WATER WAVE PROPAGATION ON NONUNIFORM BOTTOM

BY

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THESIS ABSTRACT

Name: **Mohammad Abdulrahman Mohammad AL-Suwaiyel**

Title: **Water Wave Propagation on Non-Uniform Bottom**

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Water wave propagation affects coastal structures at different levels. As a method of protection, the amplitudes of water waves are normally reduced by breakwaters. In this thesis, focus was placed on breakwater in the form of non-uniform geometries built onto the seabed. Breakwaters with rectangular cross sections are investigated for reducing the water wave transmission in deep and intermediate waters.

A parametric analysis is conducted, where the influence of geometric parameters such as the height and the width of the rectangular breakwaters considered, the effect of water wave parameters such as wavelength and the depth of the water are studied, and the influence of repeating breakwaters is numerically tested.

A general purpose MATLAB program, based on the transfer matrix method, is developed to calculate the transmission of water waves for the cases of any angular wave speed, wavelength, and depth of water over various types of breakwaters. Transmission coefficients are found to decrease with the increase of water wavelength, water depth, the number of successive rectangular breakwaters, and the decrease of the water angular speed. The developed software program can be utilized for designing the rectangular breakwaters for achieving the desired level of water wave amplitude reduction.

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ملخص الرسالة

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يؤثر انتشار الموجات المائية على التركيبة الساحلية بمستويات مختلفة . كأحد طرق الوقاية يمكن تقليص نطاقات ومدى الموجات المائية بشكل طبيعي عن طريق استخدام حواجز كسر الأمواج . في هذه الرسالة تم التركيز على حواجز كسر الأمواج في شكل بناء هندسي غير متسق في قاع البحر . حواجز كسر الأمواج من خلال القطاعات العرضية المستطيلة تستخدم لتقليل انتقال الموجات المائية في الأعماق والمياه المتوسطة .

تم إجراء تحليل بارمتري في الأماكن التي بها بارامترات هندسية مثل ارتفاع وعرض حواجز كسر الأمواج المستطيلة وتم دراسة أثر بارامترات الموجات المائية مثل الطول الموجي وعمق المياه وكذلك أختبار تأثير تكرار حواجز كسر الأمواج عددياً .

تم تطوير برنامج MATLAB المبنى على طريقة انتقال المصفوفة لحساب انتقال الموجات المائية لحالات أي سرعة لأي موجة زاوية وأي طول موجي وعمق المياه فوق الأنواع المختلفة من حواجز كسر الأمواج . وقد وجد انخفاض معاملات الانتقال مع زيادة الطول الموجى وعمق المياه وعدد حواجز كسر الأمواج المستطيلة المتتالية وانخفاض السرعة الزاوية للمياه . يمكن استخدام برنامج الحاسوب (السوفت وير) المطور لتصميم حواجز كسر الأمواج المستطيلة لتحقيق المستوى المطلوب من تقليل نطاق الموجة المائية .

درجة الماجستير في العلوم

جامعة الملك فهد للبترول والمعادن

الظهران – المملكة العربية السعودية

CHAPTER 1

INTRODUCTION

1.1 Water Waves

Water waves are surface waves. They are a mixture of longitudinal and transverse waves. Longitudinal waves are waves that have vibrations along or parallel to their direction of travel in which the motion of the medium is in the same direction as the motion of the wave. Transverse wave is a moving wave, a wave that propagates (travels) in a direction perpendicular to the direction in which the oscillations that produce the wave are moving.

Water waves accrue on the surface of water in nature or in any man-made water tank, water container and wash basin. They may be caused by winds, tides, earthquakes of moving vessels. Water waves size and forms, depending on the magnitude of the forces acting on the water. A simple illustration is that a small stone and large rock create different-size waves after impacting on water and different speeds of impact create different-size waves.

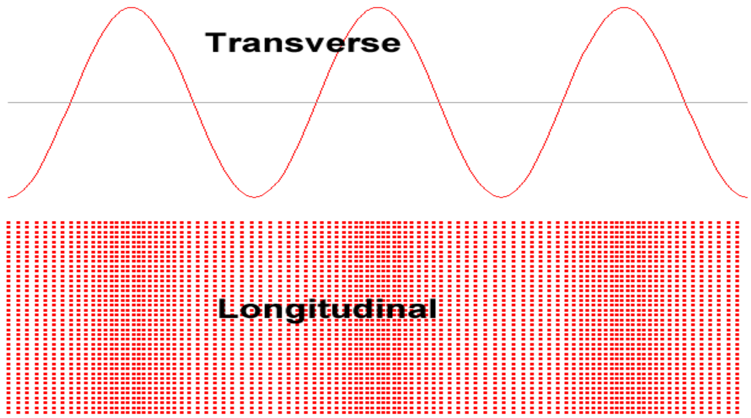


Figure (1-1): Transverse Wave and Longitudinal Wave

1.2 Water Waves Parameters and Characteristics

The important parameters to describe waves are their length and height and the water depth over which they are propagating. All other parameters, such as waves-induced water velocities and acceleration can be determined theoretically from these quantities. The length of the waves, L, is the horizontal distance between two successive wave crests or the distance between the two wave troughs. The speed of the wave, called the celerity, is defined as the wave length over the time (C=L/t).

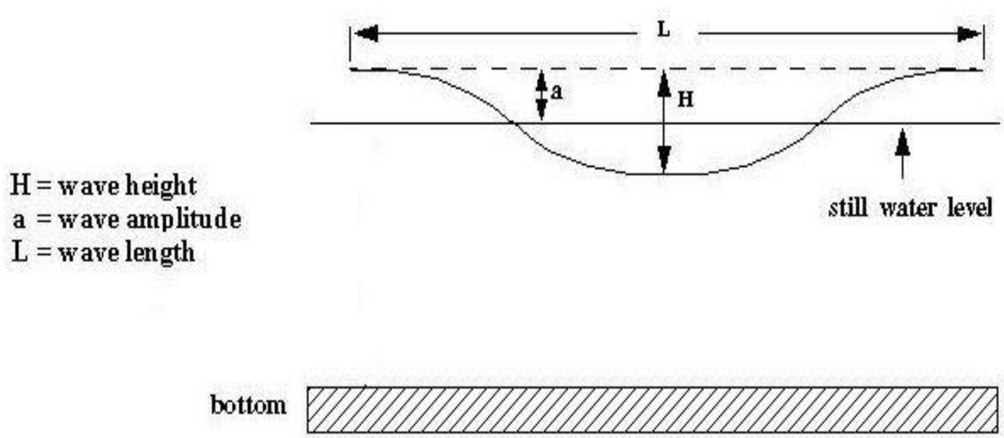


Figure (1-2): Water Wave Parameters

Dispersion of water waves generally refers to frequency dispersion. Frequency dispersion means that waves of different wavelengths travel at different phase speeds**.** Water waves are waves propagating on the water surface forced by gravity and surface tension**.** Water with a free surface is generally considered to be a dispersive medium**.**

Breaking of water surface waves may occur anywhere that the amplitude is sufficient including in mid-ocean. However, it is particularly common on beaches because waves are refracted towards the region of shallower water (because the phase velocity is lower there), and the shallow water also means that the same wave energy density gives rise to a greater surface amplitude.

1.3 Water Waves Types

Water waves are classified by the ratio of the water depth (h) to the wavelength (L) as deep ($h/L > 1/2$), intermediate ($1/2 > h/L > 1/20$), or shallow ($1/20 > h/L$). We will consider the intermediate water waver by fixing the depth and allow the wavelength to change. The ratio shall be between 0.5 and 0.05.

There are three types of water waves and they occur depending on the ratio of the water depth to wavelength (h/ L). They are divided into:

1.3.1 Deep Water Waves

Deep water waves are unaffected by the bottom of the sea floor and they are limited by the ratio of the water depth (h) to the wavelength greater than 0.5.

1.3.2 Transition Water Waves

Transition Water Waves are affected by the bottom of the sea floor and they are limited by the ratio of the water depth (h) to the wavelength (L) between about 0.05 and 0.5.

1.3.3 Shallow Water Waves

Shallow Water Waves are affected by the bottom of the sea floor and they limited by the ratio of the water depth (h) to the wavelength (L) less than 0.05.

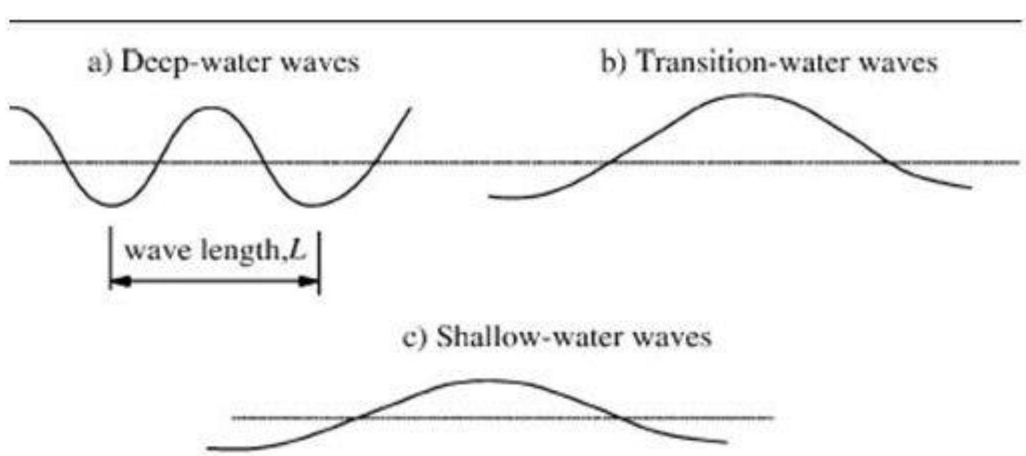


Figure (1-3): Types of Water Waves

1.4 Literature Review

The water wave propagation covered in many literatures from early eighties up to today. The literatures covered different subjects related to water wave propagation like surface gravity waves, nonlinear water wave interactions, two-dimensional numerical models, numerical model to investigate the Bragg scattering and the effect of regular bottom corrugations on water waves.

Nayfeh and Hawwa [1] considered the interaction of surface gravity waves on a non-uniformly periodic sea bad. The method of multiple scales was used to analyze the interaction leading to two coupled-mode equations. The power reflection coefficient was used as an indicator to evaluate the filter action of the bottom corrugation. The characteristics of the filtration ware found to be enhanced by imposing special types of amplitude and phase modulated periodic non-uniformities, including amplitude taper and chirped periodic variations.

Li [2] derived a new parabolic equation form the mild-slope equation. It was used as the governing equation for the propagation of periodic surface water waves without wave reflection. For the problem of forward wave propagation, the equation can be solved very efficiently by the parabolic equation method, without the angle limitation as for other parabolic models. A parabolic equation for wave-current interaction based on the wave model was also developed in his paper.

Liu and Yue [3] studied the generalized Bragg scattering of surface waves over a wavy bottom. They considered the problem in the general context of nonlinear wave-wave interactions, and provided geometric constructions for the Bragg resonance conditions for second-order triad (class I) and third-order quartet (class II and class III) wave bottom interactions.

Gotoh and Sakai [4] performed Lagrangian numerical simulation of breaking waves by the moving particle semi-implicit (MPS) method, in which the Navier-Stokes equation was discritized based on the interaction of particles. The Eulerian numerical solvers of the Navier-Stokes equation with the volume of fluid (VOF) method have difficulties in the calculation of the free surface due to the existence of the numerical diffusion derived from the advection terms. To attenuate the numerical diffusion, the procedures of the calculation of the cells involving the free surface should be very complicated one in Eulerian models. While, the MPS method is free from the numerical diffusion, hence it can calculate the free surface clearly, even under the existence of the fragmentation and the coalescence of fluid. Their study, the breaking waves were simulated on the several bottom configurations, namely a uniform slope, a permeable uniform slope and a vertical wall with small step on its foot. The time series of the water surface profiles and the velocity fields were displayed to show the performance of the MPS method in the wave breaking simulations.

Yamada and Takikawa [5] investigated two-dimensional numerical models and the internal characteristics of plunging breakers on a uniform slope were proposed under the assumption that the energy dissipation associated with the turbulence and vortex motions after wave breaking could be evaluated directly by the Reynolds stress terms. The

qualitative and quantitative accuracies of the models were examined by comparing turbulence properties with experimental results for plunging breakers on a uniform slope. Furthermore, the internal characteristics of plunging breakers were numerically investigated.

Yu and Mei [6] used a quantitative theory to describe the formation mechanism of sand bars under surface water waves. By assuming that the slopes of waves and bars were comparably gentle and sediment motion was dominated by the bed load, an approximate evolution equation for bar height was derived. During the slow formation, bars and waves affect each other through the Bragg scattering mechanism, which consisted of two concurrent processes: energy transfer between waves propagating in opposite directions and change of their wavelengths. Both effects were found to be controlled locally by the position of bar crests relative to wave nodes. Comparison with available laboratory experiments was discussed and theoretical examples were studied to help understand the coupled evolution of bars and waves in the field.

Park et al. [7] developed an analytical model that can predict the scattering of irregular water normally incident upon an array of vertical cylinders. To examine the predictability of the developed model, laboratory experiments have been made for the reflection and the transmission of irregular waves from arrays of circular cylinders with various diameters and gap widths as shown in Figure (1-4). Both model and experimental data showed that the wave reflection and transmission become larger and smaller, respectively, as the wave steepness increases, which was desirable feature of the cylinder breakwaters.

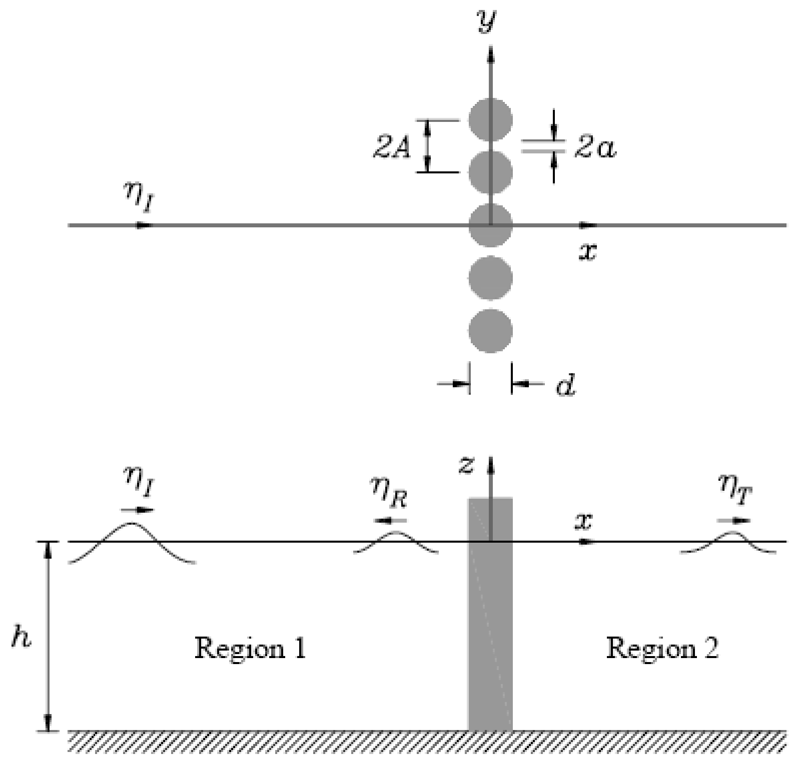


Figure (1-4): Schematic Diagram for the Wave Scattering by Vertical Cylinders. [7]

Luan and Ye [8] studied the propagation of acoustic waves in one dimensional water duct containing many air filled blocks by the transfer matrix formalism. They computed the interface vibration and the energy distribution of the air blocks. By considering periodic arrangement, the band structure was calculated analytically and the Lyapunove exponent and it variance were computed numerically.

Sobey [9] established analytical solution for both water surface elevation and flow in a manner suitable for the evaluation of shallow water wave codes. The contribution of both free and forced modes was identified, together with the role of friction.

Balas and Inan [10] modeled numerically the propagation of waves from Deep Ocean to a shoreline. Model equations govern combined effects of shoaling, refraction, diffraction and breaking. Linear, harmonic and irrotational waves were considered, and the effects of currents and reflection on the wave propagation were assumed to be negligible. To describe the wave motion, mild slope equation has been decomposed into three equations that were solved in terms of wave height, wave approach angle and wave phase function.

Ray et al. [11] studied the influence of a homogeneous current in the incident surface wave direction on the wave-reflecting power of a submerged plate experimentally. Results concerning reflection versus the wave period (in a fixed frame) for various amplitudes have shown a weak influence of the current both on the location of maxima and minima and on their amplitude. The locations of the maximum reflected energy are then weakly modified by the current contrary to the energy that was decreased. Moreover, reflections measured either for various amplitudes at given frequency or for dichromatic waves show a wave behavior correctly described by a linear approach.

Hsu et al. [12] developed a numerical model to investigate the Bragg scattering of water waves by multiply composite artificial bars. The characteristics of both normal and oblique incident waves on the Bragg scattering were investigated. Numerical examples indicate that the performance of the Bragg resonance for multiply composite artificial bars could be greatly improved by increasing both the relative bar height and the number

of bars with different intervals. The resulting higher-order harmonic components of the Bragg resonance were shown to be significant, and increase the bandwidth of high performance. Figure(1-5) show the experimental setup, where region A was used to measure and to calibrate the incident wave conditions, six wave gauges were installed at region B to estimate the reflected waves and one wave gauge is placed at region C to estimate the transmitted waves.

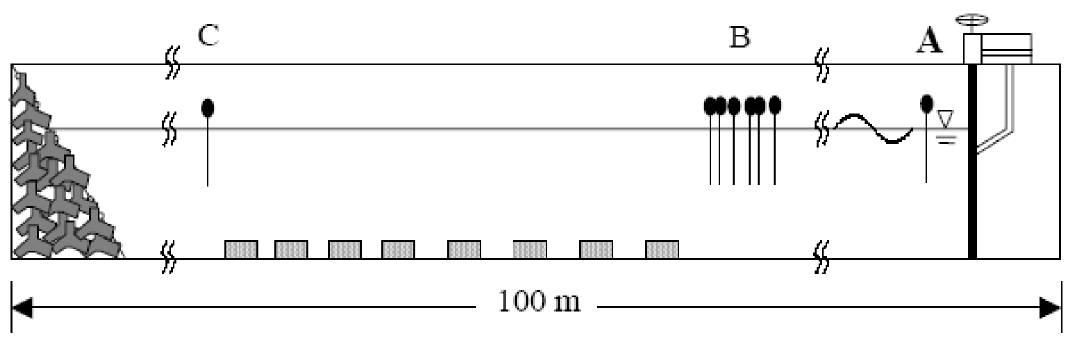


Figure (1-5): Wave Flume System and Experimental Setup. [12]

Ye [13] provided a derivation of the formula recently used for investigation Bragg resonance in waves on a shallow fluid over a periodically drilled bottom. The equation was also compared with other existing theories. As an application, the theory was extended to the case of the water waves propagating over a column with an arbitrary array of cylindrical stops. For a regular array, the formulation for computing band structures was also presented.

Porter [14] simplified version of the more recently derived modified mild-slop equation. The standard and revised mild-slop equations compared analytically in the context of two-dimensional plane wave scattering and it was found that they lead to values of the reflected wave amplitude that differ at lowest order in the mild-slope parameter, for a general topography.

An and Ye [15] investigated the phenomenon of band gaps and Anderson localization of water waves over one-dimensional periodic and random bottoms by the transfer matrix method. The results indicate that the range of localization in random bottoms can be coincident with the band gaps for the corresponding periodic bottoms. Inside the gap of localization regime, a collective behavior of water waves appears. The results were also compared with acoustic and optical situations.

Guyenne and Nicholls [16] presented a numerical method for the computation of surface water waves over bottom topography. It was based on a series expansion representation of the Dirichlet–Neumann operator in terms of the surface and bottom variations. This method was computationally very efficient using the fast Fourier transform. As an application, they performed computations of solitary waves propagating over plane slopes and compareed the results with those obtained from a boundary element method. A good agreement was found between the two methods.

Ardhuin and Magne [17] presented a theory that describes the scattering of random surface gravity waves by small-amplitude topography, with horizontal scales of the order

of the wavelength, in the presence of an irrotational and almost uniform current. A perturbation expansion of the wave action to order $\eta 2$ yields an evolution equation for the wave action spectrum, where η= max (h)/H was the small-scale bottom amplitude normalized by the mean water depth. Application of the theory to waves over current-generated sand waves suggests that forward scattering found to be significant, resulting in a broadening of the directional wave spectrum, while back-scattering should be generally weaker.

Zhenhua [18] steadied the influence of the current on the scattering of wave by a vertical slotted barrier and was investigated experimentally in a wave flume. The separation of incident and reflected waves was carried out by a two-point method that takes into account the effects of the current. He suggested that the tidal currents should be takes into consideration in an economical design of slotted breakwaters. Figure (1-6) shows the set up of his experiment.

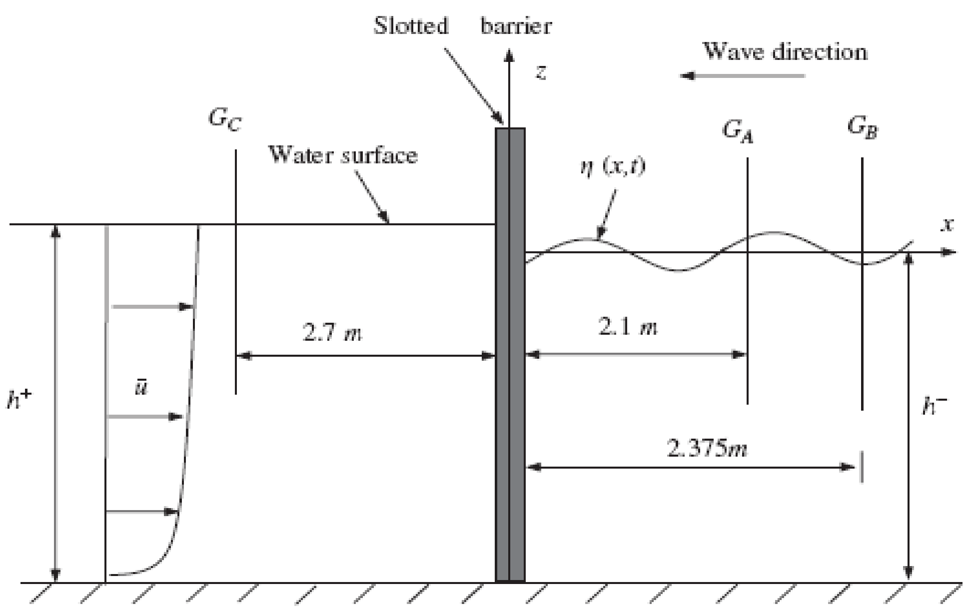


Figure (1-6):Sketch of the experimental set-up (side view). [18]

Elgarayhi [19] used the mapping method for the periodic wave solutions and the corresponding solitary solutions for the shallow water equations and the generalized Klein–Gordon equation. The solutions obtained included as well the shock wave solution, complex line period, complex line solution and rational solutions. Moreover, the obtained solutions were degenerated in terms of hyperbolic function solutions and trigonometric function solutions when the modulus of the Jacobi elliptic function is driven to 1 and 0, respectively and results were presented.

Landry et al. [20] presented a quantitative data on the sorting of sediments on a sandy seabed understanding waves. Starting from a flat bed composed of a homogeneous mixture of a coarse and a fine sand with mean diameters 0.11 and 0.21 mm.

Howard and Yu [21] studied some effects of regular bottom corrugations on water waves in a long rectangular tank with vertical end walls and open top. In particular, they considered motions which were normal modes of oscillation in such a tank. Attention was focused on the modes whose intermodal spacing, in the absence of corrugations, would be near the wavelength of the corrugations. They studied these effects using an asymptotic theory, which assumes that the bottom corrugations are of small amplitude and that the motions are slowly varying everywhere. The exact theory confirms the essential correctness of the asymptotic results for the slowly varying aspects of the motions. The rapidly varying parts (evanescent waves) were, however, needed to satisfy accurately the true boundary conditions, hence of importance to the flow near the end walls.

Zhao et al. [22] used the Wiener-Hopf technique to present the diffraction of surface waves by floating elastic plate, based on the dynamical theories of water waves and Mindlin thick plates. Firstly, the problem was related to a wave guide in water of finite depth, which was analyzed to determine the poles. The resulting hybrid boundary value problem was reduced to solve an infinite system of linear algebraic equations. The results obtained were compared with those calculated by an alternative analysis, and with experimental data. Finally, the effects of the geometric and physical parameters on the distribution of deflection and bending moments in plates were analyzed and discussed.

Bagatur [23] proposed modified Newton-Raphson solution for dispersion of transition water waves for practical applications. The wave dispersion equation is a nonlinear equation. The wave dispersion equation for transition water waves were solved by modified NR technique with Chebyshev approximation implemented in the computer programs prepared with VBA computer language. An example of the given numerical solution model was presented.

Zheng et al. [24] presented an effective boundary element method (BEM) for the interaction between oblique waves and long prismatic structures in water of finite depth. The BEM method was applied to the calculation of the hydrodynamic coefficients and wave exciting for long horizontal rectangular and circular structures. The performance of the present method was demonstrated by comparisons of results with those generated by other analytical and numerical methods.

1.5 Proposed Work and Thesis Objectives

The main motivation is to improve the non-uniform bottoms of the seabad to implement it in the coast of sea to minimize the water wave propagation effects on the structures built at the coast of the sea. From the literature review and the papers studied deeply, there is existing evidence that can manipulate wave waves to beehive forgivable way by making changes in the geometry of the sea bottom to reduce the transmission of the water wave. Rectangular geometry is selected as the sea bottom and we will model analytical solution supported with parametric analysis based on the water wave dispersion and the continuity of pressure and velocity to achieve desirable result of transmission.

CHAPTER 2

BACKGROUND ON WATER WAVES

2.1 Linear and Non-Linear Wave Theory

Linear wave theory gives a linearized description of the propagation of gravity waves on the surface of a homogeneous fluid layer. The theory assumes that the fluid layer has a uniform mean depth, and that the fluid flow is ideal (without viscosity), homogeneous, incompressible (density ρ is constant), irrotation, constant pressure at the surface and surface tension is neglected. This theory was first published, in correct form, by George Biddell Airy in the 19th century.

The Linear wave theory is often applied in ocean engineering and coastal engineering for the modeling of random sea states giving a description of the wave kinematics and dynamics. The linear wave theory in two-dimensional can be described in Cartesian co-ordinates x, y with y = 0 at the still water level (positive upwards)

η (x, t) = the free water surface; t = time (s)

u ,v = velocity components in the x ,y directions, respectively

ϕ (x ,y, t) = the two-dimensional velocity potential (m/s)

ρ = the fluid density

g = gravitational acceleration

a = wave amplitude = H/2

H = wave height (m)

k = wave number = 2π/L (m^{-1})

L = wave length (m)

σ = wave frequency = 2π /T

T = wave period (s)

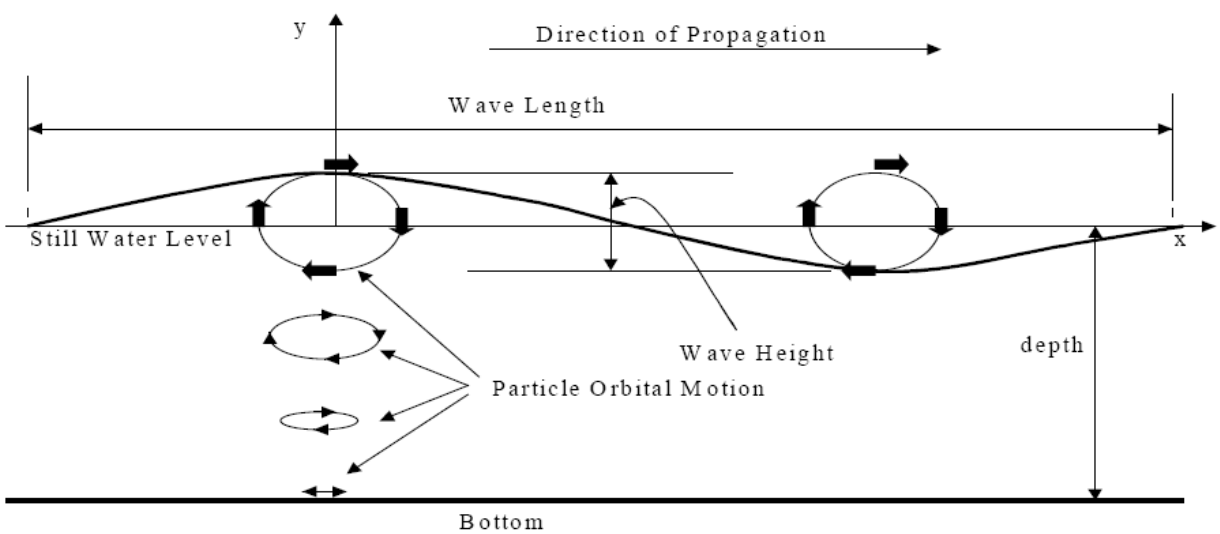
h = mean water depth (m)

C = wave celerity = L/T (m/s)

Linear wave theory is a solution of the Laplace equation:[27]

$$\frac{\delta^2\phi}{\delta x^2}+\frac{\delta^2\phi}{\delta y^2}=0 \qquad (2\text{-}1)$$

The particular flow in any condition is determined by the boundary conditions, in this case specific boundary conditions at the free surface of the fluid and at the bottom.



Figure(2-1): Definition of Linear Wave Theory. [27]

The solution for the potential function satisfying the Laplace equation (1) subject to the boundary conditions is :[27]

$$\phi = \left(\frac{ga}{\sigma}\right).\frac{\cosh k(y+h)}{\cosh kd}.\sin(kx - \omega t) \qquad (2\text{-}2)$$

$$\phi = \left(\frac{gHT}{4\pi}\right).\frac{\cosh\left[\left(\frac{2\pi}{L}\right)(y+h)\right]}{\cosh\left(\frac{2\pi d}{L}\right)}.\sin 2\pi\left(\frac{x}{L} - \frac{t}{T}\right) \qquad (2\text{-}3)$$

$$\eta = a\cos(kx - t) = (H/2)\cos 2(x/L - t/T) \qquad (2\text{-}4)$$

$$\omega = (gk\tanh(kh))^{1/2} \qquad (2\text{-}5)$$

$$L = (gT^2/2\pi)\tanh(2\pi h/L) \qquad (2\text{-}6)$$

$$C = ((gL/2\pi)\tanh(2\pi h/L))^{1/2} \qquad (2\text{-}7)$$

In deep water $h/L > 0.5$, $\tanh(2\pi h/L)\ H \approx 1.0$ [27]

$$L_o = gT^2/2\pi = 1.56T^2 \qquad (2\text{-}8)$$

In shallow water $h/L < 0.04$, $\tanh(2\pi h/L) \approx 2\pi h/L$ [27]

$$L = T(gh)^{1/2};\ C = \sqrt{gh} \qquad (2\text{-}9)$$

For all depth the wave length, L can be found in iteration form:

$$h/L_o = d/L \tanh(2\pi h/L) \qquad (2\text{-}10)$$

We can define the particle velocities**,** from the derivation of the Laplace equation, for irrotational flow , [27]

$$u = \frac{\delta\phi}{\delta x},\ v = \frac{\delta\phi}{\delta y} \qquad (2\text{-}11)$$

$$u = \left(\frac{\pi H}{T}\right).\frac{\cosh\left[\frac{2\pi(y+h)}{L}\right]}{\sinh\left(\frac{2\pi d}{L}\right)}\cos 2\pi\left(\frac{x}{L} - \frac{t}{T}\right) \qquad (2\text{-}12)$$

$$v = \left(\frac{\pi H}{T}\right).\frac{\sinh\left[\frac{2\pi(y+h)}{L}\right]}{\sinh\left(\frac{2\pi d}{L}\right)}.\sin 2\pi\left(\frac{x}{L} - \frac{t}{T}\right) \qquad (2.13)$$

In wave motion the pressure distribution in the vertical is no longer hydrostatic and is given by:

$$\frac{P}{\rho g} = \frac{\cosh 2\pi\left[\frac{y+h}{L}\right]}{\cosh 2\pi d/L}.\eta \ - y \qquad (2\text{-}14)$$

The total energy per wave per unit width of crest, E, is a function of the wave length and the wave height:

$$E = \ \rho g H^2 L/8 \qquad (2\text{-}15)$$

For a non-linear solution, the free surface boundary conditions have to be applied at that free surface,η. But η is unknown, therefore solutions have been developed, notably by Stokes, in series form for which the coefficients of the series can be derived. Thus, the free-surface is given by:

$$\eta = a\cos(\theta) + b\cos(2\theta) + c\cos(3\theta) + d\cos(4\theta) + e\cos(5\theta) \ + \ldots \qquad (2\text{-}16)$$

To obtain a solution to, say, third order, terms greater than order three are ignored. Taken to first order the solution is a linear wave. Solutions are given in terms of elliptic integrals of the first kind; the solution at one limit is identical with linear wave theory and at the other is identical to Solitary Wave Theory.

2.2 Regular Wave Theory

Wave theories are approximations to reality. They may describe some phenomena well under certain conditions that satisfy the assumptions made in their derivation. They may fail to describe other phenomena that violate those assumptions. In adopting a theory, care must be taken to ensure that the wave phenomenon of interest is described reasonably well by the theory adopted, since shore protection design depends on the ability to predict wave surface profiles and water motion, and on the accuracy of such predictions.

A water wave theory is generally developed under the assumptions that the fluid is incompressible and in-viscid, the wave motion is irrotational, and the wave is periodic and uniform in time and space with the period (T) and the wave height (H). The basic hydraulic quantities regarding water waves are the still water depth (h), the water surface profile (η), the wave height (H), the wave amplitude (a), the wavelength (L), the wave celerity (C), the wavenumber (k), the angular frequency (ω), and the wave period (T). Important dimensionless quantities are, the shallowness or relative water depth (h/L), and the wave steepness (H/L).

If the regular wave is periodic in time and space, then C, L and T satisfy: $C = \frac{L}{T}$

2.3 Dispersion of Water Waves

Dispersion of water waves generally refers to frequency dispersion. Frequency dispersion means the waves of different wavelengths travel at different phase speeds. Water waves are waves propagating on the water surface, forced by gravity and surface tension. As a result, water with a free surface is generally considered to be a dispersive medium.

Surface gravity waves, moving under the forcing of gravity, propagate faster for increasing wavelength. For a certain wavelength, gravity waves in deeper water have an lager phase speed than that in shallower water. In contrast the capillary waves which are only forced by surface tension, propagate faster for shorter wavelengths. Besides frequency dispersion, water waves also exhibit amplitude dispersion. This is a nonlinear effect, by which waves of larger amplitude have a different phase speeds than waves with small-amplitude. From the generalized dispersion relation for water waves [25]:

$$\omega^2 = kg \tanh(kh) \qquad (2\text{-}17)$$

At deep water, tanh (kh) = 1

The dispersion relation of water wave for deep water can be approximated as:

$$\omega = \sqrt{kg} \qquad (2\text{-}18)$$

At shallow water , tanh(kh) = kh

For shallow water, the water wave can be approximated as:

$$\omega = \sqrt{k^2gh} \qquad (2\text{-}19)$$

2.4 Water Wave Celerity

As waves pass some fixed point, the time between cosecutive crests is the wave period (T). The speed of the wave, or its celerity, C, is the distance travelled by a crest per unit time. The wave celerity is a function of both wavelength and the water relative depth : [27]

$$c = \frac{L}{T} \tag{2-20}$$

The small amplitude theory requires that both a/L, and a/d be small. Using this assumption and solving the equation of motion for small amplitude waves yield the following expression for the wave celerity .[27]

$$C = \sqrt{\frac{gL}{2\pi} \tanh 2\pi \frac{h}{L}} \tag{2-21}$$

In deep water the celerity is independent of the water depth, it depends on the wavelength. Then, the celerity equation is reduced to: [27]

$$C = \sqrt{\frac{gL}{2\pi}} \tag{2-22}$$

In shallow water the celerity is independent of the wavelength, it depends on the water depth and the celerity equation is reduced to: [27]

$$C = \sqrt{gh} \tag{2-23}$$

2.5 Water Wave Refraction, Reflection and Diffraction

Refraction of waves involves a change in the direction of waves as they pass from one medium to another. Refraction, or the bending of the path of the waves, is accompanied by a change in speed and wavelength of the waves. The speed of a wave is dependent on the properties of the medium through which the waves travel. If the medium is changed, the speed of the wave changes. The most significant property of water which would affect the speed of waves traveling on its surface is the depth of the water. Water waves travel fastest when the medium is the deepest. Thus, if water waves are passing from deep water into shallow water, they will slow down and decrease in speed will also be accompanied by a decrease in wavelength. So, as water waves are transmitted from deep water into shallow water, the speed decreases, the wavelength decreases, and the direction changes.

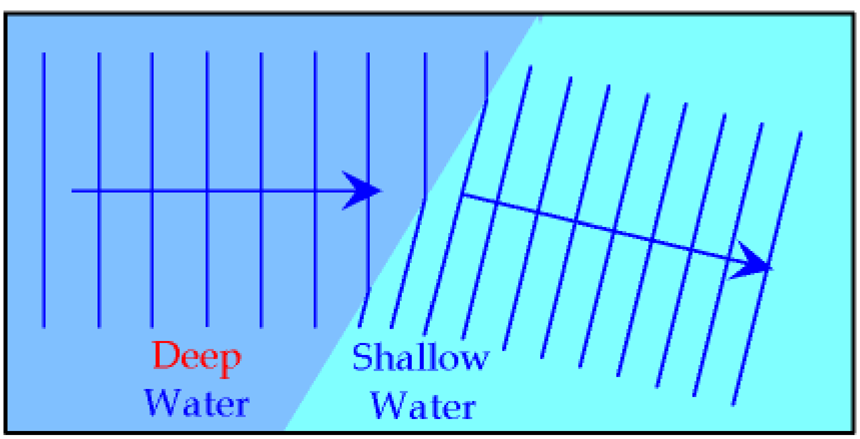


Figure (2-2): Water Waves Refraction

Reflection involves a change in direction of waves when they bounce off a barrier. Reflection is the change in direction of a wavefront at an interface between two different media so that the wavefront returns into the medium from which it originated. The law of reflection states that for specular reflection the angle at which the wave is incident on the surface equals the angle at which it is reflected.

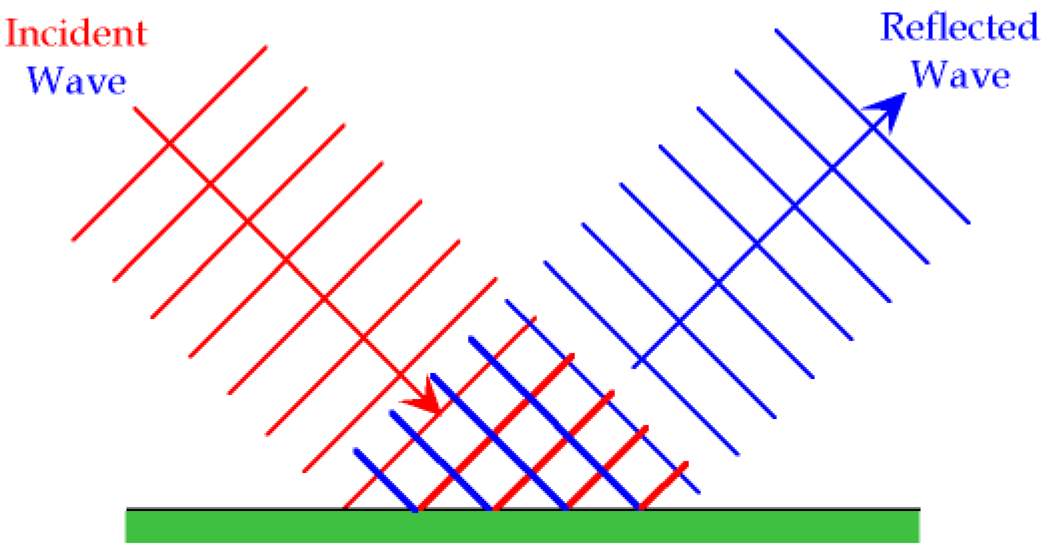


Figure (2-3) Water Waves Reflection

Diffraction involves a change in direction of waves as they pass through an opening or around a barrier in their path. Water waves have the ability to travel around corners, around obstacles and through opening. Diffraction can be demonstrated by placing small barriers and obstacles in a ripple tank and observing the path of the water waves as they encounter the obstacles. The waves are seen to pass around the barrier into the regions behind it; subsequently the water behind the barrier is disturbed. The amount of diffraction (the sharpness of the bending) increases with increasing wavelength and decreases with decreasing wavelength. In fact, when the wavelength of the waves is smaller than the obstacle, no noticeable diffraction occurs.

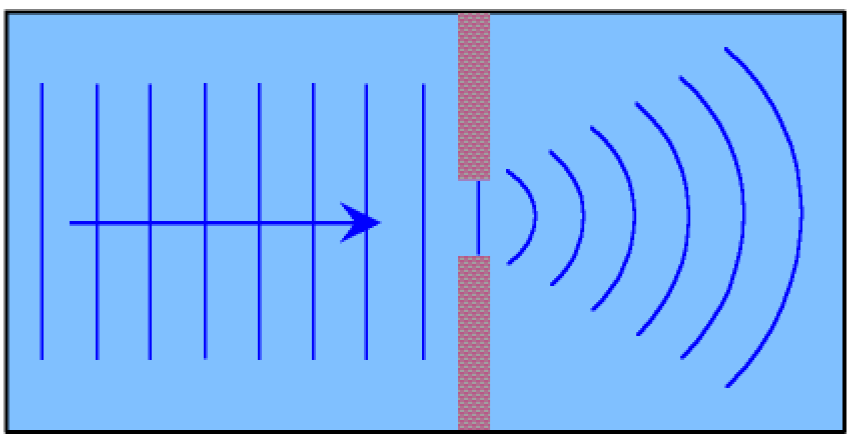


Figure (2-4):Water Waves Diffraction

2.6 Breaking Waves

Water particles on the ocean surface travel in an orbital motion. When a wave crest approaches, the water particles rise and move forward. At the position below the crest, the water particles stop rising and are moving forward at the speed of the crest. As the trough advances, the particles slow their falling rate and start moving backward, until at the bottom of the trough they move only backward. As a deep-water wave moves into shallow water, the water particle orbits become flattened circles or ellipses. The orbits are compressed and the forward speed of the wave is reduced due to the interaction with the bottom.

Waves may break in a number of different ways. Steep waves on mild slopes tend to break by spilling water gently from their crests, and there is little reflection of the incident wave energy. In contrast, long low waves on steep slopes tend not to break at all. Instead, they surge up and down the slope with most of the wave energy being reflected. For regular waves, a useful parameter for describing wave behavior on a slope is the 'surf similarity parameter' of Iribarren number, N_I [26]:

$$N_I = \frac{\tan\beta}{\sqrt{\frac{H}{L_o}}} \qquad (2\text{-}24)$$

in which β is the slope angle, wave height H is measured at the toe of the slope and

$$L_o = \frac{g\,T^2}{2\pi} \qquad (2\text{-}25)$$

2.6.1 Spilling Breakers

Spilling breakers usually occur where there is only a gently sloping shoreline. Spilling breakers start breaking slowly some distance from shore and are caused when a layer of water at the crest moves forward faster than the wave as a whole and only the top part of the wave curls over. Foam forms at the crest and eventually covers the leading face of the breaker [26].

$$N_I < 0.4 \quad (2\text{-}26)$$

Figure (2-5): Spilling Breakers

2.6.2 Plunging Breakers

When the crest travels faster than the base of the breaker, it curls over and forms a tunnel, with a convex back and a concave front, and then falls downward violently toward the wave trough, the energy is dissipated over a short distance. Plunging breakers appear when there is greater slope to the bottom and are usually associated with the long swells generated by distant storms. The energy dissipated by plunging breakers is concentrated at the plunge point (i.e., where the water hits the bed) and can have great

erosive effect. Plunging breaking waves are the most spectacular type of breakers and are much beloved by surfers [26].

$$0.4 < N_1 < 2.3 \quad (2\text{-}27)$$

Figure (2-6): Plunging Breakers

2.6.3 Collapsing Breakers:

Collapsing breakers are similar to plunging breakers, except that the front face of the waves may be less steep and instead of the crest curling over, the wave collapses in the middle or near the bottom of the wave instead of at the top. Such breakers represent a transition form from plunging to surging breakers and usually happen on beaches with rather steep slopes, and under moderate wind conditions.

$$2.3 < N_I < 3.2 \quad (2\text{-}28)$$

Figure (2-7): Collapsing Breakers

2.6.4 Surging Breakers:

Surging breakers are formed on extremely steep shores. Surging breakers are typically formed from long, low waves. Thus, the front faces and crests remain relatively unbroken as the waves roll onto the beach in a brief surge of water.

$$N_1 > 3.2 \quad (2\text{-}29)$$

Figure (2-8): Surging Breakers

CHAPTER 3

WATER WAVES OVER SEABED WITH RECTANGULAR BREAKWATERS

In this chapter, an analytical solution for the problem of wave propagation over non-uniform bottom is presented. We selected to have a sea bad with rectangular breakwaters and each rectangular shape will be a step (N). We will derive the equation for the defined shape to find out how the shape and the number of steps will affect the water wave reflection and transmission. We will consider in our analytical solution only the transition on intermediate water waves ($0.5 > h/L > 0.05$) and the deep water waves ($h/L > 0.5$). The analytical solution will be complemented by parametric analysis in chapter four.

3.1 Derivation of Water Waves Dispersion

Dispersion of water waves depend on the depth of the water and the wavenumber. We assumed the following:

- Ideal fluid with no viscosity
- Two-dimensional wave field
- Homogeneous fluid
- Incompressible with constant density ρ
- Irrotational

- Constant pressure at the surface and neglect the surface tension

The motion of water waves is governed by the Laplace equation with the consideration of the boundary conditions. Governing equation of wave motion in two dimensions X and Z:

$$\frac{\partial^2 \varphi}{\partial X^2} + \frac{\partial^2 \varphi}{\partial Z^2} = 0 \qquad (3\text{-}1)$$

Boundary Conditions (B.C.) at the free surface and at defined depth d

At the free Surface Z=0

$$\frac{\partial^2 \varphi}{\partial t^2} + g\,\frac{\partial \varphi}{\partial Z} = 0 \qquad (3\text{-}2)$$

At Z= - d

$$\frac{\partial \varphi}{\partial X} + \frac{\partial \varphi}{\partial Z} = 0 \qquad (3\text{-}3)$$

Using the separation of variables approach, the solution of equation (3-1) is assumed as

$$\varphi = A.e^{ikx}\, f(Z).e^{i\omega t} \qquad (3\text{-}4)$$

Where A = amplitude
k = wavenumber
t = time
ω = angular speed

$$f(Z) = C_1 \cosh(kZ) + C_2 \sinh(kZ)$$

$$\varphi = A\, e^{ikx}(C_1 \cosh(kZ) + C_2 \sinh(kZ))e^{i\omega t} \qquad (3\text{-}5)$$

We differentiate φ with respect to time(t) and we get

$$\frac{\partial \varphi}{\partial t} = A\, e^{ikx}(C_1 \cosh(kZ) + C_2 \sinh(kZ))e^{i\omega t}\,(i\omega) \qquad (3\text{-}6)$$

$$\frac{\partial^2 \varphi}{\partial t^2} = -A\, e^{ikx}(C_1 \cosh(kZ) + C_2 \sinh(kZ))e^{i\omega t}(\omega^2) \qquad (3\text{-}7)$$

We differentiate φ with respect to Z and we get

$$\frac{\partial \varphi}{\partial Z} = Ak\, e^{ikx}(C_1 \sinh(kZ) + C_2 \cosh(kZ))e^{i\omega t} \tag{3-8}$$

$$\frac{\partial^2 \varphi}{\partial Z^2} = Ak^2\, e^{ikx}(C_1 \cosh(kZ) + C_2 \sinh(kZ))e^{i\omega t} \tag{3-9}$$

$$\frac{\partial^2 \varphi}{\partial Z^2} = Ak^2\, e^{ikx} f\,(Z) e^{i\omega t} = A\, e^{ikx} f''(Z) e^{i\omega t} \tag{3-10}$$

We differentiate φ with respect to x and we get

$$\frac{\partial \varphi}{\partial X} = ikA\, e^{ikx}(C_1 \cosh(kZ) + C_2 \sinh(kZ))e^{i\omega t} \tag{3-11}$$

$$\frac{\partial^2 \varphi}{\partial X^2} = -k^2 A e^{ikx}(C_1 \cosh(kZ) + C_2 \sinh(kZ))e^{i\omega t} \tag{3-12}$$

$$\frac{\partial^2 \varphi}{\partial X^2} == -k^2 A e^{ikx}\, f(Z) e^{i\omega t} \tag{3-13}$$

By substituting equation (3-7) and equation (3-8) in (3-2) at Z=0, we will get

$$-A\, e^{ikx}(C_1 \cosh(kZ) + C_2 \sinh(kZ))e^{i\omega t}(\omega^2) + gAk\, e^{ikx}(kC_1 \sinh(kZ) + kC_2 \cosh(kZ))e^{i\omega t} = 0$$

By dividing the above equation by A, $e^{i\omega t}$, e^{ikx}, we get

$$-(C_1 \cosh(kZ) + C_2 \sinh(kZ))(\omega^2) + gk(C_1 \sinh(kZ) + C_2 \cosh(kZ))=0$$

We divided above equation by $\cosh(kZ)$, we get

$$-(C_1 + C_2 \tanh(kZ))(\omega^2) + gk(C_1 \tanh(kZ) + C_2)=0$$

And $\tanh(0) = 0$

$$-(C_1)(\omega^2) + gk(C_2)=0$$

$$(C_1) = \frac{gk}{\omega^2}(C_2) \tag{3-14}$$

We will consider the wave at Z= - d and it shall satisfy the two equations (3-1) and (3-3)

$$\frac{\partial\varphi}{\partial x} + \frac{\partial\varphi}{\partial Z} = 0 \qquad \text{and} \qquad \frac{\partial^2\varphi}{\partial X^2} + \frac{\partial^2\varphi}{\partial Z^2} = 0$$

For equation (3-3),

$$Ak\, e^{ikx}(C_1 \sinh(kZ) + C_2\, \cosh(kZ))e^{i\omega t} + ikA\, e^{ikx}(C_1 \cosh(kZ) + C_2\, \sinh(kZ))e^{i\omega t} = 0$$

By dividing by A, k , e^{ikx} and $e^{i\omega t}$, we get

$$(C_1 \sinh(kZ) + C_2\, \cosh(kZ)) + i(C_1 \cosh(kZ) + C_2\, \sinh(kZ)) = 0 \qquad \text{(3-15)}$$

We divided the equation by cosh (kZ), we get

$$(C_1 \tanh(kZ) + C_2\,) + i(C_1 + C_2\, \tanh(kZ)) = 0 \qquad \text{(3-16)}$$

We have two parts real part and the real part will consider

$$C_2 = -C_1 \tanh(kZ) \qquad \text{(3-17)}$$

From (3-14), we can drive the dispersion equation

$$C_2 = \frac{gk}{\omega^2}(C_2\,) \tanh(kZ)$$

$$\omega^2 = -gk \tanh(kZ)$$

At the defined depth of the water, Z= -d, which will result on

$$\omega^2 = gk \tanh(kd) \qquad \text{(3-18)}$$

3.2 Modeling Water Wave Propagation over One Rectangular Breakwater

Water wave propagation was modeled for the rectangular sea bottom to consider the transmitted and the reflected amplitude. The dispersion equation was used to calculate the wavenumber (k) based on assumed specific angular speed (ω) and wavelength (L). Based on the calculated wavenumber, the transmission and the reflection rate were found by the continuity of velocity and pressure at the two edges of the rectangular.

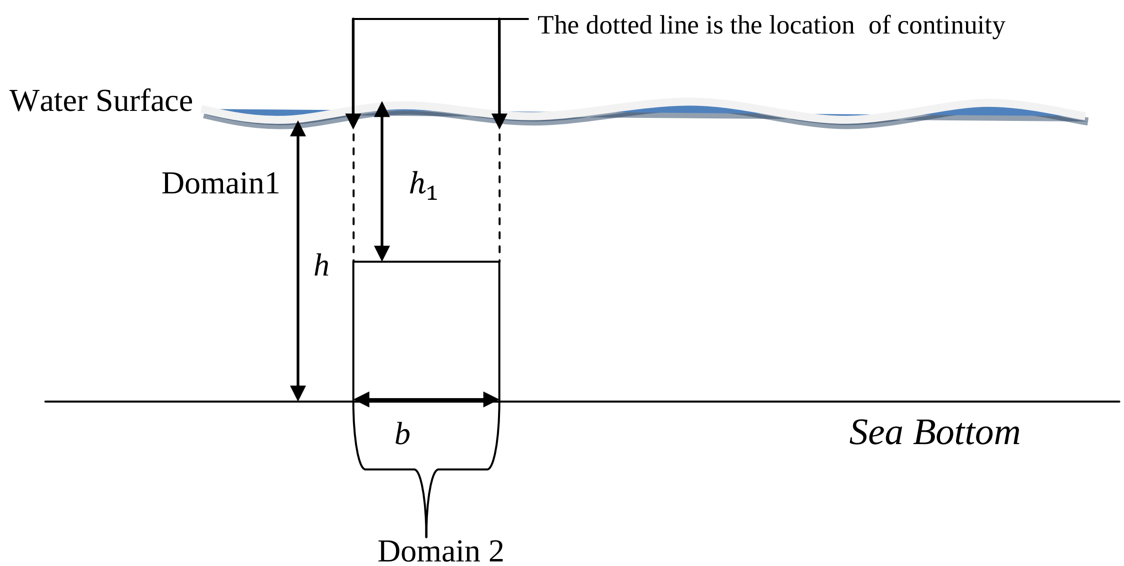


Figure (3-1): Setup of the One Rectangular Breakwater with the Main Parameters

3.2.1 Calculating Wavenumber (k)

The following flow chart in figure (3-2) will summarize the main steps in calculating the wavenubmer (k) by the MATLAB based on assumed numbers

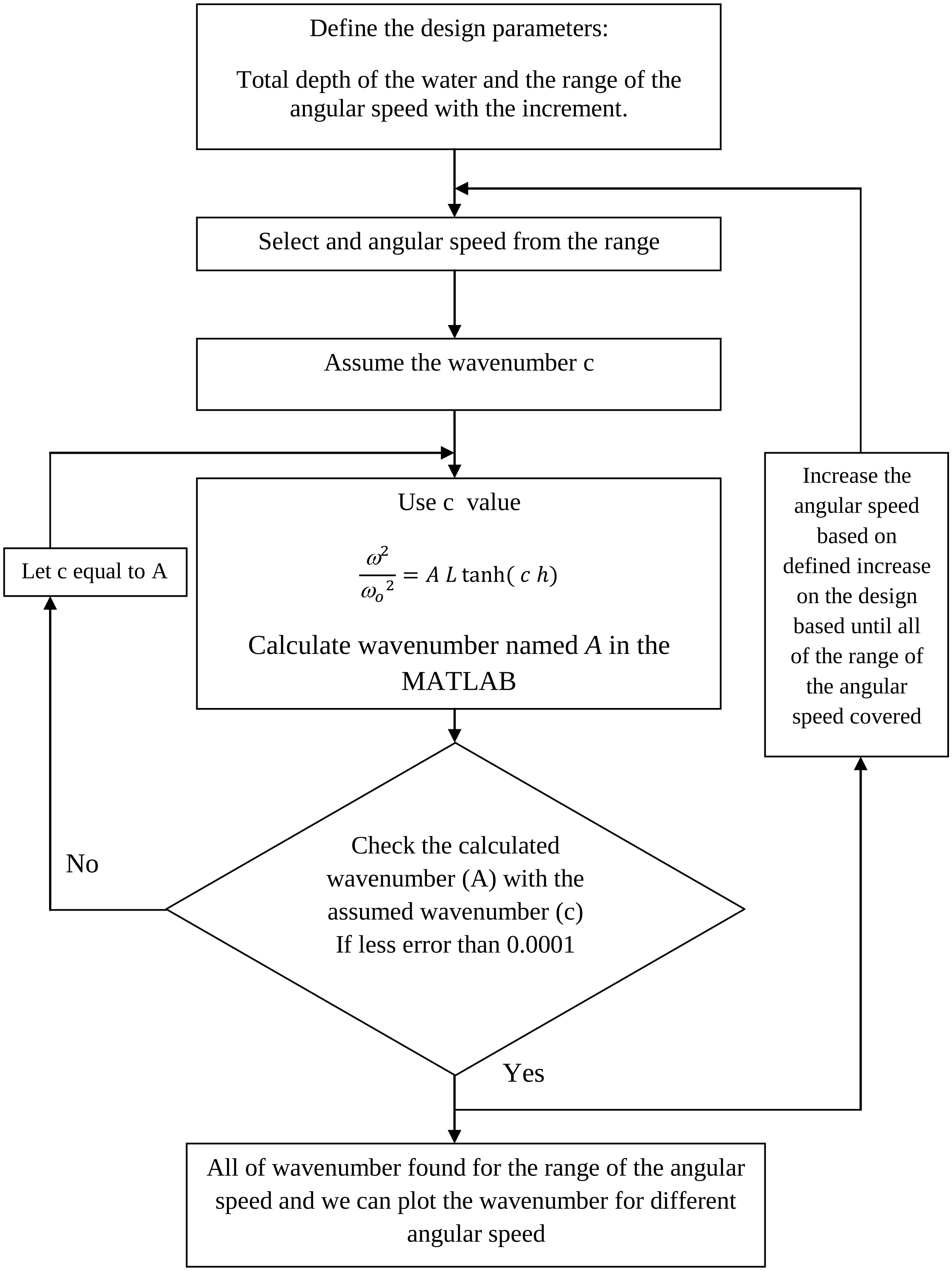


Figure (3-2): Flow Chart for Calculating the Wavenumber

Each step consist of two depths, one is the depth of the water from the still water level to the sea bottom and the other from the still water level to the top of the rectangular breakwaters. We need to calculate the wavenumber for the each rectangular breakwater twice for each depth. Figure (3-3) illustrates the main steps for calculating the two wavenumbers for the two levels in flow diagram.

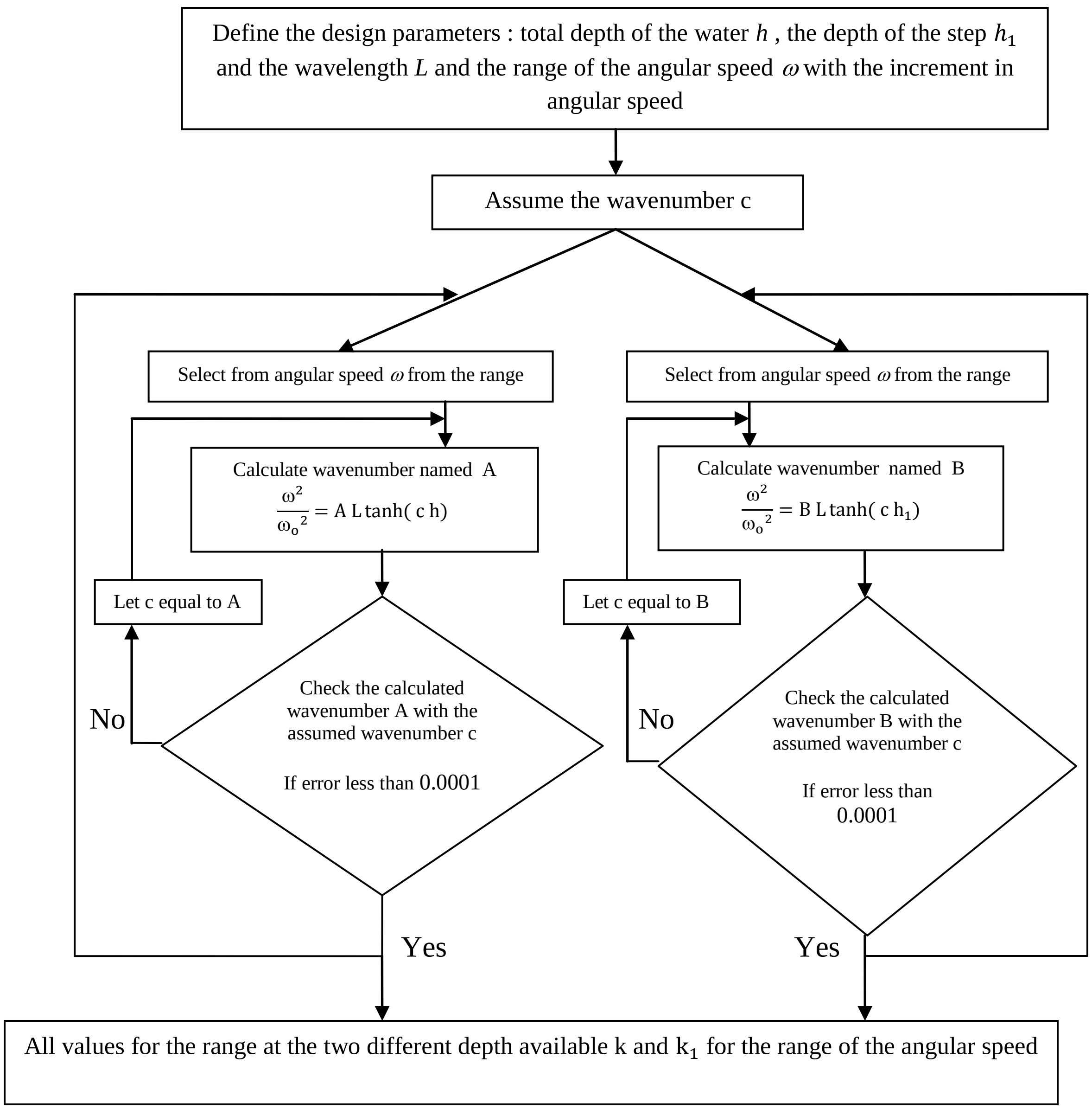


Figure (3-3): Flow Chart for Calculating the Wavenumber (k and k_1) for Two Levels

3.2.2 Transmission of Water Waves Over One Rectangular Breakwater

The water wave will be represented in the ϕ equation which composed of two waves one in the positive direction $A\exp(ikx - i\omega t)$ and the other in the negative direction$B\exp(-ikx - i\omega t)$. This can be represented in the following equation (3-19).

$$\phi = A\exp(ikx - i\omega t) + B\exp(-ikx - i\omega t) \tag{3-19}$$

In each step, we break the step into two domain, domain1 and domain 2 and the equation (3-19) modified where A_n the amplitude in domain n. Equation (3-19) is modified and represented as,

$$\phi = A_n\exp(ikx - i\omega\, t) + B_n\exp(-ikx - i\omega\, t) \tag{3-20}$$

We will maintain the continuity equation at the end of each domain of the step for the pressure and the velocity by the two equations.

$$P_1 = P_2 \tag{3-21}$$

$$v_{x1} = v_{x2} \tag{3-22}$$

We started with the pressure and defined as

$$P = -\rho gZ + i\rho\omega\left(\frac{\partial\emptyset}{\partial t}\right) \tag{3-23}$$

$$\frac{\partial\emptyset}{\partial t} = -i\omega A_n\exp(ikx - i\omega\, t) - i\omega B_n\exp(-ikx - i\omega\, t) \tag{3-24}$$

By substituting equation (3-24) in equation (3-23), we get

$$P = -\rho gZ + i\rho\omega(-i\omega A_n\exp(ikx - i\omega\, t) - i\omega B_n\exp(-ikx - i\omega\, t)) \tag{3-25}$$

For the continuity of pressure, the pressure shall satisfy equation (3-21) at any point between the two domains of water wave with the following amplitude of water wave:

A_1 = Amplitude of the Insident water wave

B_1 = Amplitude of the Reflected water wave

A_2 = Amplitude of the Transmitted water wave

B_2 = Amplitude of the oposite water wave

exp(-iωt) , $-\rho gZ$ and iρω will be dropped from both sides of equation (2-24) which will result in

$$A_1 \exp(ikx) + B_1 \exp(-ikx) = A_2 \exp(ikx) + B_2 \exp(-ikx) \qquad (3\text{-}26)$$

For the continuity of the velocity shall satisfy equation(3-22) at any point between the two domains of the water wave. The velocity defined as

$$\mathrm{v} = \frac{1}{\mathrm{i}\rho\omega}\frac{\partial \mathrm{P}}{\partial \mathrm{x}} \qquad (3\text{-}27)$$

$$\frac{\partial \mathrm{P}}{\partial \mathrm{x}} = \mathrm{i}\rho\omega(-(\mathrm{ik_n})\mathrm{i}\omega \mathrm{A_n} \exp(\mathrm{ik_n x} - \mathrm{i}\omega \mathrm{t}) - (-\mathrm{ik_n})\mathrm{i}\omega \mathrm{B_n} \exp(-\mathrm{ik_n x} - \mathrm{i}\omega \mathrm{t})) \qquad (3\text{-}28)$$

$$\mathrm{v} = (-(\mathrm{ik_n})\mathrm{i}\omega \mathrm{A_n} \exp(\mathrm{ik_n x} - \mathrm{i}\omega \mathrm{t}) - (-\mathrm{ik_n})\mathrm{i}\omega \mathrm{B_n} \exp(-\mathrm{ik_n x} - \mathrm{i}\omega \mathrm{t}))$$

$$\mathrm{v} = (\mathrm{k_n}\omega \mathrm{A_n} \exp(\mathrm{ik_n x} - \mathrm{i}\omega \mathrm{t}) - \mathrm{k_n}\omega \mathrm{B_n} \exp(-\mathrm{ik_n x} - \mathrm{i}\omega \mathrm{t})) \qquad (3\text{-}29)$$

exp(-iwt) and ω will be dropped from both sides of equation (3-21) which will result with

$$\mathrm{k_1 A_1} \exp(\mathrm{ikx}) - \mathrm{k_1 B_1} \exp(-\mathrm{ikx}) = \mathrm{k_2 A_2} \exp(\mathrm{ikx}) - \mathrm{k_2 B_2} \exp(-\mathrm{ikx}) \qquad (3\text{-}30)$$

Transforming equation (3-26) and (3-30) to matrix before solving the two equations

$$\begin{bmatrix} \exp(ik_1x) & \exp(-ik_1x) \\ k_1\exp(ik_1x) & -k_1\exp(-ik_1x) \end{bmatrix}\begin{bmatrix} A_1 \\ B_1 \end{bmatrix} = \begin{bmatrix} \exp(ik_2x) & \exp(-ik_2x) \\ k_2\exp(ik_2x) & -k_2\exp(-ik_2x) \end{bmatrix}\begin{bmatrix} A_2 \\ B_2 \end{bmatrix} \quad (3\text{-}31)$$

By multiplying both sides by inverse of the left side to get Identity Matrix with $\begin{bmatrix} A_1 \\ B_1 \end{bmatrix}$, we get the following equation (3-32).

$$\begin{bmatrix} A_1 \\ B_1 \end{bmatrix} = \frac{-1}{2k_1}\begin{bmatrix} -(k_1 + k_2)\exp(ik_2x - ik_1x) & (-k_1 + k_2)\exp(-ik_2x + ik_1x) \\ (k_2 - k_1)\exp(ik_2x + ik_1x) & -(k_2 + k_1)\exp(ik_1x - ik_2x) \end{bmatrix}\begin{bmatrix} A_2 \\ B_2 \end{bmatrix} \quad (3\text{-}32)$$

By assuming the amplitude of incident wave is scaled one and no opposite wave phasing the incident wave:

$A_1 = 1$ and $B_2 = 0$

We will calculate the amplitude of the transmitted and reflected water wave

$$1 = \frac{(k_1+k_2)}{2k_1}\exp(ik_2x - ik_1x)A_2$$

$$A_2 = \frac{2k_1}{(k_1+k_2)\exp(ik_2x-ik_1x)} \quad (3\text{-}33)$$

$$B_1 = \frac{-1}{2k_1}(k_2 - k_1)\exp(ik_2x + ik_1x)A_1$$

$$B_1 = \frac{(k_1-k_2)\exp(ik_2x+ik_1x)}{(k_1+k_2)\exp(ik_2x-ik_1x)} \quad (3\text{-}34)$$

The transmission and reflection rate can be calculated from the scattering matrix M

$$[M] = \frac{-1}{2k_1}\begin{bmatrix} -(k_1 + k_2)\exp(ik_2x - ik_1x) & (-k_1 + k_2)\exp(-ik_2x + ik_1x) \\ (k_2 - k_1)\exp(ik_2x + ik_1x) & -(k_2 + k_1)\exp(ik_1x - ik_2x) \end{bmatrix} \quad (3\text{-}35)$$

$$[M] = \begin{bmatrix} M_{11} & M_{12} \\ M_{21} & M_{22} \end{bmatrix}$$

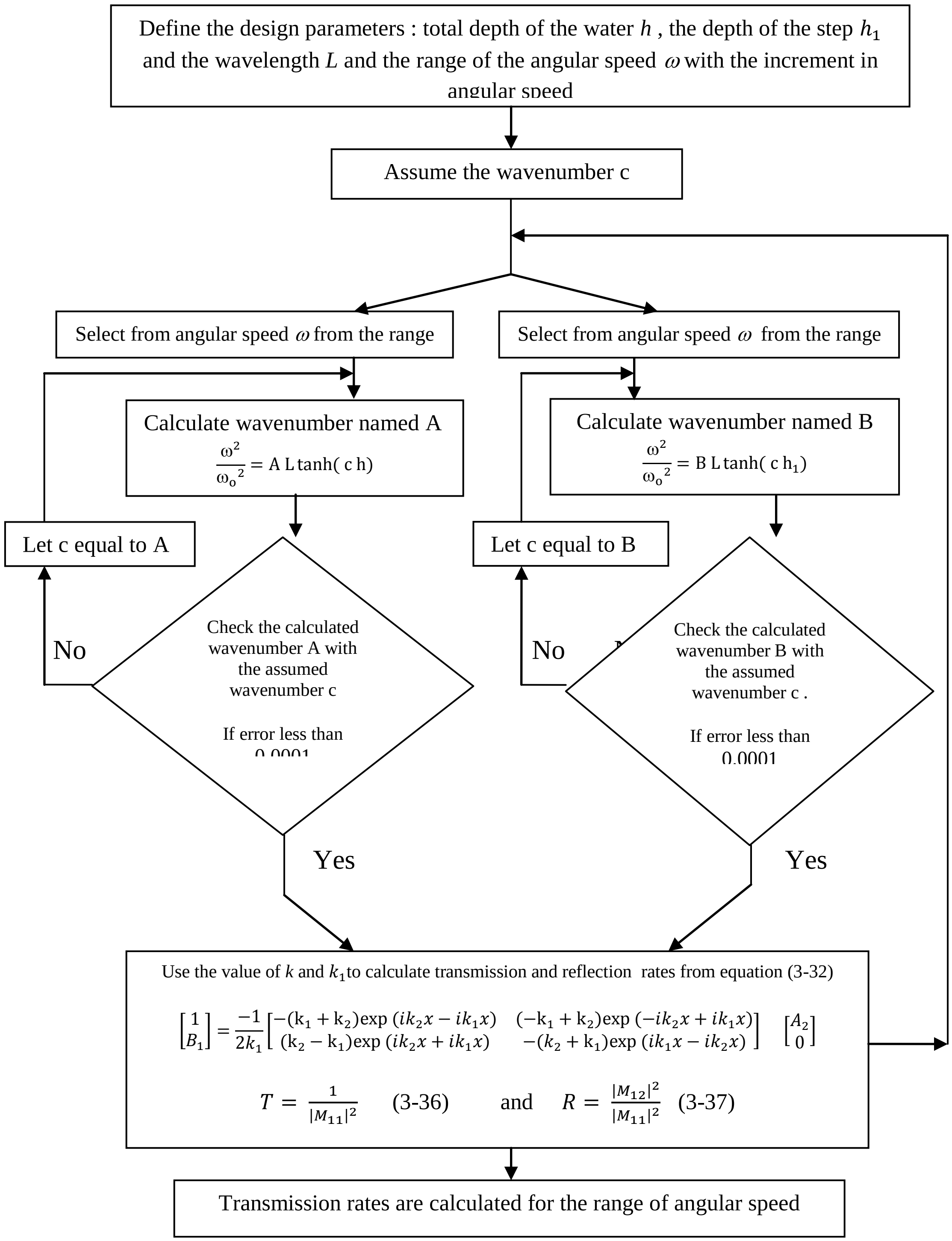
The transmission rate and the reflections rate are related by $T + R = 1$, which is a consequence of energy conservation. The transmission rate defined as

$$T = \frac{1}{|M_{11}|^2} \tag{3-36}$$

The reflection rate defined as

$$R = \frac{|M_{12}|^2}{|M_{11}|^2} \tag{3-37}$$

Figure (3-4) illustrate the transmitted and reflected rate of the water wave for the range of angular speed on the flow chart.



Figure(3-4):Flow Chart for Calculating the Transmission Rate Over One Rectangular Breakwater

3.3 Modeling the Water Wave Propagation Over Number Of Rectangular Breakwaters

The work done and equation (3-32) are modified for number of rectangular Breakwaters by consider number of Rectangular Breakwaters (N). We will explain the methodology by representing each step by two domains with two wavenumber k_n, k_{n+1}.

$$\begin{bmatrix} A_n \\ B_n \end{bmatrix} = \frac{-1}{2k_1} \begin{bmatrix} -(k_n + k_{n+1})\exp(ik_{n+1}x - ik_n x) & (-k_n + k_{n+1})\exp(-ik_{n+1}x + ik_n x) \\ (k_{n+1} - k_n)\exp(ik_{n+1}x + ik_n x) & -(k_{n+1} + k_n)\exp(ik_n x - ik_{n+1}x) \end{bmatrix} \begin{bmatrix} A_{n+1} \\ B_{n+1} \end{bmatrix} \quad (3\text{-}38)$$

The scattering matrix M_n defined as:

$$M_n = \frac{-1}{2k_1} \begin{bmatrix} -(k_n + k_{n+1})\exp(ik_{n+1}x - ik_n x) & (-k_n + k_{n+1})\exp(-ik_{n+1}x + ik_n x) \\ (k_{n+1} - k_n)\exp(ik_{n+1}x + ik_n x) & -(k_{n+1} + k_n)\exp(ik_n x - ik_{n+1}x) \end{bmatrix} \quad (3\text{-}39)$$

$$\begin{bmatrix} A_n \\ B_n \end{bmatrix} = [M_n] \begin{bmatrix} A_{n+1} \\ B_{n+1} \end{bmatrix} \quad (3\text{-}40)$$

$$\begin{bmatrix} A_n \\ B_n \end{bmatrix} = [M_n][M_{n+1}][M_{n+2}] \begin{bmatrix} A_{n+3} \\ B_{n+3} \end{bmatrix} \quad (3\text{-}41)$$

The equation is modified for N rectangular breakwaters for general use

$\begin{bmatrix} A_n \\ B_n \end{bmatrix} = [M_n]^N \begin{bmatrix} A_{n+1} \\ B_{n+1} \end{bmatrix}$, where N is the number of rectangular breakwaters

$$\begin{bmatrix} A_1 \\ B_1 \end{bmatrix} = [M_1]^N \begin{bmatrix} A_2 \\ B_2 \end{bmatrix} \quad (3\text{-}42)$$

$$\begin{bmatrix} A_1 \\ B_1 \end{bmatrix} = \left(\frac{-1}{2k_1}\right)^N \begin{bmatrix} -(k_1 + k_2)\exp(ik_2 x - ik_1 x) & (-k_1 + k_2)\exp(-ik_2 x + ik_1 x) \\ (k_2 - k_1)\exp(ik_2 x + ik_1 x) & -(k_2 + k_1)\exp(ik_1 x - ik_2 x) \end{bmatrix}^N \begin{bmatrix} A_2 \\ B_2 \end{bmatrix} \quad (3\text{-}43)$$

By assuming $B_2 = 0$ and $A_1 = 1$

$$\begin{bmatrix} 1 \\ B_1 \end{bmatrix} = (\frac{-1}{2k_1})^N \begin{bmatrix} -(k_1 + k_2)\exp(ik_2x - ik_1x) & (-k_1 + k_2)\exp(-ik_2x + ik_1x) \\ (k_2 - k_1)\exp(ik_2x + ik_1x) & -(k_2 + k_1)\exp(ik_1x - ik_2x) \end{bmatrix}^N \begin{bmatrix} A_2 \\ 0 \end{bmatrix} \quad (3\text{-}44)$$

The transmission and reflection rate can be calculated from the transfer matrix M_N

$$[M]^N = (\frac{-1}{2k_1})^N \begin{bmatrix} -(k_1 + k_2)\exp(ik_2x - ik_1x) & (-k_1 + k_2)\exp(-ik_2x + ik_1x) \\ (k_2 - k_1)\exp(ik_2x + ik_1x) & -(k_2 + k_1)\exp(ik_1x - ik_2x) \end{bmatrix}^N \quad (3\text{-}45)$$

The transmission rate and the reflections rate are related by $T_N + R_N = 1$, which is a consequence of energy conservation. The transmission rate defined as

$$T_N = \frac{1}{|M_{11}|^2} \quad (3\text{-}46)$$

The reflection rate defined as

$$R_N = \frac{|M_{12}|^2}{|M_{11}|^2} \quad (3\text{-}47)$$

Figure (3-6) illustrates the main steps for calculating the transmission rate for number of rectangular breakwater in flow diagram.

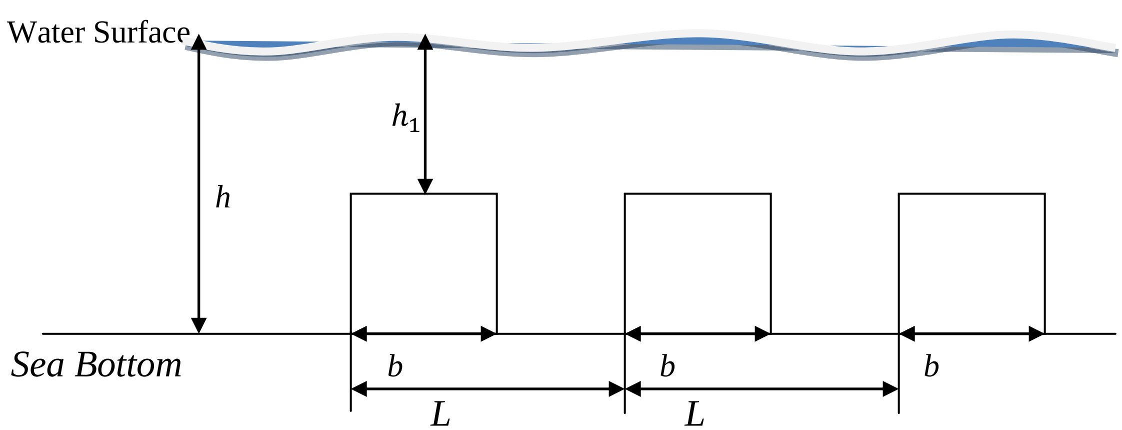


Figure (3-5): Setup for Number of Rectangular Breakwaters

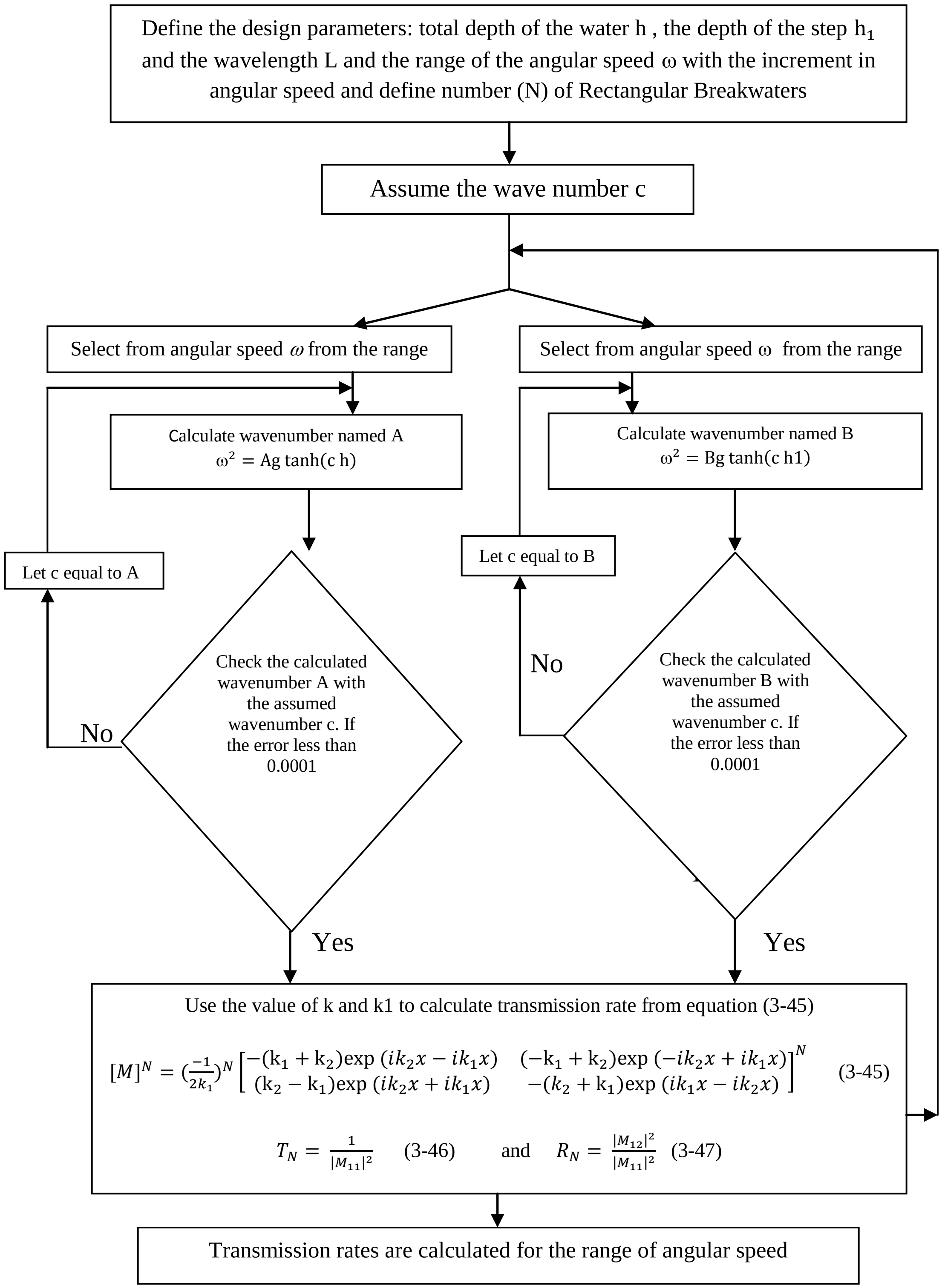


Figure (3-6) : Flow Chart for Calculating the Transmission Rates Over Number of Rectangular Breakwaters

CHAPTER 4

PARAMETRIC ANALYSIS

We used the analytical solution in chapter three in our parametric analysis to find how the water wave propagation interacts with selected non-uniform bottoms. We calculated the wavenumber form the dispersion of the water waves and utilized it to study the effects of depth changes and wavelength changes. MATLAB software program is used to calculate the wavenumber for the two levels of the rectangular breakwater. The transfer matrix method is used to calculate the transmission rates. A parametric analysis is performed to study the effect of changing angular speed, wavelength, the geometry of the rectangular breakwater (width and height) and the number of breakwaters. Results of the numerical solutions are considered to be helpful in the designing optimal non-uniform sea bottom to obtain desired levels of transmission and reflection.

4.1 Dispersion Analysis

Focusing on the dispersion equation of water waves over non-uniform bottoms, we consider how the depth of the water (h) and the wavelength (L) will affect the wavenumber for range of angular speed (ω).

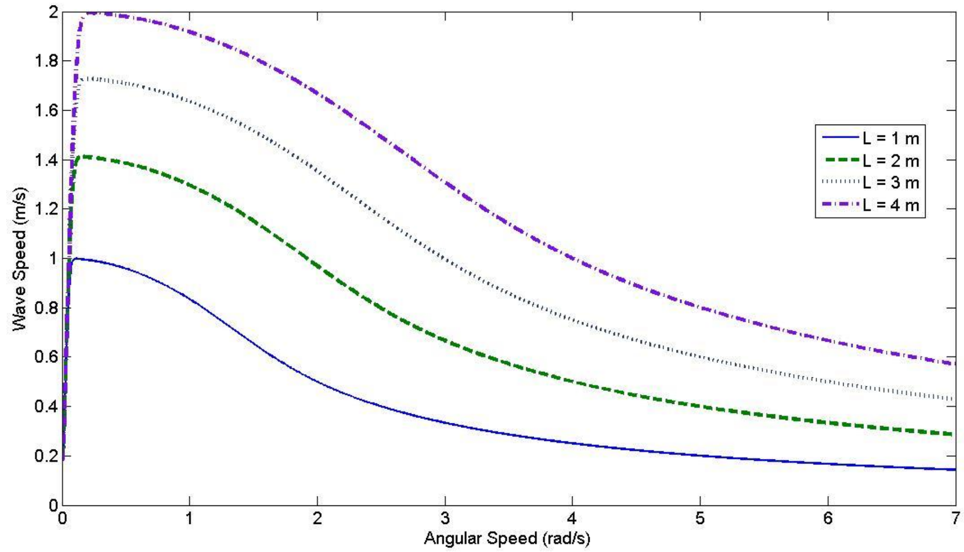


Figure (4-1): Effect of Wavelength on Wave Speed

For selected range of angular speeds from zero to seven rad/s and the four wavelength (L) (1, 2, 3 and 4m), the wave speeds were changed with the angular speed and the wavelength. The wave speed decreases with increasing the angular speed (ω) and increases with increasing the wavelength (L) as shown in figure(4-1).

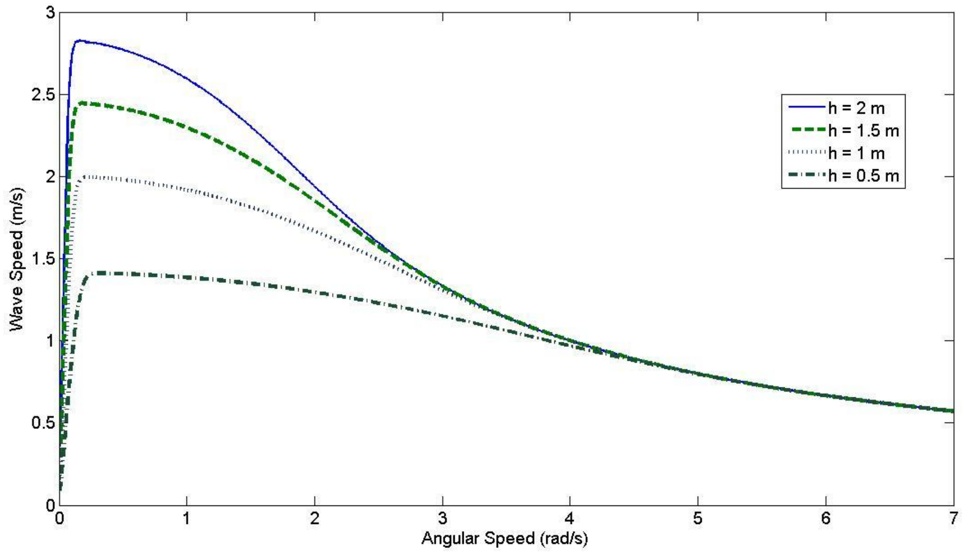


Figure (4-2): Effect of Water Depth on the Wave Speed

For selected range of angular speed from zero to five rad/s and four depth of water (h) (2, 1.5, 1, 0.5 m) for specific wavelength (L=4 m), the wave speed ware changed with the angular speed (ω) and the depth of water (h). The wave speed decreases with increasing the angular speed (ω), increases with increasing the depth of the water (h) and at angular speed higher than five rad/s will have the same value of wave speed for different depths of water (h) as shown in figure (4-2).

4.2 Water Wave Propagation over Rectangular Breakwaters

We consider in this section how the rectangular breakwater affect the transmission of the water wave as transmission rates. This section of the chapter will cover one and number (N) of rectangular breakwaters up to 200 with different geometries (widths and heights) for different depth of the water from one meter to five meters with the consideration the intermediate water wave range and deep water. All of the calculation done by the MATLAB and attached in Appendix A and the results represented in charts.

The assumptions for the numerical solution with one step are :

- The angular speed range from 0 to 5 rad/s
- Depth of the water from 1 to 4 m
- Wavelength range from 1 to 4 m
- The width of the rectangular breakwater range from 0.2 to 0.8 of the wavelength and the depth ranger from 0.2 to 0.8 of the depth of the water.

We consider one rectangular break water with fix wavelength (L=2 m), fix depth of water (h=1m), fix width of the rectangular breakwater (d=0.4L= 0.8 m) and five different of heights of the step (0.3 h , 0.4 h, 0.5 h , 0.6h and 0.7 h) to find how the height of the step will affect the transmission rates.

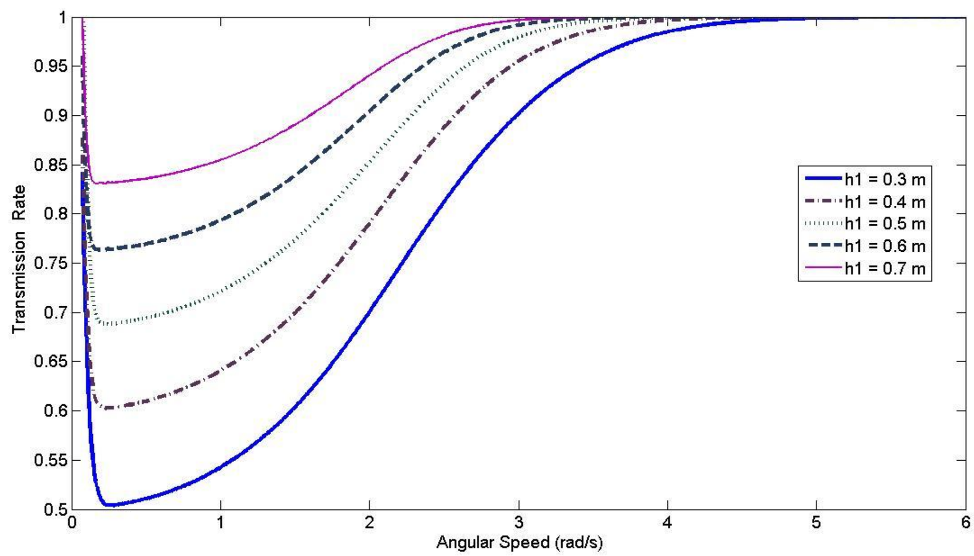


Figure (4-3): Effect of the Breakwater Height on The Transmission Rate

For the effect of the breakwater height, the transmission rates (T) were found for different height of breakwaters(h_1) for range of angular speed (ω). The transmission rate (T) is increased with the reduction on the height of the rectangular breakwater by increasing h_1 and angular speed (ω) as shown in figure (4-3).

The second consideration is the width of the step and the change of the transmission rates. The water depth (h=1 m), depth of the step ($h_1 = 0.4$) and wavelength (L=2m) were fixed for three different widths of the rectangular breakwaters (b=0.2,0.5,0.8) for range of angular speed (zero to five rad/s).

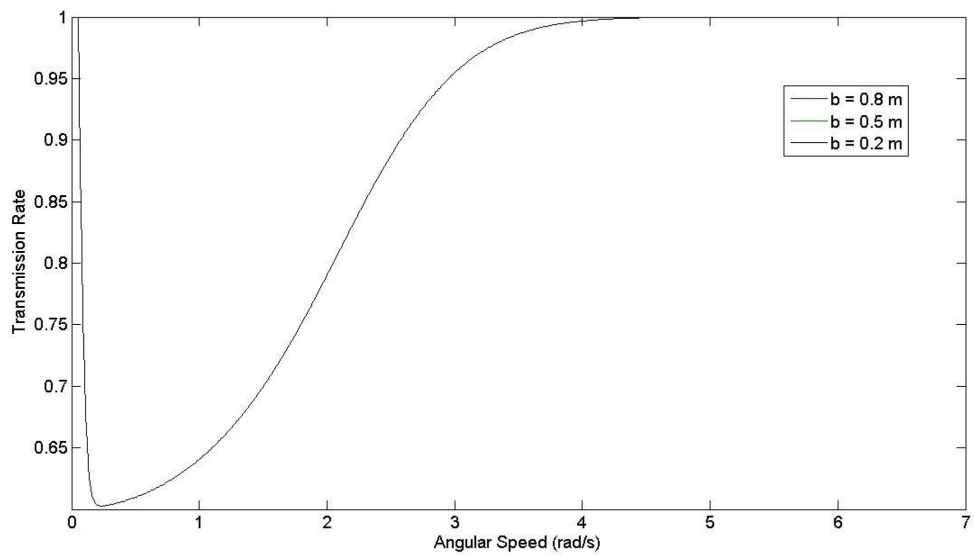


Figure (4-4): Effect of Breakwater Width on the Transmission Rate

The transmission rates (T) were increased with increasing the angular speed (ω). And transmission rates (T) will not change with the width of rectangular break water (d). We will consider the width of the rectangular break water to be fixed (d=0.2L) in all of the calculation.

The third consideration is the change of the wavelength (L) and the change of the transmission rate. The water depth (h=1 m), depth of the step ($h_1 = 0.4$ m) and the width of the rectangular breakwater (d=0.4 m) were fixed for different wavelength (L=2, 3, 4,5 and 6 m) for range of angular speed as shown in figure (4-5).

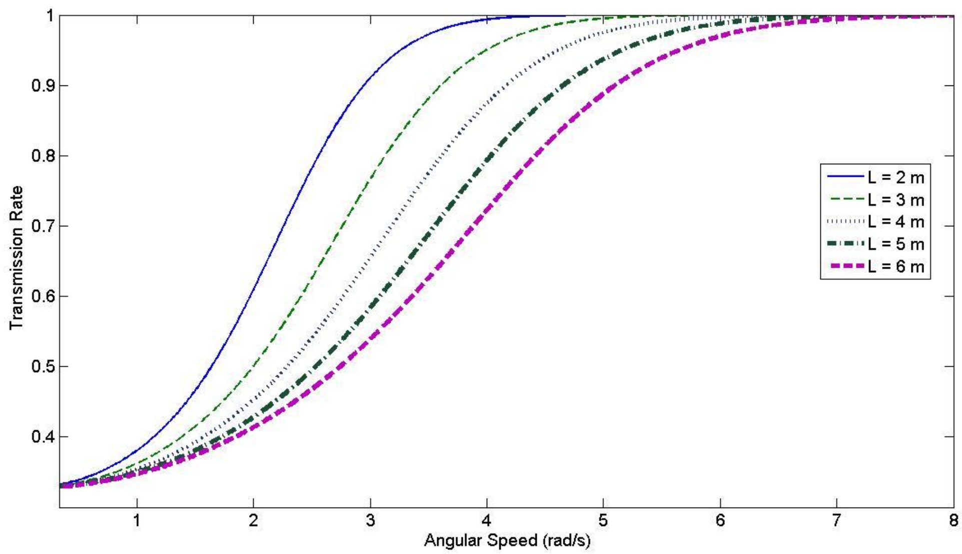


Figure (4-5) : Effect of Wavelength on The Transmission Rate

From figure (4-5), the transmission rates (T) were increased with increasing with increasing the angular speed (ω), decreased with increasing the wavelength (L) and the transmission rates (T) of long wave less than short wave and were increased with the angular speed (ω).

We consider one rectangular break water and new we will consider up to 200 rectangular breakwaters . Each of the following case in this section will consider the following number of rectangular breakwater, one, two, three, four, ten, fifty, one hundred and two hundred rectangular breakwaters in series. The next cases will find the change in the transmission rates for specific wavelength (L), depth of water (h) and height of rectangular break water (h_1) for three different heights (0.2h, 0.5h and 0.8h). We will consider this for three wavelengths (1,2 and 4 m) with the following parameters:

- Wave length L= 1 m
- Frequency range w from 0.1 to 6 rad/s

- The width of the step fixed d=0.2 m
- The water depth h=1 m
- The depth of the step h_1= 0.2 m

The transmission rates are found for different number of rectangular breakwaters (N=1,2,3,4,10,50,100 and 200) as shown in figure (4-6).

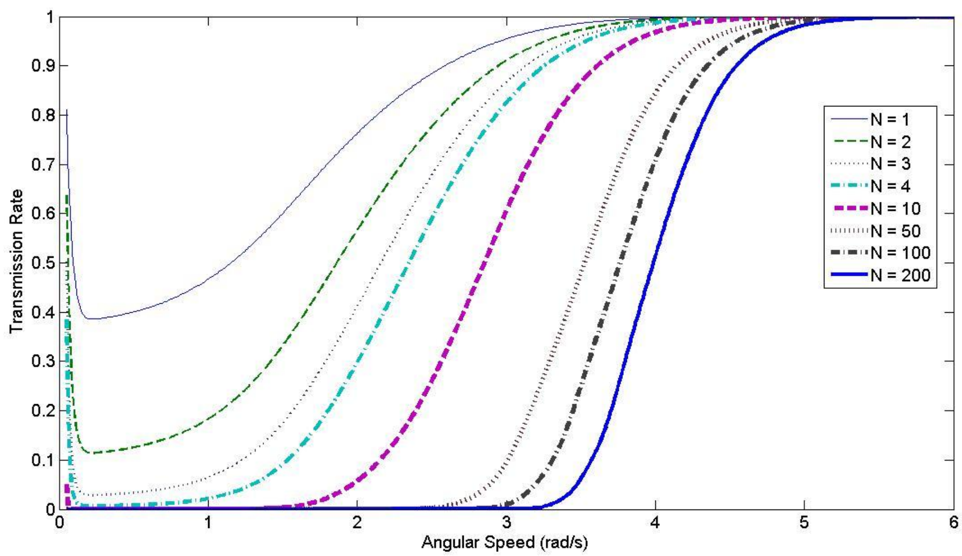


Figure (4-6) : The Transmission Rates for L=1 , h =1 , d=0.2 and $h_1 = 0.2$ for N=1,2,3,4,10,50,100 and 200

The same parameter are used with decreasing the height of the rectangular breakwaters by increasing h_1 = 0.5m as in figure (4-7) and h_1 =0.8m in figure (4-8).

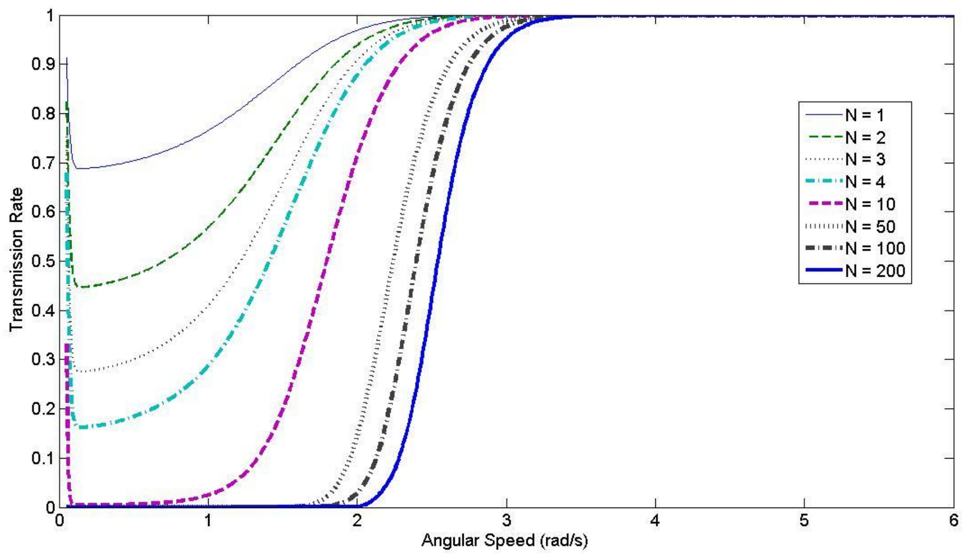
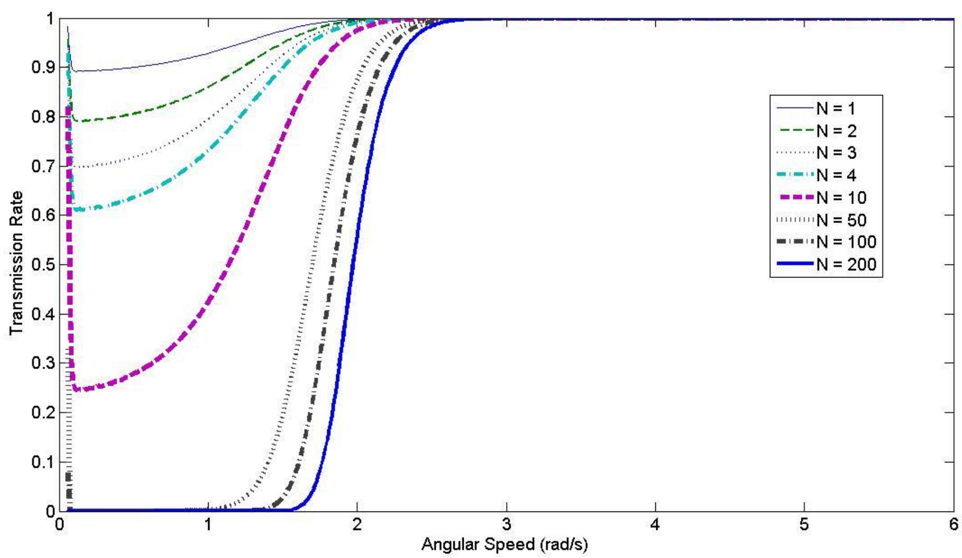


Figure (4-7) : The Transmission Rates for L=1 , h =1 , d=0.2 and $h_1 = 0.5$ for N=1,2,3,4,10,50,100 and 200



Figure(4-8):The Transmission Rates for L=1 , h =1 , d=0.2 and $h_1 = 0.8$ for N=1,2,3,4,10,50,100 and 200

From figure (4-6), figure(4-7) and figure(4-8), the transmission rates were increased with decreasing the height (h_1) of the breakwaters and decreased with increasing the number breakwaters.

We increased the wavelength L to 2 m with the following parameters:

- Angular speed range ω from 0.1 to 8 rad/sec
- The width of the step fixed d=0.4 m
- The water depth h=1m
- The depth of the step h_1= 0.2m

The transmission rates are found for different number of steps (N=1,2,3,4,10,50,100 and 200) and in figure (4-9)

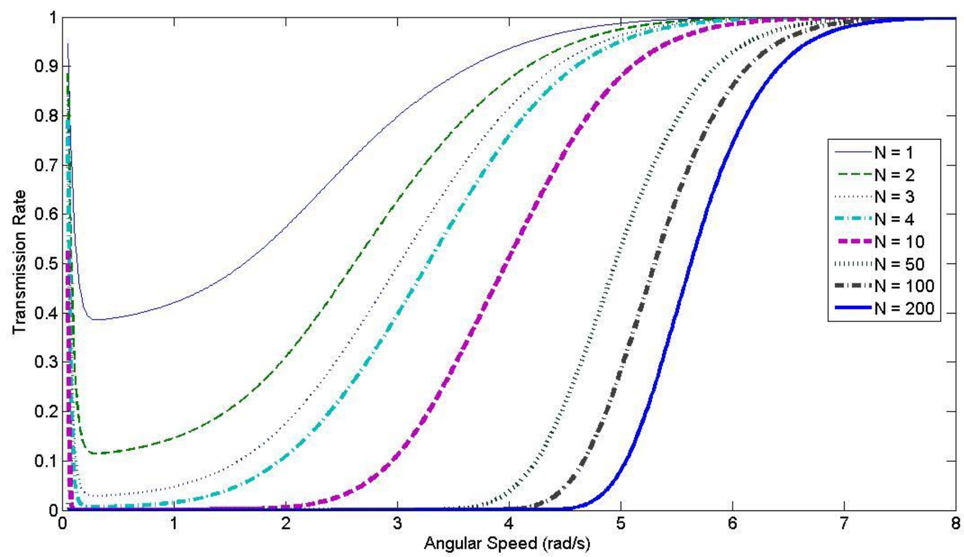


Figure (4-9) : The Transmission Rates for L=2 , h =1 , d=0.2 and $h_1 = 0.2$ for N=1,2,3,4,10,50,100 and 200

The same parameter were used with decreasing the height of the breakwater by increasing h_1 = 0.5 as in figure (4-10) and h_1 =0.8 as in figure (4-11).

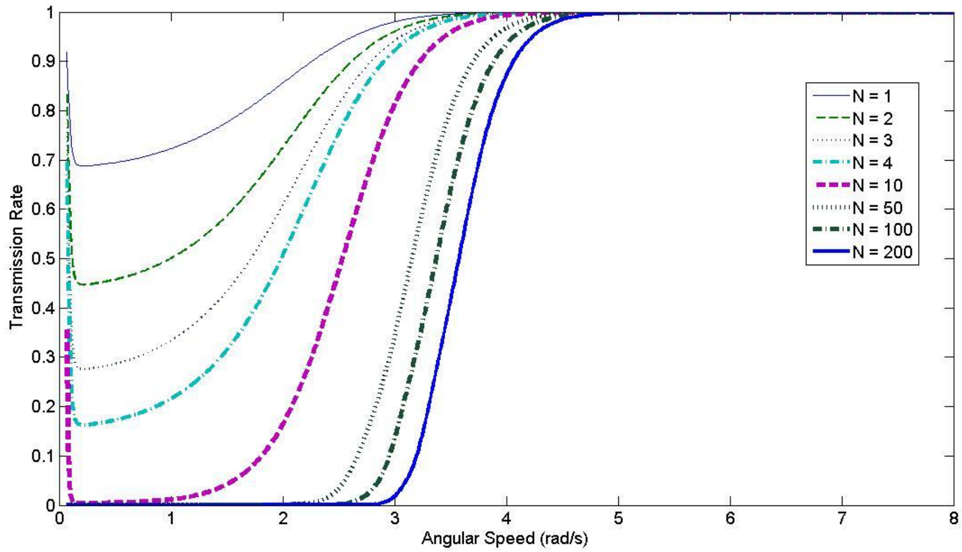
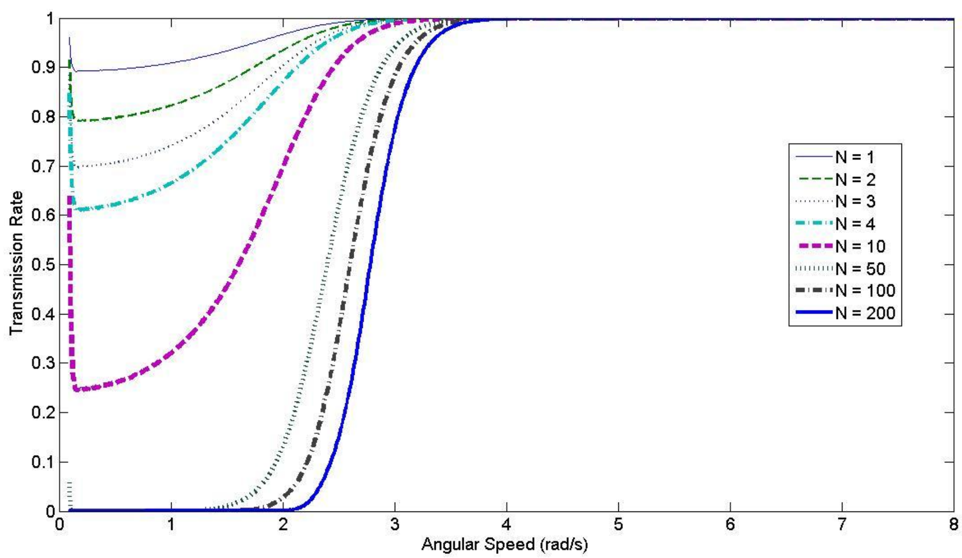


Figure (4-10) : The Transmission Rates for L=2 , h =1 , d=0.2 and $h_1 = 0.5$ for N=1,2,3,4,10,50,100 and 200



Figure(4-11):The Transmission Rates for L=2 , h =1 , d=0.2 and $h_1 = 0.8$ for N=1,2,3,4,10,50,100 and 200

From figure (4-9), figure(4-10) and figure (4-11), the transmission rates (T) were decreased with decreasing the height of the breakwaters and decreased with increasing

the number of the breakwaters. For the change of the wavelength, the transmission rates were decreased by increasing the wavelength.

We increase the wave length L to 4 m with the following parameters:

- Angular Speed (ω) range from 0 to 10 rad/s
- The width of the step fixed d=0.8 m
- The water depth h=1 m
- The depth of the step h_1= 0.2

The transmission rates are found for different number of steps (N=1, 2, 3, 4, 10, 50, 100 and 200) as in figure (4-12)

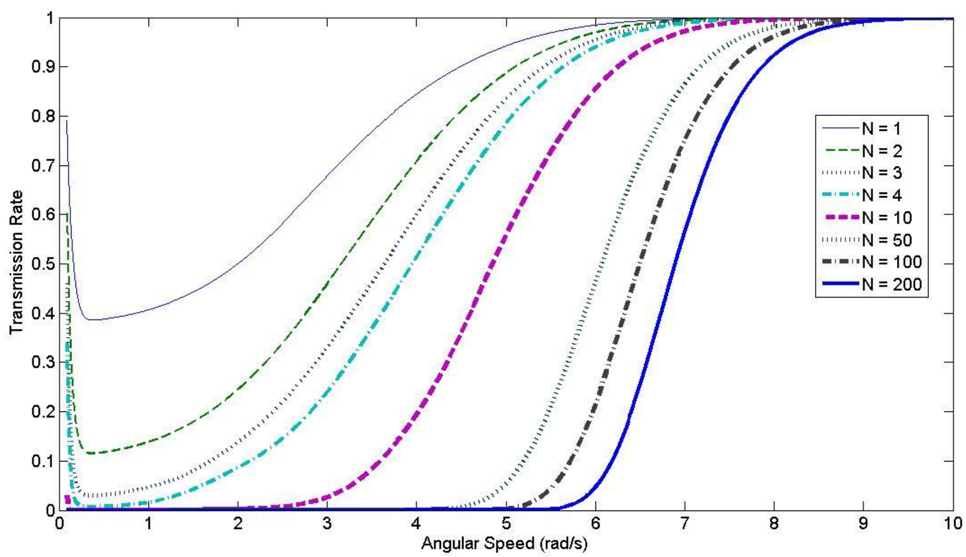


Figure (4-12) : The Transmission Rates for L=4 , h =1 , d=0.2 and $h_1 = 0.2$ for N=1,2,3,4,10,50,100 and 200

The same parameters were used with decreasing the height of the breakwaters by increasing the h_1 = 0.5 as in figure (4-13) and h_1 =0.8 as in figure (4-14).

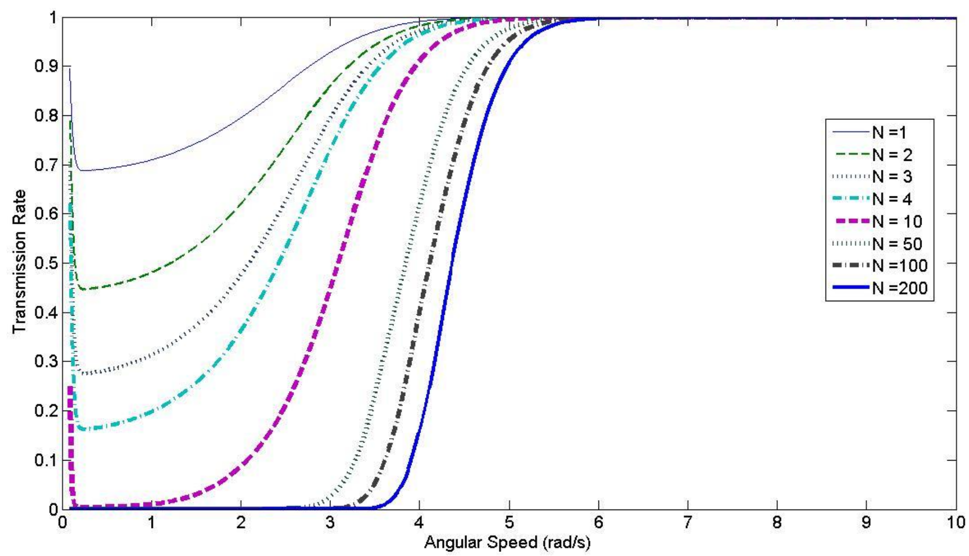


Figure (4-13) : The Transmission Rates for L=4 , h =1 , d=0.2 and $h_1 = 0.5$ for N=1,2,3,4,10,50,100 and 200

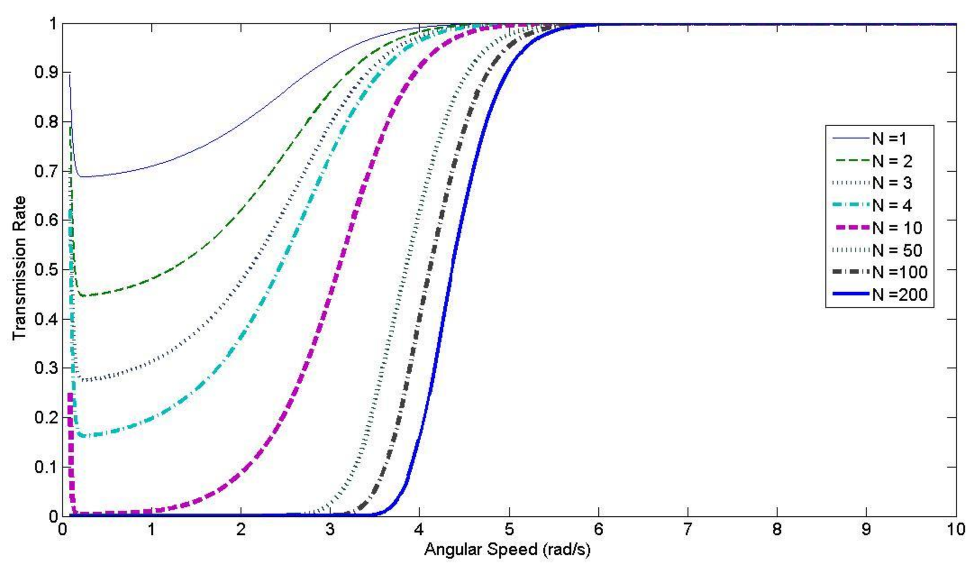


Figure (4-14) : The Transmission Rates for L=4 , h =1 , d=0.2 and $h_1 = 0.8$ for N=1,2,3,4,10,50,100 and 200

From the above figures, the transmission rates were decreased with increasing the height of the breakwaters, decreased with increasing the number of breakwaters and decreased by increasing the wavelength of water wave

After the calculation of the transmission rates for different wavelength, and height of rectangular break water, we consider now the different depth of the water with 0.5 height rectangular breakwater of the depth of the water for number of rectangular breakwaters (N= 1,2,3,4,10,50,100 and 200).For the following parameters, we calculate the transmission rates at different wavelength (L) and depth of water h for N= 1,2,3,4,10,50,100 and 200

- Angular Speed range ω from 0 to 6 rad/sec
- The width of the step fixed d=0.2L = 0.2 m
- The water depth h=1m
- The depth of the step h_1= 0.5 meter

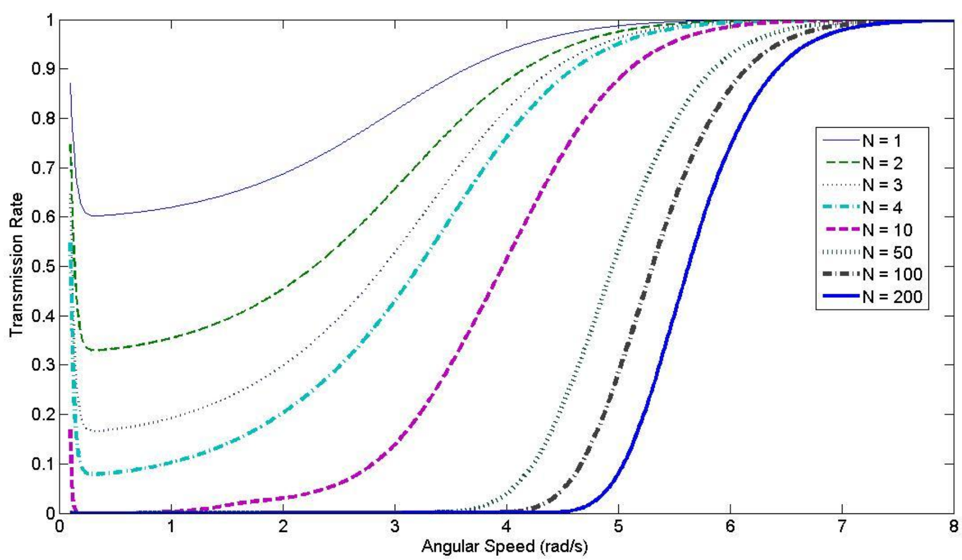


Figure (4-15) : The Transmission Rates for L=1 , h =1 , d=0.2 and $h_1 = 0.5$ for N=1,2,3,4,10,50,100 and 200

The transmission rates are found for different number of rectangular breakwaters (N=1,2,3,4,10,50,100 and 200) in figure (4-15) and the same parameters are used with

increasing the depth of the water (h =2 m and h_1=1) m as in figure (4-16) and (h =4 m and h_1= 2m) as in figure (4-17) .

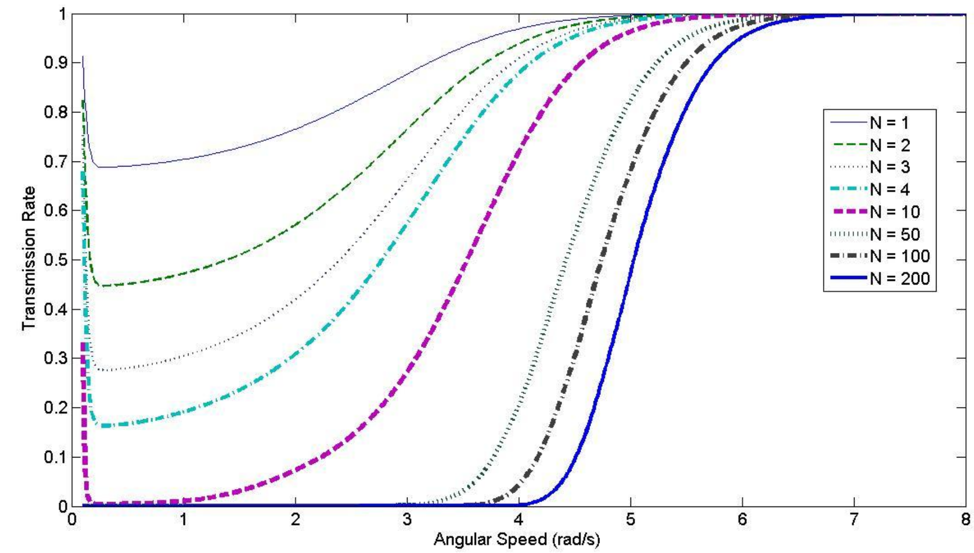


Figure (4-16) : The Transmission Rates for L=1 , h =2 , d=0.2 and $h_1 = 1$ for N=1,2,3,4,10,50,100 and 200

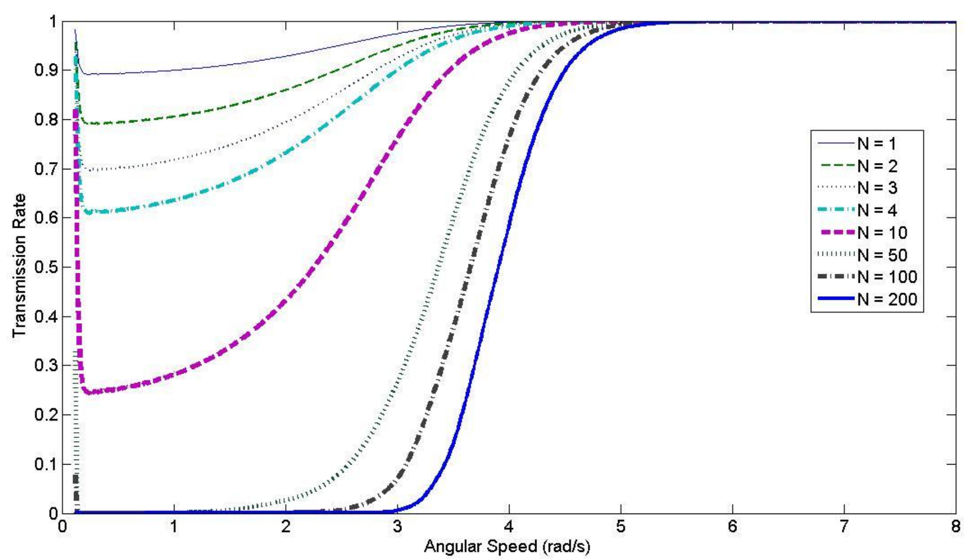


Figure (4-17) : The Transmission Rates for L=1 , h =4 , d=0.2 and $h_1 = 2$ for N=1,2,3,4,10,50,100 and 200

From figure (4-15), figure (4-16) and figure (4-17), the transmission rates were decreased with increasing the depth of water and decreased with increasing the number of breakwaters.

The wavelength L is increased to 2 m with the following parameters:

- Angular speed range ω from 0.1 to 6 rad/sec
- The width of the step fixed d=0.4m
- The water depth h=1m
- The depth of the step h_1= 0.5m

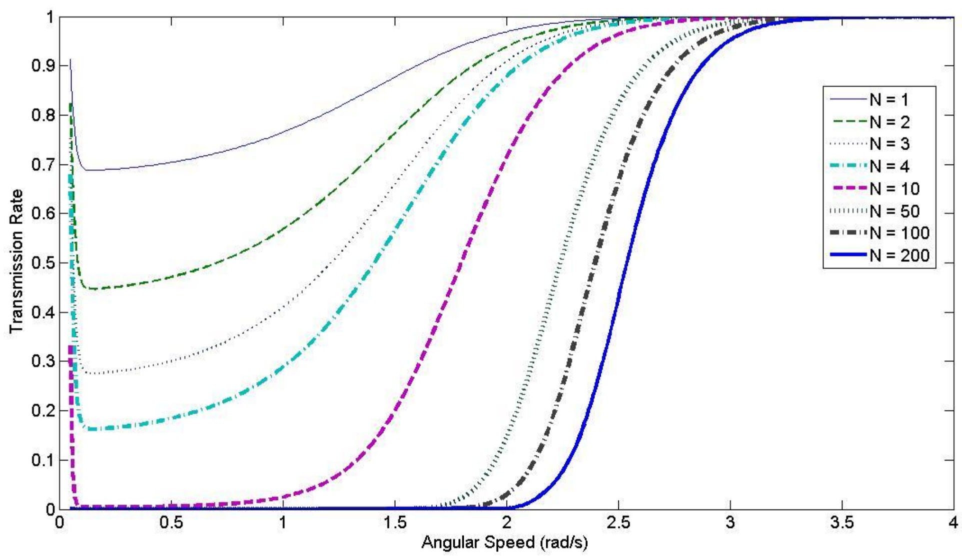


Figure (4-18) : The Transmission Rates for L=2 , h =1 , d=0.2 and $h_1 = 0.5$ for N=1,2,3,4,10,50,100 and 200

The transmission rates are found for different number of rectangular breakwaters (N=1,2,3,4,10,50,100 and 200) in figure (4-18) and the same parameters are used with increasing the depth of the water (h =2 m and h_1=1) m as in figure (4-19) and (h =4 m and h_1= 2m) as in figure (4-20) .

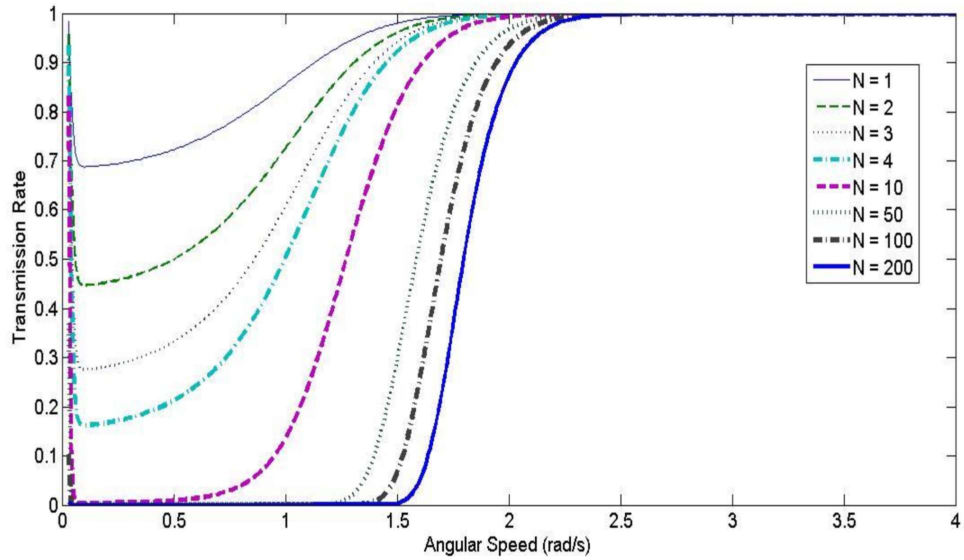


Figure (4-19) : The Transmission Rates for L=2 , h =2 , d=0.2 and $h_1 = 1$ for N=1,2,3,4,10,50,100 and 200

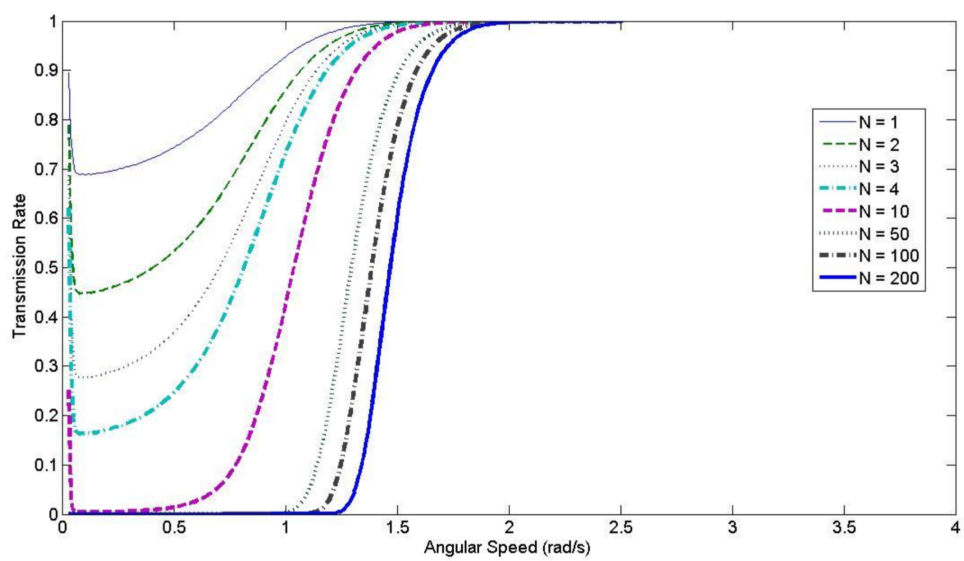


Figure (4-20) : The Transmission Rates for L=2 , h =4 , d=0.2 and $h_1 = 2$ for N=1,2,3,4,10,50,100 and 200

From figure (4-18), figure (4-19) and figure (4-20), the transmission rates were decreased with increasing the depth of water, decreased with increasing the number of breakwaters and decreased with increasing the wavelength.

The wavelength L is increased to 4 m with the following parameters:

- Angular speed range ω from 0 to 7 rad/s
- The width of the step fixed d=0.8 m
- The water depth h=1 m
- The depth of the step h_1= 0.5 m

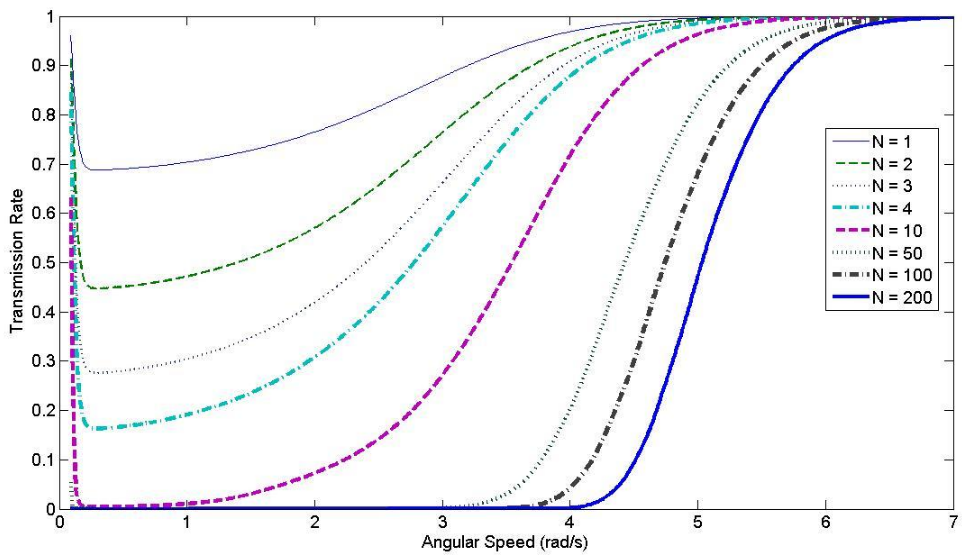


Figure (4-21) : The Transmission Rates for L=4 , h =1 , d=0.2 and $h_1 = 0.5$ for N=1,2,3,4,10,50,100 and 200

The transmission rates are found for different number of rectangular breakwaters (N=1,2,3,4,10,50,100 and 200) in figure (4-21) and the same parameters are used with increasing the depth of the water (h =2 m and h_1=1) m as in figure (4-22) and (h =4 m and h_1= 2m) as in figure (4-23) .

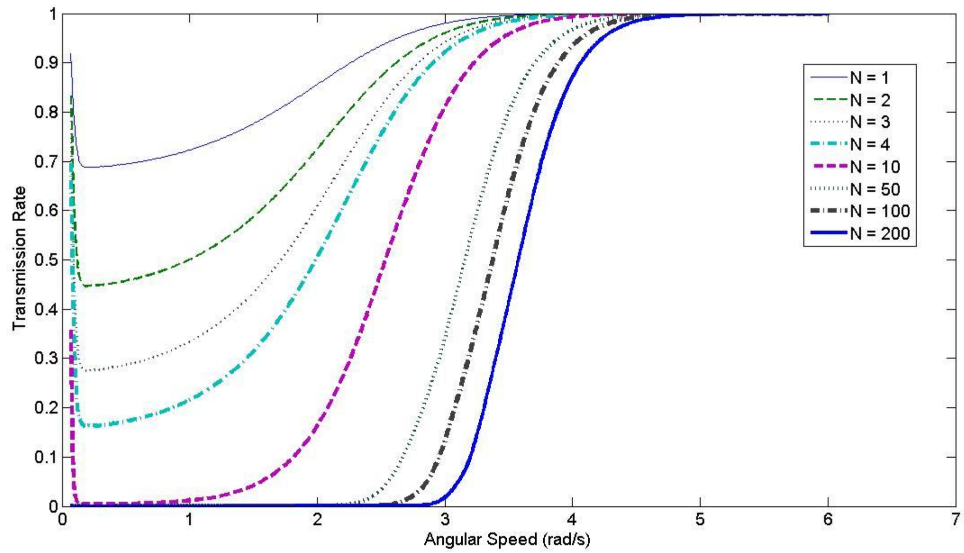


Figure (4-22) : The Transmission Rates for L=4 , h =2 , d=0.2 and $h_1 = 1$ for N=1,2,3,4,10,50,100 and 200

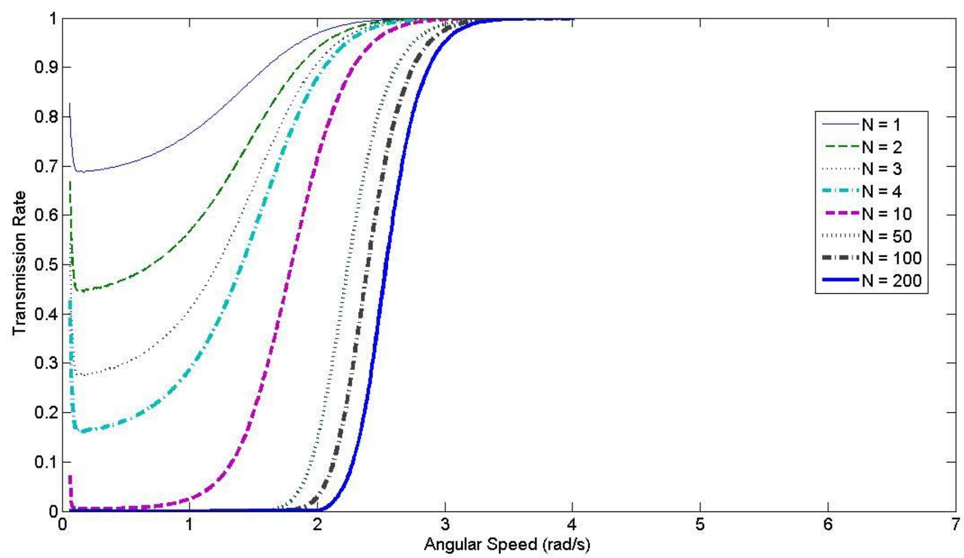


Figure (4-23) : The Transmission Rates for L=4 , h =4 , d=0.2 and $h_1 = 2$ for N=1,2,3,4,10,50,100 and 200

From figure (4-21), figure (4-22) and figure (4-23), the transmission rates were decreased with increasing the depth of water, decreased with increasing the number of breakwaters and decreased with increasing the wavelength.

We find that as the depth of the water increase the transmission rate increase and as the wavelength increase the transmission rates reduced for more than ten rectangular breakwaters. This will help to consider the more than ten rectangular breakwaters as the depth increased and the wavelength increased.

CHAPTER 5

CONCLUSIONS

This chapter provides a summary of results and conclusion from analytical solutions in chapter three and the parametric analyses in chapter four with recommendations on water wave propagation over rectangular breakwaters.

The analytical solutions of chapter 3 are utilized in chapter 4 to get numerical illustrations using MATLAB programs. Three main parameters in the dispersion of water wave propagation which are the angular speed (ω), the wavelength (L) and the depth of water (h) were used as inputs to calculate the wavenumber as an output. Numerical results showed how the wavenumber and transmission rates changes for different water depths, width and height of rectangular breakwaters and wavelengths over range of rectangular breakwaters. It was found that the wave speed decreased with increasing the angular speed and increase with increasing the depth of watet.

Using the dispersion equation for one rectangular breakwater, as a representative unit cell, by the transfer matrix method which was based on the continuity of the pressure and velocity showed how the transmission rates changes with the height of the breakwater and wavelength. The transmission rates were found to increase with increasing the

angular speed, increased with decreasing the height of the rectangular breakwaters, decrease with increasing the wavelength and showed no change with changing the width of the rectangular breakwaters .

For a set of rectangular breakwaters up to 200, the change of the transmission rates were found as the depth of water changed as well as when the wavelength and the height of the breakwaters changed. The transmission rate decreased with increasing the angular speed, decreased with increasing the height of the rectangular breakwaters, decreased with increasing wavelength, and decrease with increasing the number of rectangular breakwaters.

The water wave propagation could be controlled as it smacked onto the coast of the sea by rectangular breakwaters built at the seabed with the consideration the height of the rectangular breakwater and the depth of the water. The three main natural parameters wavelength, angular speed and the depth of the water were considered in designing the rectangular breakwaters. To summarize the above results, one note that the transmission rates of the water wave

- Increase with increasing the angular speed and it is out of the control of the designer .
- Decrease with increasing the wavelength and it is out of the control of the designer.
- Decrease with increasing the depth of the water and it is out of the control of the designer.
- Decrease with increasing the height of rectangular breakwaters

- Decrease with increasing the number of the rectangular breakwaters

For long waves, as the wavelength increased, one needed to increase the number of steps or the height of the rectangular breakwaters in order to get the best result from the non-uniform bottom to reduce the transmission rates to the acceptable range.

Hence, through this study, one could calculate the transmission rate for any defined conditions (wavelength, angular speed, depth of the water) and could provide the optimum design parameters for rectangular breakwaters in terms of height and number to reduce the water wave propagation to optimal result of transmission. The main advantage of selecting submerged rectangular breakwaters over the floating breakwaters were less affect on ships movement, keep the beautification of the coast of the sea which will encourage the implementation and can be easily designed for any range of depth of water and wavelength.

Lastly, one can provide the following recommendation based on the findings of this thesis:

- In order to get desirable water wave transmission coefficients, the designer of the submersible rectangular breakwater need the location of the breakwater with the range of water depth, range of wave length and range of angular speed.
- The width of the rectangular breakwater shall be 20 % of the wavelength, since the width of the rectangular breakwater will not affect the transmission rate.
- It is recommended that the number of breakwaters not to exceed fifty in series.
- For long waves, the number of the breakwaters will control the wave transmission and for short wave, the height of the breakwaters will control the transmission.
- Future work can consider different level instead of identical breakwaters.

APPENDICES

Appendix-A

The following MATLAB program written to calculate the wavenumber .

```
%%%%%%%%%%%%%%%  Assumed Numbers   %%%%%%%%%
d=0.2;
L=1;
h=1;
h1=0.1;
wo=(9.81*L)^.5;
w=[0.01:.01:5.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:501 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%
c=pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k(r)=A;
end
W = w/wo ;
plot(W,k)
```

The following MATLAB program written to calculate the wavenumber k at h and k_1 at h_1.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%
d=0.2;
L=1;
h=1;
h1=0.1;
wo=(9.81*L)^.5;
w=[0.01:.01:5.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:501 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k(r)=A;
%%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
   end
   k1(r)=B;
    end
W=w/wo;
plot(W,k,W,k1)
```

The following MATLAB program is written to calculate the transmission rate over one rectangular breakwaters for range of angular speed.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%
d=0.2;
L=1;
h=1;
h1=0.1;
wo=(9.81*L)^.5;
w=[0.01:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:801 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%
  for n=1:1000
     A=(w(r))^2/((wo)^2*L*tanh(c*h));
      if abs (A-c) < 0.0001
        break
      else
         c=A;
      end
  end
  k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%
  for n=1:1000
     B=(w(r))^2/((wo)^2*L*tanh(c*h1));
      if abs (B-c) < 0.0001
        break
      else
        c=B;
      end
  end
  k1(r)=B;
 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%
 x=0.2;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A2(r)=1/(abs(P(1,1)))^2;
end
W=w/wo;
plot(W,A2)
xlabel('Angular Speed (rad/s)')
ylabel(' Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate over number of rectangular breakwaters for range of angular speed.

```
 %%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%
d=0.2;
L=1;
h=1;
N=5
h1=0.1;
wo=(9.81*L)^.5;
w=[0.01:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:801 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k(r)=A;
%%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
   end
   k1(r)=B;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%
  x=0.2;
     M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
     M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
     M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
     M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
     P= [M1(r) M2(r); M3(r) M4(r)]^N;
     A2(r)=1/(abs(P(1,1)))^2;
end
W=w/wo;
plot(W,A2)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the wave speed for different wavelength for range of angular speed as shown in figure (4-1) page 46.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%%
L=1;
h=1;
wo=(9.81*L)^.5;
w=[0.01:.01:7.01]*wo;
W=w/wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:701 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%
c=pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k1(r)=A;
   S1(r)=(w(r)/(k1(r)*wo));
end
L=2;
h=1;
wo=(9.81*L)^.5;
w=[0.01:.01:7.01]*wo;
W=w/wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:701 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%
c=pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k2(r)=A;
   S2(r)=(w(r)/(k2(r)*wo));
end
L=3;
h=1;
wo=(9.81*L)^.5;
w=[0.01:.01:7.01]*wo;
W=w/wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:701 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%%
c=pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
```

```
   k3(r)=A;
   S3(r)=(w(r)/(k3(r)*wo));
end
L=4;
h=1;
wo=(9.81*L)^.5;
w=[0.01:.01:7.01]*wo;
W=w/wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:701 % dummy counter for frequency
%%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%
c=pi;
%%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k4(r)=A;
   S4(r)=(w(r)/(k4(r)*wo));
end
plot(W,S1,W,S2,W,S3,W,S4)
xlabel('Angular Speed (rad/s)')
ylabel('Wave Speed (m/s)')
```

The following MATLAB program is written to calculate the wave speed for different depth of water for range of angular speed as shown in figure (4-2) page 47.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%
L=4;
h=2;
wo=(9.81*L)^.5;
w=[0.01:.01:7.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:701 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%
c=pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k1(r)=A;
   S1(r)=(w(r)/(k1(r)*wo));
end
W=w/wo;
L=4;
h=1.5;
wo=(9.81*L)^.5;
w=[0.01:.01:7.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:701 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%
c=pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k2(r)=A;
   S2(r)=(w(r)/(k2(r)*wo));
end
W=w/wo;
L=4;
h=1;
wo=(9.81*L)^.5;
w=[0.01:.01:7.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:701 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%
c=pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
```

```
   k3(r)=A;
   S3(r)=(w(r)/(k3(r)*wo));
end
W=w/wo;
L=4;
h=0.5;
wo=(9.81*L)^.5;
w=[0.01:.01:7.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:701 % dummy counter for frequency
%%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%
c=pi;
%%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k4(r)=A;
   S4(r)=(w(r)/(k4(r)*wo));
end
W=w/wo;
plot(W,S1,W,S2,W,S3,W,S4)
xlabel('Angular Speed (rad/s)')
ylabel('Wave Speed (m/s)')
```

The following MATLAB program is written to calculate the Transmission Rate for different height of rectangular breakwater for range of angular speed as shown in figure (4-3) page 49.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%
L=2;
h=1;
h1=0.3;
wo=(9.81*L)^.5;
w=[0.07:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:595 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k(r)=A;
 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
   end
   k1(r)=B;
 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%
  x=0.2*L;
     M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
     M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
     M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
     M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
     P1= [M1(r) M2(r); M3(r) M4(r)];
     A21(r)=1/(abs(P1(1,1)))^2;
end
L1=2;
h=1;
h1=0.4;
wo=(9.81*L1)^.5;
w=[0.07:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r1=1:595 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%
   for n1=1:1000
      A=(w(r1))^2/((wo)^2*L1*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
```

```
        end
    end
    k(r1)=A;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%
    for n1=1:1000
       B=(w(r1))^2/((wo)^2*L1*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
    end
    k1(r1)=B;
 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%
  x=0.2*L1;
     M1(r1) = ((k(r1)+k1(r1))/(2*k(r1)))*exp(-i*k(r1)*x+i*k1(r1)*x) ;
     M2(r1) = ((+k(r1)-k1(r1))/(2*k(r1)))*exp(-i*k(r1)*x-i*k1(r1)*x)  ;
     M3(r1) = ((k(r1)-k1(r1))/(2*k(r1)))*exp(i*k(r1)*x+i*k1(r1)*x) ;
     M4(r1) = ((k(r1)+k1(r1))/(2*k(r1)))*exp(i*k(r1)*x-i*k1(r1)*x)  ;
     P12= [M1(r1) M2(r1); M3(r1) M4(r1)];
     A22(r1)=1/(abs(P12(1,1)))^2;
end
L2=2;
h=1;
h1=0.5;
wo=(9.81*L2)^.5;
w=[0.05:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r2=1:595 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%
    for n=1:1000
       A=(w(r2))^2/((wo)^2*L2*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
    end
    k(r2)=A;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%
    for n2=1:1000
       B=(w(r2))^2/((wo)^2*L2*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
    end
    k1(r2)=B;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%
  x=0.2*L2;
     M1(r2) = ((k(r2)+k1(r2))/(2*k(r2)))*exp(-i*k(r2)*x+i*k1(r2)*x) ;
     M2(r2) = ((+k(r2)-k1(r2))/(2*k(r2)))*exp(-i*k(r2)*x-i*k1(r2)*x)  ;
     M3(r2) = ((k(r2)-k1(r2))/(2*k(r2)))*exp(i*k(r2)*x+i*k1(r2)*x) ;
     M4(r2) = ((k(r2)+k1(r2))/(2*k(r2)))*exp(i*k(r2)*x-i*k1(r2)*x)  ;
     P13= [M1(r2) M2(r2); M3(r2) M4(r2)];
     A23(r2)=1/(abs(P13(1,1)))^2;
end
L3=2;
h=1;
```

```
h1=0.6;
wo=(9.81*L3)^.5;
w=[0.07:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r3=1:595 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
  for n3=1:1000
    A=(w(r3))^2/((wo)^2*L3*tanh(c*h));
     if abs (A-c) < 0.0001
       break
     else
       c=A;
     end
  end
  k(r3)=A;
 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%
  for n3=1:1000
    B=(w(r3))^2/((wo)^2*L3*tanh(c*h1));
     if abs (B-c) < 0.0001
       break
     else
       c=B;
     end
  end
  k1(r3)=B;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%
 x=0.2*L3;
   M1(r3) = ((k(r3)+k1(r3))/(2*k(r3)))*exp(-i*k(r3)*x+i*k1(r3)*x) ;
   M2(r3) = ((+k(r3)-k1(r3))/(2*k(r3)))*exp(-i*k(r3)*x-i*k1(r3)*x)  ;
   M3(r3) = ((k(r3)-k1(r3))/(2*k(r3)))*exp(i*k(r3)*x+i*k1(r3)*x) ;
   M4(r3) = ((k(r3)+k1(r3))/(2*k(r3)))*exp(i*k(r3)*x-i*k1(r3)*x)  ;
   P14= [M1(r3) M2(r3); M3(r3) M4(r3)];
   A24(r3)=1/(abs(P14(1,1)))^2;
end
L4=2;
h=1;
h1=0.7;
wo=(9.81*L)^.5;
w=[0.07:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r4=1:595 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
  for n4=1:1000
    A=(w(r4))^2/((wo)^2*L4*tanh(c*h));
     if abs (A-c) < 0.0001
       break
     else
       c=A;
     end
  end
  k(r4)=A;
  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%%
  for n4=1:1000
    B=(w(r4))^2/((wo)^2*L4*tanh(c*h1));
     if abs (B-c) < 0.0001
       break
     else
       c=B;
     end
```

```
   end
   k1(r4)=B;
 %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%% %%%%%%%
 x=0.2*L4;
    M1(r4) = ((k(r4)+k1(r4))/(2*k(r4)))*exp(-i*k(r4)*x+i*k1(r4)*x) ;
    M2(r4) = ((+k(r4)-k1(r4))/(2*k(r4)))*exp(-i*k(r4)*x-i*k1(r4)*x)  ;
    M3(r4) = ((k(r4)-k1(r4))/(2*k(r4)))*exp(i*k(r4)*x+i*k1(r4)*x) ;
    M4(r4) = ((k(r4)+k1(r4))/(2*k(r4)))*exp(i*k(r4)*x-i*k1(r4)*x)  ;
    P15= [M1(r4) M2(r4); M3(r4) M4(r4)];
    A25(r4)=1/(abs(P15(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A25)
xlabel(' Angular Speed (rad/s) ')
ylabel(' Transmission  Rate')
```

The following MATLAB Program is written to calculate transmission rate for different width of the rectangular breakwaters for range of angular speed as shown in figure (4-4) page 50.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%%
L=2;
h=1;
h1=0.4;
wo=(9.81*L)^.5;
w=[0.01:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:601 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
          c=A;
       end
   end
   k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
   end
   k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%%
 x=0.2*L;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P1= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P1(1,1)))^2;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%%
 x=0.5*L;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P2=[M1(r) M2(r); M3(r) M4(r)];
    A22(r)=1/(abs(P2(1,1)))^2;
 %%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%%
 x=0.8*L;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P3= [M1(r) M2(r); M3(r) M4(r)];
    A23(r)=1/(abs(P3(1,1)))^2;
end
W=w/wo;
```

```
plot(W,A21,W,A22,W,A23)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program written to calculate the transmission rate for different wavelength for range of angular speed as shown in figure (4-5) page 51.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%
L=2;
h=1;
h1=0.4;
wo=(9.81*L)^.5;
w=[0.01:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:801 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
          c=A;
       end
   end
   k(r)=A;
  %%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
   end
   k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%%%
 x=0.2*L;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P1= [M1(r) M2(r); M3(r) M4(r)]^2;
    A21(r)=1/(abs(P1(1,1)))^2;
end
L1=3;
h=1;
h1=0.4;
wo=(9.81*L1)^.5;
w=[0.01:.01:8.01]*wo;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r1=1:801 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%%
   for n1=1:1000
      A=(w(r1))^2/((wo)^2*L1*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
          c=A;
       end
   end
   k(r1)=A;
```

```
  %%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%
   for n1=1:1000
      B=(w(r1))^2/((wo)^2*L1*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
   end
   k1(r1)=B;
%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%
  x=0.2*L1;
     M1(r1) = ((k(r1)+k1(r1))/(2*k(r1)))*exp(-i*k(r1)*x+i*k1(r1)*x) ;
     M2(r1) = ((+k(r1)-k1(r1))/(2*k(r1)))*exp(-i*k(r1)*x-i*k1(r1)*x)  ;
     M3(r1) = ((k(r1)-k1(r1))/(2*k(r1)))*exp(i*k(r1)*x+i*k1(r1)*x) ;
     M4(r1) = ((k(r1)+k1(r1))/(2*k(r1)))*exp(i*k(r1)*x-i*k1(r1)*x)  ;
     P12= [M1(r1) M2(r1); M3(r1) M4(r1)]^2;
     A22(r1)=1/(abs(P12(1,1)))^2;
end
L2=4;
h=1;
h1=0.4;
wo=(9.81*L2)^.5;
w=[0.01:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r2=1:801 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r2))^2/((wo)^2*L2*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
          c=A;
       end
   end
   k(r2)=A;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%
   for n2=1:1000
      B=(w(r2))^2/((wo)^2*L2*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
   end
   k1(r2)=B;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%%
  x=0.2*L2;
     M1(r2) = ((k(r2)+k1(r2))/(2*k(r2)))*exp(-i*k(r2)*x+i*k1(r2)*x) ;
     M2(r2) = ((+k(r2)-k1(r2))/(2*k(r2)))*exp(-i*k(r2)*x-i*k1(r2)*x)  ;
     M3(r2) = ((k(r2)-k1(r2))/(2*k(r2)))*exp(i*k(r2)*x+i*k1(r2)*x) ;
     M4(r2) = ((k(r2)+k1(r2))/(2*k(r2)))*exp(i*k(r2)*x-i*k1(r2)*x)  ;
     P13= [M1(r2) M2(r2); M3(r2) M4(r2)]^2;
     A23(r2)=1/(abs(P13(1,1)))^2;
end
L3=5;
h=1;
h1=0.4;
wo=(9.81*L3)^.5;
w=[0.01:.01:8.01]*wo;
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r3=1:801 % dummy counter for frequency
%%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%
   for n3=1:1000
      A=(w(r3))^2/((wo)^2*L3*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k(r3)=A;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%%%%%
   for n3=1:1000
      B=(w(r3))^2/((wo)^2*L3*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
   end
   k1(r3)=B;
%%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%%%%%%%
  x=0.2*L3;
     M1(r3) = ((k(r3)+k1(r3))/(2*k(r3)))*exp(-i*k(r3)*x+i*k1(r3)*x) ;
     M2(r3) = ((+k(r3)-k1(r3))/(2*k(r3)))*exp(-i*k(r3)*x-i*k1(r3)*x)  ;
     M3(r3) = ((k(r3)-k1(r3))/(2*k(r3)))*exp(i*k(r3)*x+i*k1(r3)*x) ;
     M4(r3) = ((k(r3)+k1(r3))/(2*k(r3)))*exp(i*k(r3)*x-i*k1(r3)*x)  ;
     P14= [M1(r3) M2(r3); M3(r3) M4(r3)]^2;
     A24(r3)=1/(abs(P14(1,1)))^2;
end
L4=6;
h=1;
h1=0.4;
wo=(9.81*L)^.5;
w=[0.01:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r4=1:801 % dummy counter for frequency
%%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%%%%
   for n4=1:1000
      A=(w(r4))^2/((wo)^2*L4*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k(r4)=A;
%%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%%%%%%
   for n4=1:1000
      B=(w(r4))^2/((wo)^2*L4*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
   end
   k1(r4)=B;
```

```
%%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%
 x=0.2*L4;
    M1(r4) = ((k(r4)+k1(r4))/(2*k(r4)))*exp(-i*k(r4)*x+i*k1(r4)*x) ;
    M2(r4) = ((+k(r4)-k1(r4))/(2*k(r4)))*exp(-i*k(r4)*x-i*k1(r4)*x)  ;
    M3(r4) = ((k(r4)-k1(r4))/(2*k(r4)))*exp(i*k(r4)*x+i*k1(r4)*x) ;
    M4(r4) = ((k(r4)+k1(r4))/(2*k(r4)))*exp(i*k(r4)*x-i*k1(r4)*x)  ;
    P15= [M1(r4) M2(r4); M3(r4) M4(r4)]^2;
    A25(r4)=1/(abs(P15(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A25)
xlabel(' Angular Speed (rad/s)')
ylabel(' Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-6) page 52.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%
d=0.2;
L=1;
h=1;
h1=0.2;
wo=(9.81*L)^.5;
w=[0.05:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:597 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
          c=A;
       end
   end
   k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
   end
   k1(r)=B;
 %%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%% %%%%%
 x=0.2;
     M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
     M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
     M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
     M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
     P= [M1(r) M2(r); M3(r) M4(r)];
     A21(r)=1/(abs(P(1,1)))^2;
     P2= [M1(r) M2(r); M3(r) M4(r)]^2;
     A22(r)=1/(abs(P2(1,1)))^2;
     P3= [M1(r) M2(r); M3(r) M4(r)]^3;
     A23(r)=1/(abs(P3(1,1)))^2;
     P4= [M1(r) M2(r); M3(r) M4(r)]^4;
     A24(r)=1/(abs(P4(1,1)))^2;
     P10= [M1(r) M2(r); M3(r) M4(r)]^10;
     A210(r)=1/(abs(P10(1,1)))^2;
     P50= [M1(r) M2(r); M3(r) M4(r)]^50;
     A250(r)=1/(abs(P50(1,1)))^2;
     P100= [M1(r) M2(r); M3(r) M4(r)]^100;
     A2100(r)=1/(abs(P100(1,1)))^2;
     P200= [M1(r) M2(r); M3(r) M4(r)]^200;
     A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-7) page 53.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%
d=0.2;
L=1;
h=1;
h1=0.5;
wo=(9.81*L)^.5;
w=[0.05:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:597 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
          c=A;
       end
   end
   k(r)=A;
  %%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
   end
   k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%
 x=0.2;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-8) page 53.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%
d=0.2;
L=1;
h=1;
h1=0.8;
wo=(9.81*L)^.5;
w=[0.06:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:596 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
           c=A;
        end
   end
   k(r)=A;
%%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
   end
   k1(r)=B;
%%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%
  x=0.2;
     M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
     M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
     M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
     M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
     P= [M1(r) M2(r); M3(r) M4(r)];
     A21(r)=1/(abs(P(1,1)))^2;
     P2= [M1(r) M2(r); M3(r) M4(r)]^2;
     A22(r)=1/(abs(P2(1,1)))^2;
     P3= [M1(r) M2(r); M3(r) M4(r)]^3;
     A23(r)=1/(abs(P3(1,1)))^2;
     P4= [M1(r) M2(r); M3(r) M4(r)]^4;
     A24(r)=1/(abs(P4(1,1)))^2;
     P10= [M1(r) M2(r); M3(r) M4(r)]^10;
     A210(r)=1/(abs(P10(1,1)))^2;
     P50= [M1(r) M2(r); M3(r) M4(r)]^50;
     A250(r)=1/(abs(P50(1,1)))^2;
     P100= [M1(r) M2(r); M3(r) M4(r)]^100;
     A2100(r)=1/(abs(P100(1,1)))^2;
     P200= [M1(r) M2(r); M3(r) M4(r)]^200;
     A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-9) page 54.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%
d=0.4;
L=2;
h=1;
h1=0.2;
wo=(9.81*L)^.5;
w=[0.05:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:797 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%
  for n=1:1000
     A=(w(r))^2/((wo)^2*L*tanh(c*h));
      if abs (A-c) < 0.0001
        break
      else
         c=A;
      end
  end
  k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%
  for n=1:1000
     B=(w(r))^2/((wo)^2*L*tanh(c*h1));
      if abs (B-c) < 0.0001
        break
      else
        c=B;
      end
  end
  k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%
 x=0.4;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-10) page 55.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%
d=0.4;
L=2;
h=1;
h1=0.5;
wo=(9.81*L)^.5;
w=[0.07:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:795 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
  for n=1:1000
     A=(w(r))^2/((wo)^2*L*tanh(c*h));
      if abs (A-c) < 0.0001
        break
      else
        c=A;
      end
  end
  k(r)=A;
%%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%
  for n=1:1000
     B=(w(r))^2/((wo)^2*L*tanh(c*h1));
      if abs (B-c) < 0.0001
        break
      else
        c=B;
      end
  end
  k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%
 x=0.4;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-11) page 55.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%
d=0.4;
L=2;
h=1;
h1=0.8;
wo=(9.81*L)^.5;
w=[0.09:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:793 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
  for n=1:1000
     A=(w(r))^2/((wo)^2*L*tanh(c*h));
      if abs (A-c) < 0.0001
        break
      else
         c=A;
      end
  end
  k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%
  for n=1:1000
     B=(w(r))^2/((wo)^2*L*tanh(c*h1));
      if abs (B-c) < 0.0001
        break
      else
        c=B;
      end
  end
  k1(r)=B;
 %%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%
 x=0.4;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-12) page 56.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%
d=0.6;
L=3;
h=1;
h1=0.2;
wo=(9.81*L)^.5;
w=[0.09:.01:10.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:993 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%
  for n=1:1000
     A=(w(r))^2/((wo)^2*L*tanh(c*h));
      if abs (A-c) < 0.0001
        break
      else
         c=A;
      end
  end
  k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%
  for n=1:1000
     B=(w(r))^2/((wo)^2*L*tanh(c*h1));
      if abs (B-c) < 0.0001
        break
      else
        c=B;
      end
  end
  k1(r)=B;
%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%
 x=0.6;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-13) page 57.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%
d=0.6;
L=3;
h=1;
h1=0.5;
wo=(9.81*L)^.5;
w=[0.09:.01:10.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:993 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
         c=A;
       end
   end
   k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
   end
   k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%%
  x=0.6;
     M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
     M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
     M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
     M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
     P= [M1(r) M2(r); M3(r) M4(r)];
     A21(r)=1/(abs(P(1,1)))^2;
     P2= [M1(r) M2(r); M3(r) M4(r)]^2;
     A22(r)=1/(abs(P2(1,1)))^2;
     P3= [M1(r) M2(r); M3(r) M4(r)]^3;
     A23(r)=1/(abs(P3(1,1)))^2;
     P4= [M1(r) M2(r); M3(r) M4(r)]^4;
     A24(r)=1/(abs(P4(1,1)))^2;
     P10= [M1(r) M2(r); M3(r) M4(r)]^10;
     A210(r)=1/(abs(P10(1,1)))^2;
     P50= [M1(r) M2(r); M3(r) M4(r)]^50;
     A250(r)=1/(abs(P50(1,1)))^2;
     P100= [M1(r) M2(r); M3(r) M4(r)]^100;
     A2100(r)=1/(abs(P100(1,1)))^2;
     P200= [M1(r) M2(r); M3(r) M4(r)]^200;
     A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-14) page 57.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%
d=0.6;
L=3;
h=1;
h1=0.5;
wo=(9.81*L)^.5;
w=[0.09:.01:10.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:993 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%
  for n=1:1000
     A=(w(r))^2/((wo)^2*L*tanh(c*h));
      if abs (A-c) < 0.0001
        break
      else
         c=A;
      end
  end
  k(r)=A;
%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%
  for n=1:1000
     B=(w(r))^2/((wo)^2*L*tanh(c*h1));
      if abs (B-c) < 0.0001
        break
      else
        c=B;
      end
  end
  k1(r)=B;
%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%
 x=0.6;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-15) page 58.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%
d=0.8;
L=4;
h=1;
h1=0.4;
wo=(9.81*L)^.5;
w=[0.1:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:792 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%
  for n=1:1000
     A=(w(r))^2/((wo)^2*L*tanh(c*h));
      if abs (A-c) < 0.0001
        break
      else
         c=A;
      end
  end
  k(r)=A;
%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%
  for n=1:1000
     B=(w(r))^2/((wo)^2*L*tanh(c*h1));
      if abs (B-c) < 0.0001
        break
      else
        c=B;
      end
  end
  k1(r)=B;
%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%
 x=0.8;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-16) page 59.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%
d=0.8;
L=4;
h=1;
h1=0.5;
wo=(9.81*L)^.5;
w=[0.1:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:792 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
  for n=1:1000
     A=(w(r))^2/((wo)^2*L*tanh(c*h));
      if abs (A-c) < 0.0001
        break
      else
         c=A;
      end
  end
  k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%
  for n=1:1000
     B=(w(r))^2/((wo)^2*L*tanh(c*h1));
      if abs (B-c) < 0.0001
        break
      else
        c=B;
      end
  end
  k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%
 x=0.8;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-17) page 59.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%
d=0.8;
L=4;
h=1;
h1=0.8;
wo=(9.81*L)^.5;
w=[0.12:.01:8.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:790 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%%
  for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
          c=A;
       end
  end
  k(r)=A;
%%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%%%
  for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
  end
  k1(r)=B;
%%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%%%
 x=0.8;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-18) page 60.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%%
d=0.2;
L=1;
h=1;
h1=h*0.5;
wo=(9.81*L)^.5;
w=[0.05:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:597 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
          c=A;
       end
   end
   k(r)=A;
%%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
   end
   k1(r)=B;
%%%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%
 x=0.2;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-19) page 61.

```
%%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%
d=0.2;
L=1;
h=2;
h1=h*0.5;
wo=(9.81*L)^.5;
w=[0.03:.01:6.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:599 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
          c=A;
        end
   end
   k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
   end
   k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%%%
 x=0.2;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-20) page 61.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%
d=0.2;
L=1;
h=3;
h1=h*0.5;
wo=(9.81*L)^.5;
w=[0.03:.01:2.51]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:249 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
  for n=1:1000
     A=(w(r))^2/((wo)^2*L*tanh(c*h));
      if abs (A-c) < 0.0001
        break
      else
         c=A;
      end
  end
  k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%
  for n=1:1000
     B=(w(r))^2/((wo)^2*L*tanh(c*h1));
      if abs (B-c) < 0.0001
        break
      else
        c=B;
      end
  end
  k1(r)=B;
%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%
 x=0.2;
    M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
    M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
    M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
    M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
    P= [M1(r) M2(r); M3(r) M4(r)];
    A21(r)=1/(abs(P(1,1)))^2;
    P2= [M1(r) M2(r); M3(r) M4(r)]^2;
    A22(r)=1/(abs(P2(1,1)))^2;
    P3= [M1(r) M2(r); M3(r) M4(r)]^3;
    A23(r)=1/(abs(P3(1,1)))^2;
    P4= [M1(r) M2(r); M3(r) M4(r)]^4;
    A24(r)=1/(abs(P4(1,1)))^2;
    P10= [M1(r) M2(r); M3(r) M4(r)]^10;
    A210(r)=1/(abs(P10(1,1)))^2;
    P50= [M1(r) M2(r); M3(r) M4(r)]^50;
    A250(r)=1/(abs(P50(1,1)))^2;
    P100= [M1(r) M2(r); M3(r) M4(r)]^100;
    A2100(r)=1/(abs(P100(1,1)))^2;
    P200= [M1(r) M2(r); M3(r) M4(r)]^200;
    A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-21) page 62.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%%
d=0.8;
L=4;
h=1;
h1=h*0.5;
wo=(9.81*L)^.5;
w=[0.09:.01:7.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:693 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
        if abs (A-c) < 0.0001
          break
        else
          c=A;
        end
   end
   k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
        if abs (B-c) < 0.0001
          break
        else
          c=B;
        end
   end
   k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%
 x=0.8;
     M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
     M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
     M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
     M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
     P= [M1(r) M2(r); M3(r) M4(r)];
     A21(r)=1/(abs(P(1,1)))^2;
     P2= [M1(r) M2(r); M3(r) M4(r)]^2;
     A22(r)=1/(abs(P2(1,1)))^2;
     P3= [M1(r) M2(r); M3(r) M4(r)]^3;
     A23(r)=1/(abs(P3(1,1)))^2;
     P4= [M1(r) M2(r); M3(r) M4(r)]^4;
     A24(r)=1/(abs(P4(1,1)))^2;
     P10= [M1(r) M2(r); M3(r) M4(r)]^10;
     A210(r)=1/(abs(P10(1,1)))^2;
     P50= [M1(r) M2(r); M3(r) M4(r)]^50;
     A250(r)=1/(abs(P50(1,1)))^2;
     P100= [M1(r) M2(r); M3(r) M4(r)]^100;
     A2100(r)=1/(abs(P100(1,1)))^2;
     P200= [M1(r) M2(r); M3(r) M4(r)]^200;
     A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-22) page 63.

```
 %%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%%
d=0.8;
L=4;
h=2;
h1=h*0.5;
wo=(9.81*L)^.5;
w=[0.07:.01:6.01]*wo;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:595 % dummy counter for frequency
%%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      A=(w(r))^2/((wo)^2*L*tanh(c*h));
       if abs (A-c) < 0.0001
         break
       else
          c=A;
       end
   end
   k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%%
   for n=1:1000
      B=(w(r))^2/((wo)^2*L*tanh(c*h1));
       if abs (B-c) < 0.0001
         break
       else
         c=B;
       end
   end
   k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%
 x=0.8;
     M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
     M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
     M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
     M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
     P= [M1(r) M2(r); M3(r) M4(r)];
     A21(r)=1/(abs(P(1,1)))^2;
     P2= [M1(r) M2(r); M3(r) M4(r)]^2;
     A22(r)=1/(abs(P2(1,1)))^2;
     P3= [M1(r) M2(r); M3(r) M4(r)]^3;
     A23(r)=1/(abs(P3(1,1)))^2;
     P4= [M1(r) M2(r); M3(r) M4(r)]^4;
     A24(r)=1/(abs(P4(1,1)))^2;
     P10= [M1(r) M2(r); M3(r) M4(r)]^10;
     A210(r)=1/(abs(P10(1,1)))^2;
     P50= [M1(r) M2(r); M3(r) M4(r)]^50;
     A250(r)=1/(abs(P50(1,1)))^2;
     P100= [M1(r) M2(r); M3(r) M4(r)]^100;
     A2100(r)=1/(abs(P100(1,1)))^2;
     P200= [M1(r) M2(r); M3(r) M4(r)]^200;
     A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

The following MATLAB program is written to calculate the transmission rate for specific depth, width of rectangular breakwaters, wavelength and number of rectangular breakwater up to 200 for range of angular speed as shown in figure (4-23) page 63.

```
%%%%%%%%%%%%%%% Assumed Numbers   %%%%%%%%%%%%%%%%%%%%%%%%
d=0.8;
L=4;
h=4;
h1=h*0.5;
wo=(9.81*L)^.5;
w=[0.06:.01:4.01]*wo;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
for r=1:396 % dummy counter for frequency
%%%%%%%%%%%%%%% Assumed c= assumed value %%%%%%%%%%%%%%%%%%%%
c=0.5*pi;
%%%%%%%%%%%%%%% Calculating K by Assuming C %%%%%%%%%%%%%%%%%%%
  for n=1:1000
    A=(w(r))^2/((wo)^2*L*tanh(c*h));
     if abs (A-c) < 0.0001
       break
     else
        c=A;
     end
  end
  k(r)=A;
%%%%%%%%%%%%%%% Calculating K1 by Assuming C %%%%%%%%%%%%%%%%%%%
  for n=1:1000
    B=(w(r))^2/((wo)^2*L*tanh(c*h1));
     if abs (B-c) < 0.0001
       break
     else
       c=B;
     end
  end
  k1(r)=B;
%%%%%%%%%%%%%% Calculating Transmission  %%%%%%%%%%%%%%%%%%%%%%
 x=0.8;
   M1(r) = ((k(r)+k1(r))/(2*k(r)))*exp(-i*k(r)*x+i*k1(r)*x) ;
   M2(r) = ((+k(r)-k1(r))/(2*k(r)))*exp(-i*k(r)*x-i*k1(r)*x)  ;
   M3(r) = ((k(r)-k1(r))/(2*k(r)))*exp(i*k(r)*x+i*k1(r)*x) ;
   M4(r) = ((k(r)+k1(r))/(2*k(r)))*exp(i*k(r)*x-i*k1(r)*x)  ;
   P= [M1(r) M2(r); M3(r) M4(r)];
   A21(r)=1/(abs(P(1,1)))^2;
   P2= [M1(r) M2(r); M3(r) M4(r)]^2;
   A22(r)=1/(abs(P2(1,1)))^2;
   P3= [M1(r) M2(r); M3(r) M4(r)]^3;
   A23(r)=1/(abs(P3(1,1)))^2;
   P4= [M1(r) M2(r); M3(r) M4(r)]^4;
   A24(r)=1/(abs(P4(1,1)))^2;
   P10= [M1(r) M2(r); M3(r) M4(r)]^10;
   A210(r)=1/(abs(P10(1,1)))^2;
   P50= [M1(r) M2(r); M3(r) M4(r)]^50;
   A250(r)=1/(abs(P50(1,1)))^2;
   P100= [M1(r) M2(r); M3(r) M4(r)]^100;
   A2100(r)=1/(abs(P100(1,1)))^2;
   P200= [M1(r) M2(r); M3(r) M4(r)]^200;
   A2200(r)=1/(abs(P200(1,1)))^2;
end
W=w/wo;
plot(W,A21,W,A22,W,A23,W,A24,W,A210,W,A250,W,A2100,W,A2200)
xlabel('Angular Speed (rad/s)')
ylabel('Transmission Rate')
```

NOMENCLATURE

a	:	Wave amplitude (m)
C	:	Celerity
E	:	Energy per wave per unit width
g	:	Gravitational acceleration
H	:	Wave height (m)
h	:	Water depth (m)
k	:	Wavenumber
L	:	Wavelength (m)
R	:	Reflection rate
T	:	Wave period (s)
T	:	Transmission rate
t	:	Time (s)
u	:	Velocity in the x-direction (m/s)
v	:	Velocity in the y-direction (m/s)
A_1	:	Amplitude of incident water wave (m)
A_2	:	Amplitude of reflected water wave (m)
B_1	:	Amplitude of transmitted water wave (m)
B_2	:	Amplitude of opasite water wave (m)
k_1	:	Wavenumber in domain one
k_1	:	Wavenumber in domain two
N_I	:	Iribarren Number
P_1	:	Pressure in domain one (psig)
P_2	:	Pressure in domain two (psig)
M_N	:	Transfer matrix
M_n	:	Scattering matrix
R_N	:	Reflection rate over N rectangular breakwaters
T_N	:	Transmission rate over N rectangular breakwaters
ω	:	Angular speed (rad/s)
σ	:	Wave frequency (rad/s)

$\emptyset(x, y, t)$	:	Two Dimensional Velocity Potential (m/s)
ρ	:	Fluid density (kg/m^3)
$\eta(x, t)$	:	Free water surface
φ	:	Water wave equation

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