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Wave Reflection from Corrugated Perforated Beach and Vertical Upright Breakwater

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***Abstract*—The recent developments in the study of hydrodynamic characteristics of various coastal structures are reviewed in this paper. The method to determine the wave reflection coefficient using two fixed probe method is also demonstrated with an example. The physical model studies were conducted in a wave tank to compute the reflection coefficient of corrugated perforated beach and vertical upright breakwater with different heights. Some recent works published are reviewed here with a hope that these works can be beneficial to other researchers working in this area.**

***Keywords*— Wave reflection; reflection coefficient; vertical breakwater; beach reflection; corrugated beach**

I. INTRODUCTION

Various methods were proposed by engineers and scientists to calculate the reflection coefficient from coastal structure. This paper demonstrates the determination of wave reflection coefficient using two fixed wave probe method proposed by Goda and Suzuki (1987) and it was calculated by using Matlab code[1].

II. LITERATURE REVIEW

There are several studies that were carried out to investigate theoretically and experimentally the hydrodynamic performance of these breakwater types.

Geotube technology is mainly used in coastal structures for flood and water control by raising dykes, but they are also used to prevent beach erosion, and for shore protection and environmental applications[2][3]. The first use of geotubes in Ireland was recently undertaken to dewater freshwater DM to form a landfill cap in Dublin. In recent years, the high cost of 'traditional' rubble mound coastal structures, due to the shortage of natural rock, has allowed geotube technology to change from being an alternative construction technique to an option worthy of serious consideration[4].

Young and Firat (2011) conducted Laboratory investigations to conclude the functional dependency of reflection coefficienton dimensionless submergence parameter, D/Hi (D—the breakwater's depth of submergence and Hi—the height of the incident wave at the breakwater). They reported that maximum coefficient of reflection (C_r) value of 0.53 occurs for the dimensionless submergence depth value of zero. The C_r values decrease as the dimensionless submergence depth increases and for dimensionless submergence depth value of 2, the C_r value was 0.06 [5].

The wave transmission, reflection and energy dissipation characteristics of partiallysubmerged 'T'-type breakwaters were studied using physical models [6]. Regular and random waves, with wide ranges of wave heights and periods and a constant water depth were used. Five different depths of immersions of breakwaters were selected. The coefficient of transmission C_t and coefficient reflection C_r were obtained from the measurements and thecoefficient of energy loss, C_l is calculated using the law of conservation of energy.

A. T- type

It is foundthat the coefficient of transmission generally reduces with increased wave steepness andincreased relative water depth, d/L. This breakwater is found to be effective closer to deepwaterconditions. C_t values less than 0.35 is obtained for both normal and high input waveenergy levels, when the horizontal barrier of the T type breakwater is immersed to about 7%of the water depth. This breakwater is also found to be very efficient in dissipating the incidentwave energy to an extent of about 65% (i.e. C_l=0.8), especially for high input wave energylevels. The wave climate in front of the breakwater is also measured and studied[6].

B. ⊥ type

For any incident wave climate (moderate or storm waves), the wave transmission consistentlydecreases and the reflection increases with increased relative depth of immersion, Δ/d from-0.142 to 0.142. C_t values less than 0.3 can be easily obtained for the case of Δ/d=+0.071and 0.142, where Δ is the height of exposure (+ve) or depth of immersion (-ve) of the toptip of the vertical barrier. This breakwater is capable of dissipating wave energy to an extentof 50–80%. The overall performance of this breakwater was found to be better in the randomwave fields than in the regular waves [7].

A comparison of the hydrodynamic performance of'⊥'type and 'T'-type shows that 'T'-type breakwater is better than '⊥'type by about 20–30% under identical conditions

Rao et al. (2009) conducted physical model studies in a monochromatic wave flume to evaluate the wave transmission characteristics of a submerged plate breakwater consisting of a fixed plate of 0.50m length and 0.003 m thickness. The model was oriented at varying inclinations and submergence.

The influence of wave steepness, relative depth, relative submergence and angle of inclination on wave transmission was analysed. It was found that the horizontal plate is effective for short waves with steepness parameter higher than $5x10^{-3}$ in relative depth greater than 0.21.The plate oriented at an angle of inclination of 60^{o} is found to be effective for the entire ranges of wave parameters considered for the study and it reduces the waveheight by about 40% [8].

RueySyan Shih (2012) investigated the interactions and influence between waves and porousperpendicularpipe breakwaterswithdifferentwaveconditionsandvariouscombinationsofdiameterandtubelength. The pipebreakwatersweremodeledwith 12 mm thickplywood and fixedasan80cm x 60cmrigidframeintheflume.Theframes were stuffedwithPVCpipesofvariousdiametersranging from d = 6mmto16mm (d/h =0.024 to 0.064),whilethelengthofthe longitudinalpipesdefinedthewidthofthebreakwaters, i.e. w = 5 cm,10cm,15cmand20cm (w/h = 0.2 to 0.8). The pipes wereplacedparalleltoeachotherwithoutspacing.Pipeswere longitudinallyparalleltothedirectionofincomingwaves,andthe breakwaterwasperpendicular [9].

The results indicate that under identicalpipediameter,performanceisgreatly influenced byincreasedincidentwaveheightsforshorterwaveswhendimensionless frequency,$\sigma^2 h/g > 1.5$, butcomparativelylongwavesseemtohaveless influence when $\sigma^2 h/g < 1.5$. The reflectioncoefficientincreaseswith H_i/gT^2, andtherefore longer pipeismoreefficientinreducingthereflectioncoefficient. Shorter pipelengthsattenuatedshorterwaveswell,butwere unsatisfactory forlongerwaves.Thisresultsalsoimplythatthe transmission coefficientisslightlyaffectedbythelengthofthe pipes when $H_i/gT^2>0.004$ whilethedivergenceislargerwhen $H_i/gT^2<0.004$. Pipe breakwaterreflectionisslightlyaffectedbythediameters, but duetothesimilarityoftheporosityandpermeability,itis almost thesameforallcases.Comparisonsoftransmission coefficients andlosscoefficients,however,implythatminor diameters createhighersubstantiveattenuation.

Lamanto etal. (2014) conducted physical model studies to determine the efficiency of sub-aerial detached rubble mound breakwaters with geotextile filter media (coir fibre mat) below the armour layer as a wave attenuator in three different submergence conditions. The efficiency of the breakwater as a shoreprotection measure was determined based on the percentage ofenergy dissipated by thebreakwater and the change caused in thebeach profile.The rubble mound breakwater with geotextile fibremedia below the armour layer in zero-submerged condition wasfound to be the best of three types of breakwaters tested as itdissipated the maximum amount of wave energy [10][11].

In the present study a resolution technique is employed to determine the reflection coefficient as proposed by Goda and Suzuki (1976)[1].

III. PRINCIPLE OF RESOLUTION TECHNIQUE

Suppose we have a wave-reflection system of regular waves ina wave flume. Waves generated by a wave paddle propagate forward in theflume and are reflected by a test structure. The wave train in thepositive direction is called the incident waves and that in the negativedirection is called the reflected waves(see Fig. 1). Let the amplitude of superposedincident waves be $a_I$and that of reflected waves be a_R. Then these wavesare described to have the general form of

$$\eta_I = a_I \cos(kx - \sigma t + \varepsilon_I)$$
$$\eta_R = a_R \cos(kx - \sigma t + \varepsilon_R) \quad (1)$$

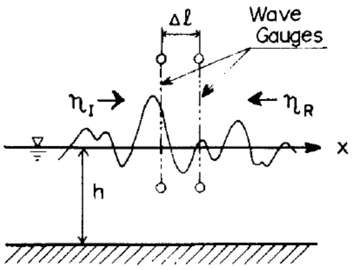

Fig. 1. Definition Sketch

Where,η_I and η_R are the surface elevations of incident and reflected waves, k is the wave number of 2π/L with L being the wavelength, σ is the angular frequency of 2π/T with T being the wave period, and ε_I and ε_R are the phase angles of incident and reflected waves.

Further, we suppose that the surface elevations are recorded at two adjacent stations of x1 and x2=x1+Δl. The observed profiles of composite waves will be

$$\eta_1 = (\eta_I + \eta_R)_{x=x_1} = A_1 \cos \sigma t + B_1 \sin \sigma t$$
$$\eta_2 = (\eta_I + \eta_R)_{x=x_1} = A_2 \cos \sigma t + B_2 \sin \sigma t \quad (2)$$

where,

$$A_1 = a_I \cos \phi_I + a_R \cos \phi_R$$
$$B_1 = a_I \sin \phi_I - a_R \sin \phi_R$$
$$A_2 = a_I \cos(k\Delta l + \phi_I) + a_R \cos(k\Delta l + \phi_R)$$
$$B_2 = a_I \, sin(k\Delta l + \phi_I) - a_R \sin(k\Delta l + \phi_R) \; (3)$$

$$\phi_I = kx_1 + \varepsilon_I$$
$$\phi_R = kx_1 + \varepsilon_R \quad (4)$$

Equation 3 can be solved to yield the estimate of

$$a_I = \frac{1}{2|sink\Delta l|}\sqrt{(A_2 - A_1 cosk\Delta l - B_1 sink\Delta l)^2 + (B_2 + A_1 sink\Delta l - B_1 cosk\Delta l)^2}$$

$$a_R = \frac{1}{2|sink\Delta l\,|}\sqrt{(A_2 - A_1 cosk\Delta l + B_1 sink\Delta l)^2 + (B_2 - A_1 sink\Delta l - B_1 cosk\Delta l)^2} (5)$$

In the calculation, the dispersion relation of the following is presumedto hold:

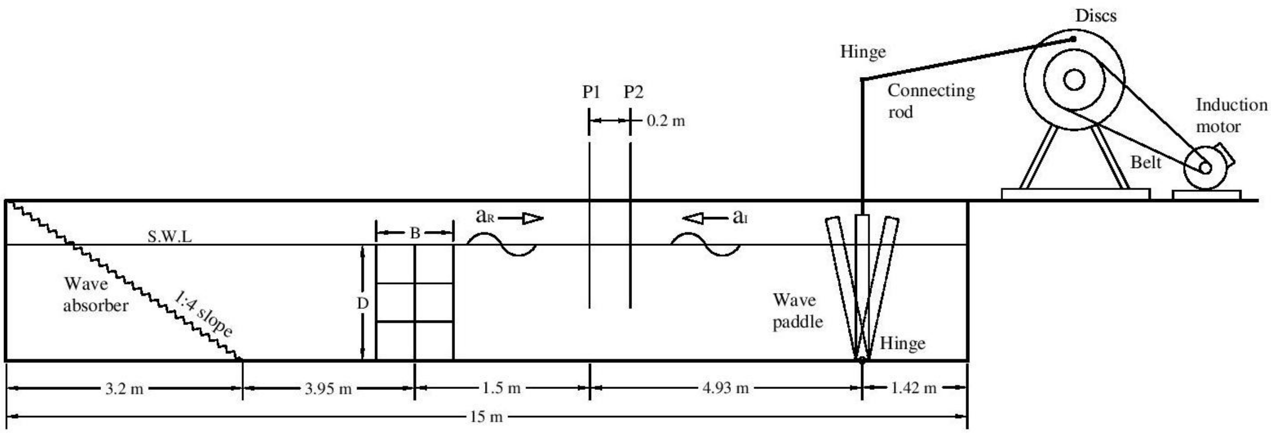

Fig. 2. Schematic representation of position of breakwater, wave absorber and wave probes in the wave tank

$$\sigma^2 = gktanhkh \qquad (6)$$

Actual wave profiles usually contain some higher harmonics. Use ofthe Fourier analysis enables estimation of amplitudes of A_1, B_1, A_2, andB_2 for the fundamental frequency as well as for higher harmonics. The amplitudesof incident and reflected waves, $a_I$and a_R, are then estimated byEq. 5. This is the procedure to be taken for regular wave tests [1].

IV. EXPERIMENTAL SETUP

The physical model studies were conducted in 15 long, 0.8 m deep and 6.75 m wide wave tank of Offshore Structures Laboratory of National Institute of Technology Calicut (NITC), India. A flap type wave generator with maximum stroke distance of 0.38 m is installed at one end of the tank. A corrugated perforated sheet wave absorber with slope 4:1 is installed at the other end of the tank (see Fig. 3). A single eccentric type wave generator was used in the model to simulate waves. The paddle was hinged at the bottom and the top was connected to two eccentric discs by connecting rods. The eccentric discs are connected to a drive shaft. A 230 volt, 3 phase induction motor was coupled to the drive shaft by a helical worm gear drive followed by V- belt driven pulley with 3 grooves. The periods and amplitude of the wave could be varied by proper adjustments on the eccentric discs.

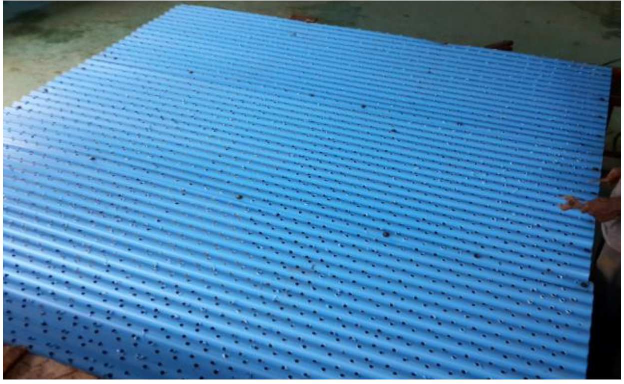

Fig. 3. Beach made of corrugated perforated sheet

The schematic representation of position of breakwater, wave absorber and wave probes in the wave tank are illustrated in Fig. 2. The model was run for 10 seconds and the wave heights were stored in the data acquisition system, which were retrievedlater.

V. MODEL SCALE

Froude scaling technique is adopted for physical modeling, which allows for the correct reproduction of gravitational and fluid inertial forces. A scale if 1:25 is chosen for the present study.

VI. MODEL DETAILS

The submerged breakwater is installed at the middlebetween the seawall and the wave generator. It consists of plainconcrete cube units with dimensions of 0.15 m × 0.15 m × 0.15 m.The tested breakwater heights (D) and widths (B) are D = 0.3 and0.45 m and B = 0.3m. The details of the tested models andexperimental setup ranges are shown in Fig. 2

VII. INSTRUMENTATION

The surface elevation was measured using a capacitive type wave probe. In this probe the sensing element changes the amount of capacitance as the water rises or lowers at the probe, thus causing a change in voltage output. The sensing element was a co-axial capacitor. It consists of an insulated (Teflon coated) metal (stainless steel) rod about 1.6 mm.The probe is connected to wave monitor modulein the electronic console by a twin core flexible cable. The wavemonitor module is provided the output signals in form of voltagedata.

VIII. DATA ACQUISITION

A 12-bit A/D converter is used for converting analog signals datacollected by the wave gauge to digital voltage data. These data arecollected by the personal computer. These data are converted tothe wave elevation by simple computer program, and then thevariation of water surface with time is drawn.

IX. ESTIMATE OF INCIDENT AND REFLECTED WAVE HEIGHTS

The resolution technique was applied to the regular waves. Trains of waves were generated in a wave tank. The wave absorber in the flume was built with corrugated perforated sheet in the slope of 4 to 1. Wave period of 1.1 sec was employed and the mean wave heights was 4.58 cm, respectively, at the water depth of 44 cm. The spacing between two wave probes (P1 and P2) was 20 cm, and continuous wave records of 10 seconds long were takenat the sampling period of At = 1/60 sec. The reflection coefficient (C_r) was calculated using the Matlab code.

X. CONCLUSION

Physical model studies were conducted to determine the reflection coefficient of perforated corrugated beach of slope 1:4 and vertical upright breakwaters of height 30cm and 45cm. The reflection coefficient obtained were 0.31 for 30 cm breakwater, 0.58 for 45 cm breakwater and for the beach, it was 0.19.

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