The study shows that seven of these factors are considered "Most Severe", fifty-two "Moderately Severe", eight "Severe", and zero "Non Severe". The most severe factors which affect maintenance are :

1 INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION

2 HIRING UNQUALIFIED DESIGNERS

3 NOT COMPLYING WITH SPECIFICATION

4 NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION

5 INADEQUATE WATER PROOFING AND DRAINAGE

6 UNQUALIFIED WORK FORCE

7 INABILITY TO READ THE DRAWINGS

2) Most of the building maintenance problems arise from unqualified consultant staff or contractor site supervisory personnel and workers. For the consultant the staff selection should be done on a systematic basis where the design engineer is tested practically and technically . The design engineer should have at least five years of experience in the construction and maintenance field so he can have a feed back of what can be done and what cannot be done. In addition, he will be aware of the construction and maintenance equipment available in the market. Regarding the contractor, the staff selection should be done through two steps. First, the worker should pass the field test, then the oral test to make sure he can communicate well. For the field supervisory personnel they should be capable of understanding and reading the design drawings carefully, and making sure that they have no language barrier with their staff, the consultant and the owner.

3) The consultant and contractor should make sure that all used construction material will serve the buildings intended use and tolerate the environmental conditions. It is expected that defects will increase in the future because new products, whose properties and problems are largely unknown, will still be misused.

4) The study shows that the three parties (consultants, contractors and owners) generally agree in the rank of defects. The contractor is considered to be the most important party who reflects the actual problems existing in the field while the consultant is the second. Consequently, these two parties have the highest agreement because they are involved more in causing the defects and on the other hand making the recommendation and repairing them. Thus, it is found that the consultant and contractors have much more experience than the owners. The study shows that the agreement between the construction contractor and consultant

is stronger than between the maintenance contractor and the consultant because of the full time relationship between the consultant and the construction contractor. The study also shows that the relation between the owner and the maintenance contractor is stronger than with the construction contractor because of the owner involvement during the repair stage is more than during the construction stage.

5) This study will help building contractors, consultants and owners to identify problems before they happen and to avoid or minimize them.

6) The study will help any of the three parties involved to understand the opinion of the other two parties. It acts like a two way communication to discuss the causes of defects and try to eliminate them.

7) Maintenance expenditure can be reduced if a diagnosis of building defects is used before conducting any work . This will ensure that the cost of remedial work is not excessive . This research can be used as a guide to identify those defects.

8) This research recommends that a strict quality assurance (QA/QC) program be implemented for the consultant and contractor to insure they follow the latest economical and practical specifications.

5.3 RECOMMENDATIONS FOR FURTHER STUDIES :

1) It is recommended that a building sample be taken and their existing types of defects . Then these defects should be recorded and each traced to its source (consultant, contractor, and owner). It is recommended that the buildings be categorized, as schools, hospitals, office buildings, industrial buildings, high rise buildings, residential buildings,etc. Accordingly each party of the three can use this information to minimize his mistakes.

2) In the UK, 20% of the annual expenditure on repairs is attributed to designs and construction defects in the building. It is recommended to conduct a similar study to compare the maintenance cost due to defects to the building maintenance budget and the construction cost.

3) It is recommended to make a study similar to this research, but on building's electrical and mechanical defects due to design and construction.

APPENDIX-I

QUESTIONNAIRE

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
COLLEGE OF ENVIRONMENTAL DESIGN
CONSTRUCTION ENGINEERING AND MANAGEMENT

Dear Sir,

I am doing a study on the defects which can happen during design and construction stages and affect maintenance .To measure the severity to these defects, and their effect on maintenance work, your cooperation in filling this questionnaire is appreciated.

Please note that the given information will be kept secret and destroyed after the data are analyzed.

ADDRESS :

M. M. Alshiha,
P. O. Box 107,
Dammam 31411,
Saudi Arabia.

PART " A "

Please answer these questions regarding your firm.

1. Which phase of the building do you perform?

   1) Owner .....[ ]

   2) Design Phase.....[ ]

   3) Construction Phase.....[ ]

   4) Maintenance Phase.....[ ]

   5) Other, Please specify _____

2. Indicate your construction or consulting or maintenance experience :

   1) Experience $\subset$ 5 years .....[ ].

   2) 5 years $\subseteq$ Experience $\subset$ 10 years.....[ ]

   3) 10 years $\subseteq$ Experience..... [ ]

3. You gained your qualification through :

   1) Experience. Which discipline _____
   2) Engineering degree. Specify _____
   3) On-job training._____

PART " B "

Company/Firm Name : _____

Telephone : _____

Answered By : _____

Date : _____

Please note the following before you start answering the questions.

1) Select only one answer for each defect.

2) The mentioned defects can be increased if you think some defects need to added and mark their degree of importance.

PART B

Q #	DEFECTS	STRON-GLY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
A	DEFECTS IN CIVIL DESIGN				
1	INADEQUATE PROVISIONS FOR MOVEMENT	[ ]	[ ]	[ ]	[ ]
2	IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS	[ ]	[ ]	[ ]	[ ]
3	IGNORING BIOLOGICAL EFFECTS	[ ]	[ ]	[ ]	[ ]
4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	[ ]	[ ]	[ ]	[ ]
5	IGNORING VARIATION IN SOIL CONDITIONS	[ ]	[ ]	[ ]	[ ]
6	IGNORING LOAD IMPACT ON STRUCTURE STABILITY	[ ]	[ ]	[ ]	[ ]
7	EXCEEDING ALLOWABLE DEFLECTION	[ ]	[ ]	[ ]	[ ]
8	IGNORING WIND EFFECTS ON THE STRUCTURE	[ ]	[ ]	[ ]	[ ]
9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	[ ]	[ ]	[ ]	[ ]
10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	[ ]	[ ]	[ ]	[ ]
B	ARCHITECTURAL DEFECTS IN DESIGN				
1	NARROW STAIRS, PASSAGES & DOORS	[ ]	[ ]	[ ]	[ ]
2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	[ ]	[ ]	[ ]	[ ]
3	SPECIFYING FINISHINGS WHICH NEED TO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	[ ]	[ ]	[ ]	[ ]
4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	[ ]	[ ]	[ ]	[ ]
5	INADEQUATE JOINTS BETWEEN FINISHED FACES	[ ]	[ ]	[ ]	[ ]

PART B
(Contd.)

Q #	DEFECTS	STRONG-LY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY				
1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	[ ]	[ ]	[ ]	[ ]
2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	[ ]	[ ]	[ ]	[ ]
3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	[ ]	[ ]	[ ]	[ ]
4	NOT CONSIDERING THE MAINTENANCE	[ ]	[ ]	[ ]	[ ]
D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF				
1	LACK OF QA/QC PROGRAM DURING DESIGN	[ ]	[ ]	[ ]	[ ]
2	POOR TECHNICAL UPDATING OR STAFF TRAINING	[ ]	[ ]	[ ]	[ ]
3	HIRING UNQUALIFIED DESIGNERS	[ ]	[ ]	[ ]	[ ]
4	DESIGNER FIELD EXPERIENCE	[ ]	[ ]	[ ]	[ ]
5	DESIGNER TECHNICAL BACKGROUND	[ ]	[ ]	[ ]	[ ]
6	DESIGNER IGNORANCE OF MATERIALS PROPERTIES	[ ]	[ ]	[ ]	[ ]
7	MISJUDGEMENT OF CLIMATIC CONDITIONS	[ ]	[ ]	[ ]	[ ]
8	MISJUDGEMENT OF USER'S INTENDED USE	[ ]	[ ]	[ ]	[ ]

PART B
(Contd.)

Q #	DEFECTS	STRONG-LY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
E	DEFECTS DUE TO CONSTRUCTION DRAWINGS				
1	LACK OF REFERENCES	[ ]	[ ]	[ ]	[ ]
2	CONFLICTING DETAILS	[ ]	[ ]	[ ]	[ ]
3	LACK OF DETAILS	[ ]	[ ]	[ ]	[ ]
F	DEFECTS DUE TO CONSTRUCTION INSPECTION				
1	LACK OF INSPECTION	[ ]	[ ]	[ ]	[ ]
2	UNQUALIFIED INSPECTOR	[ ]	[ ]	[ ]	[ ]
3	PROPONENT (OWNER) NEGLIGENCE OF THE IMPORTANCE OF INSPECTION	[ ]	[ ]	[ ]	[ ]
4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	[ ]	[ ]	[ ]	[ ]
G	DEFECTS DUE TO CIVIL CONSTRUCTION				
1	INACCURATE MEASUREMENT	[ ]	[ ]	[ ]	[ ]
2	DAMAGED FORMWORK	[ ]	[ ]	[ ]	[ ]
3	EXCAVATION TOOL CLOSE TO THE BUILDING	[ ]	[ ]	[ ]	[ ]
4	PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE	[ ]	[ ]	[ ]	[ ]
5	INADEQUATE WATER PROOFING AND DRAINAGE	[ ]	[ ]	[ ]	[ ]
6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	[ ]	[ ]	[ ]	[ ]
7	COLD JOINTS	[ ]	[ ]	[ ]	[ ]
8	LOSS IN ADHESION BETWEEN MATERIALS	[ ]	[ ]	[ ]	[ ]

PART B
(Contd.)

Q #	DEFECTS	STRONG-LY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
9	EARLY FORMWORK REMOVAL	[ ]	[ ]	[ ]	[ ]
10	POOR SOIL COMPACTION	[ ]	[ ]	[ ]	[ ]
11	INADEQUATE CURING	[ ]	[ ]	[ ]	[ ]
12	LACK OF COMMUNICATION	[ ]	[ ]	[ ]	[ ]
H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION				
1	NOT COMPLYING WITH SPECIFICATION	[ ]	[ ]	[ ]	[ ]
2	UNABLE TO READ THE DRAWINGS	[ ]	[ ]	[ ]	[ ]
3	INSUFFICIENT SITE SUPERVISION	[ ]	[ ]	[ ]	[ ]
4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	[ ]	[ ]	[ ]	[ ]
5	UNQUALIFIED SUPERVISION	[ ]	[ ]	[ ]	[ ]
6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	[ ]	[ ]	[ ]	[ ]
7	UNQUALIFIED WORK FORCE	[ ]	[ ]	[ ]	[ ]
8	MULTINATIONAL CONSTRUCTION EXPERIENCE	[ ]	[ ]	[ ]	[ ]
I	DEFECTS DUE TO CONSTRUCTION MATERIALS				
1	DIFFERENTIAL THERMAL MOVEMENTS IN DISSIMILAR MATERIAL	[ ]	[ ]	[ ]	[ ]
2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR EXISTING CLIMATIC CONDITIONS	[ ]	[ ]	[ ]	[ ]
3	USE OF NONDURABLE MATERIAL	[ ]	[ ]	[ ]	[ ]
4	USE OF EXPIRED MATERIAL	[ ]	[ ]	[ ]	[ ]
5	POOR MATERIAL HANDLING & STORAGE	[ ]	[ ]	[ ]	[ ]

PART B
(Contd.)

Q #	DEFECTS	STRONG-LY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT				
1	WRONG USE OF EQUIPMENT	[ ]	[ ]	[ ]	[ ]
2	INADEQUATE PERFORMANCE OF EQUIPMENT	[ ]	[ ]	[ ]	[ ]
3	LACK OF REQUIRED NUMBER OF EQUIPMENTS	[ ]	[ ]	[ ]	[ ]
K	DEFECTS DUE TO SPECIFICATION				
1	UNCLEAR SPECIFICATION.	[ ]	[ ]	[ ]	[ ]
2	NOT DEFINING ADEQUATE MATERIALS	[ ]	[ ]	[ ]	[ ]
3	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	[ ]	[ ]	[ ]	[ ]
4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	[ ]	[ ]	[ ]	[ ]
5	SPECIFYING INADEQUATE CONCRETE MIX DESIGN	[ ]	[ ]	[ ]	[ ]

APPENDIX-II

CROSS TABULATION OF MAINTENANCE DEFECTS WITH FREQUENCY OF ALL PARTIES

ALL PARTIES LIST FREQUENCIES

Q #	DEFECTS	STRONG-LY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
A	DEFECTS IN CIVIL DESIGN				
1	INADEQUATE PROVISIONS FOR MOVEMENT	25	78	28	9
2	IGNORING AGGRESSIVE ENVIRONMENT AND WEATHER CONDITION EFFECTS	44	88	7	1
3	IGNORING BIOLOGICAL EFFECTS	22	71	38	9
4	INADEQUATE STRUCTURAL DESIGN SUCH AS FOUNDATION	77	48	8	7
5	IGNORING VARIATION IN SOIL CONDITIONS	60	58	18	4
6	IGNORING LOAD IMPACT ON STRUCTURE STABILITY	39	65	30	6
7	EXCEEDING ALLOWABLE DEFLECTION	40	54	42	4
8	IGNORING WIND EFFECTS ON THE STRUCTURE	21	91	17	11
9	INADEQUATE CONCRETE COVER ON THE REINFORCEMENT	62	49	26	3
10	IMPROPERLY LOCATING CONDUITS AND PIPE OPENINGS AT CRITICAL STRUCTURAL LOCATIONS	42	61	30	7
B	ARCHITECTURAL DEFECTS IN DESIGN				
1	NARROW STAIRS, PASSAGES & DOORS	47	75	11	7
2	NOT RELATING EXTERIOR MATERIAL SELECTION TO CLIMATIC CONDITION	53	78	6	3
3	SPECIFYING FINISHINGS WHICH NEED TO BE REPAIRED AS A WHOLE (SUCH AS WALL PAPER)	9	73	36	22
4	NOT CONSIDERING THE LOCAL CLIMATIC CONDITION WHEN DESIGNING THE EXTERIOR SHAPE	28	77	31	4
5	INADEQUATE JOINTS BETWEEN FINISHED FACES	24	95	17	4

ALL PARTIES LIST FREQUENCIES
(Contd.)

Q #	DEFECTS	STRONG-LY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY				
1	NOT CONSIDERING SPACE OR EXIT FOR MAINTENANCE WORKER, EQUIPMENT	43	78	18	1
2	DESIGNING FOR PERMANENT FIXING WHICH SHOULD BE REMOVABLE FOR MAINTENANCE	31	62	44	3
3	NOT CONSIDERING THE AVAILABLE MAINTENANCE EQUIPMENT WHEN PERFORMING THE DESIGN	25	95	20	0
4	NOT CONSIDERING THE MAINTENANCE	37	63	39	1
D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF				
1	LACK OF QA/QC PROGRAM DURING DESIGN	39	64	27	10
2	POOR TECHNICAL UPDATING OR STAFF TRAINING	51	66	21	2
3	HIRING UNQUALIFIED DESIGNERS	76	45	17	2
4	DESIGNER FIELD EXPERIENCE	44	74	20	2
5	DESIGNER TECHNICAL BACKGROUND	44	63	26	7
6	DESIGNER IGNORANCE OF MATERIALS PROPERTIES	59	54	24	3
7	MISJUDGEMENT OF CLIMATIC CONDITIONS	37	71	30	2
8	MISJUDGEMENT OF USER INTENDED USE	30	53	48	9

ALL PARTIES LIST FREQUENCIES
(Contd.)

Q #	DEFECTS	STRONG-LY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
E	DEFECTS DUE TO CONSTRUCTION DRAWINGS				
1	LACK OF REFERENCES	19	94	22	5
2	CONFLICTING DETAILS	44	87	8	3
3	LACK OF DETAILS	47	79	11	3
F	DEFECTS DUE TO CONSTRUCTION INSPECTION				
1	LACK OF INSPECTION	53	65	19	3
2	UNQUALIFIED INSPECTOR	53	62	20	5
3	PROPONENT (OWNER) NEGLIGENCE OF THE IMPORTANCE OF INSPECTION	46	69	23	2
4	WEAKNESS OF INSPECTION RULE IN IMPLEMENTING CORRECTIVE ACTIONS DURING JOB EXECUTION	45	65	25	5
G	DEFECTS DUE TO CIVIL CONSTRUCTION				
1	INACCURATE MEASUREMENT	55	50	28	7
2	DAMAGED FORMWORK	34	76	26	4
3	EXCAVATION TOOL CLOSE TO THE BUILDING	42	66	26	6
4	PAINTING IN UNSUITABLE CONDITIONS OR ON UNSUITABLE SURFACE	34	74	23	5
5	INADEQUATE WATER PROOFING AND DRAINAGE	63	56	19	2
6	INSUFFICIENT REINFORCEMENT CONCRETE COVER	61	54	22	3
7	COLD JOINTS	19	82	29	10
8	LOSS IN ADHESION BETWEEN MATERIALS	41	69	23	7

ALL PARTIES LIST FREQUENCIES
(Contd.)

Q #	DEFECTS	STRONG-LY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
9	EARLY FORMWORK REMOVAL	35	70	28	7
10	POOR SOIL COMPACTION	47	66	24	3
11	INADEQUATE CURING	46	68	20	6
12	LACK OF COMMUNICATION	34	79	23	4
H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION				
1	NOT COMPLYING WITH SPECIFICATION	58	74	6	2
2	INABILITY TO READ THE DRAWINGS	60	63	13	4
3	INSUFFICIENT SITE SUPERVISION	46	85	6	3
4	POOR COMMUNICATION WITH THE DESIGN FIRM AND THE OWNER	40	76	23	1
5	UNQUALIFIED SUPERVISION	46	70	22	2
6	SPEEDY COMPLETION OR CHEAP QUALITY WORK	50	65	21	4
7	UNQUALIFIED WORK FORCE	65	53	19	3
8	MULTINATIONAL CONSTRUCTION EXPERIENCE	9	72	42	17
I	DEFECTS DUE TO CONSTRUCTION MATERIALS				
1	DIFFERENT THERMAL MOVEMENTS IN DISSIMILAR MATERIAL	28	80	30	2
2	SELECTION OF MATERIAL WHICH IS UNSUITABLE FOR EXISTING CLIMATIC CONDITIONS	57	59	22	2
3	USE OF NONDURABLE MATERIAL	56	56	27	1
4	USE OF EXPIRED MATERIAL	55	45	36	4
5	POOR MATERIAL HANDLING & STORAGE	20	77	40	3

ALL PARTIES LIST FREQUENCIES
(Contd.)

Q #	DEFECTS	STRONG-LY AFFECTS	MODERA-TELY AFFECTS	SLIGHTLY AFFECTS	DOES NOT AFFECT
J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT				
1	WRONG USE OF EQUIPMENT	23	74	37	6
2	INADEQUATE PERFORMANCE OF EQUIPMENT	17	82	34	7
3	LACK OF REQUIRED NUMBER OF EQUIPMENTS	13	65	56	6
K	DEFECTS DUE TO SPECIFICATION				
1	UNCLEARSPECIFICATION	36	63	38	3
2	NOT DEFINING ADEQUATE MATERIALS	43	66	29	2
3	NOT SPECIFYING THE QA/QC CONSTRUCTION PROCEDURE	25	57	44	14
4	NOT SPECIFYING THE ALLOWABLE LOAD LIMITS	37	46	52	5
5	SPECIFYING INADEQUATE CONCRETE MIX DESIGN	55	51	31	3

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VITA

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