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A STUDY OF HYDRAULIC WAVE BREAKERS

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Abstract— Breaking of waves occurs on beaches and this result in erosion of beach which leads to long term littoral drift and a serious impact on coastline. Coastal structures designed for this purpose are usually quite massive and expensive to build. In the present study a special type of wave breaker known as hydraulic wave breaker was used to break waves so that wave dissipate the energy. A Hydraulic or Water-jet Wave breaker is formed by- forcing water through a series of nozzles mounted on a manifold pipe. The primary objective was to measure wave attenuation. It was found that waves with shorter wave lengths are easy to break; as anticipated the attenuation decreased for increase in water depth; Steep waves were easy to break; the manifold is placed in two different directions; one is placing on the bed and other placing opposite to incident wave on the surface level and the latter has more transmission. The average K_T value observed for all such set of experiments when manifold placed bottom was found to be 0.423 i.e. the average breaking of waves was found to be 57.69 %. But when jet placed in opposite direction the average value of K_T was found to be 0.309 i.e. the average breaking of waves is found to 69.14%. The increase in the percentage of breaking for the jet placed in opposite direction with respect to jet placed bottom is found to be 19.84 %.

Keywords— Littoral drift, Coastal, Hydraulic or Water-jet Wave breaker, manifold, nozzles, attenuation.

I. INTRODUCTION

The pneumatic breakwater was conceived about 50 years ago as a device which would attenuate ocean waves by a curtain of air rather than by reflection or absorption of energy by the massive structures customarily used. It consists of a perforated pipe, usually on the harbor floor, through which compressed air is forced. As the air bubbles rise they impart a drag to adjacent water particles resulting in an upward motion of the air-water mixture. When this mixture reaches the surface; the air escapes while the flow of water branches into two horizontal currents. While the turbulence induced by this system produces some attenuation of the waves, it is usually considered that one of the horizontal currents, opposing the incoming wave, results in breaking of the wave and consequent turbulent diffusion of the incident wave energy. For best results the axis of the perforated pipe should be normal to the direction of wave advance.

In the present study a special type of wave breaker known as hydraulic wave breaker was used to break waves so that wave dissipate the energy. A **Hydraulic** or **Water-jet Wave breaker** is formed by- forcing water through a series of nozzles mounted on a manifold (Fig.1) pipe which is installed perpendicular to the direction of the incident waves. The jets create a surface current which results in breaking of the incident wave. Apparently, this effect is primarily responsible for attenuation of the incident wave. An earlier development, the pneumatic breakwater, operates on a similar principle with a horizontal surface current induced by rising air bubbles. It was found that the pneumatic breakwater generates two surface currents. One opposes the incident waves, and the second or leeward current has no appreciable detrimental effect on the waves with the result that about half of the energy supplied to the system is wasted. This suggested the possibility of utilizing horizontal water jets in which all of the surface current could be directed against the incident wave.

Fig.1 Two different views showing the pipe manifold mounted with nozzles

II. EXPERIMENTAL INVESTIGATIONS

A. Experimental Facilities

1) Wave Flume: The present study was carried out in a 30m long, 1.2m wide and 1.2m deep wave flume in the Department of Civil Engineering, Andhra University College of Engineering, Visakhapatnam, Andhra Pradesh, India. The wave flume is made of concrete wall on one side and glass wall on the other side. The wave flume was shown in Fig.2. The flume is capable of generating regular waves of different amplitudes and frequencies. One end of the flume is fitted with wave maker. The experiment was carried for two water depths 0.47m and 0.61m. Experiments were conducted by generating two different wave heights i.e. (100and 150 mm) and four different time periods i.e. (1.5, 2.0, 2.5 and 3.0 s). The pipe manifold was kept at a distance of 13.50m from the wave generator. A pump of capacity 5 H.P is used to pump the flow from sump provided beside the wave flume into the manifold and the jets provided to the manifold will hit the upcoming incident wave and break the wave. The Experimental setup is shown in Fig.3

Fig.2 Wave Flume at Coastal laboratory, Andhra University, Visakhapatnam.

2) Water Pump: A 5 H.P Water Pump is installed to pump the water from the sump beside the wave flume into the pipe manifold as shown in Fig.4. Discharge capacities are tabulated in Table. I

Table. I Discharge calculations of the pump

S. No	**Valve Opening**	**Area of sump (m^2)**	**Fall in level of sump (cm)**	**Time taken (s)**	**Discharge(Q) (Lps)**
1	Full	20.09	10	140	14.35
2	¾	20.09	10	147	13.66
3	½	20.09	10	162	12.40
4	¼	20.09	10	190	10.57

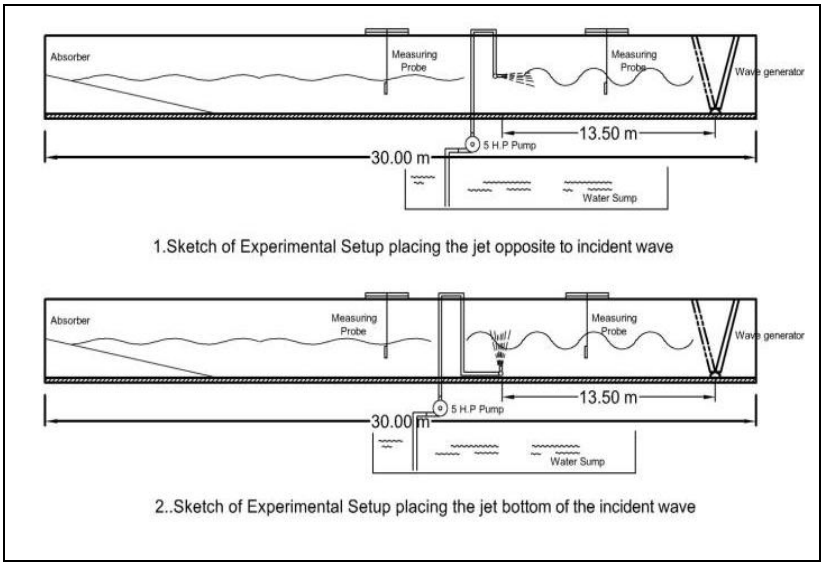

Fig.3 Schematic diagram of the experimental setup

Fig.4 Pump and manifold installed wave flume.

3) Pipe Manifold: A pipe manifold is fabricated for present study of length 1.20m and with diameter of 2'' used for forcing water jets through the ½'' nozzles mounted on the manifold. The pipe manifold was placed at 14m from wave maker and two different directions; bottom of the bed and on the still water level opposite to the incident waves.

4) Wave Maker: Most modern tanks use one of two types of scientific Wave maker: flap or piston. The Wave Flume in our present study is fitted with servo-computer controlled piston type wave maker (Fig.5a) and can generate periodic waves of required amplitude and frequency. The wave maker is at one end of the wave flume, and at the other end is a wave absorber (a beach or special wave absorbing constructions). The wave maker used for the present study can generate waves of different amplitudes and time periods. To give input data a computer is used as shown in Fig 5b. An inbuilt program is developed to open the window as shown in Fig 5c. The desired input data such as amplitude and time period can be given in the window.

(a)servo-computer controlled piston (b) Wave generating Computer (c) Wave Input Interface

Fig.5 Wave Maker and its components

5) Wave Probe: A simple and robust instrument for the measurement and recording of water waves in hydraulic models and ship tanks, which works on the principle of measuring the electrical conductivity between two parallel wires. The wave probe is a conductive type and consists of two concentric stainless steel electrodes separated by Teflon windings. Electrodes measure the conductivity of the instantaneous water volume when it is immersed. The conductivity is proportional to the variation in the water surface elevation. A set of compensation electrodes mounted at the bottom end of wave gauge to balance the influence of temperature or salinity changes in the water. Two wave probes used in the present work to measure the incident wave height and wave transmitted wave height. Fig.6 shows wave probe with wave meter.

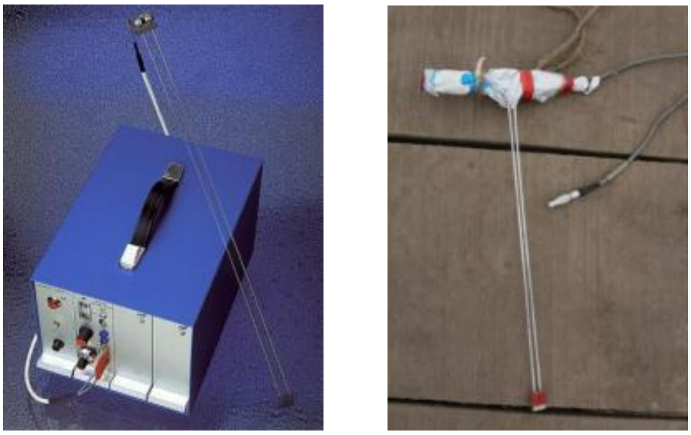

Fig.6 Wave Probe with Wave meter

7) Wave Meter: A wave meter is a simple electronic instrument used to measure the frequency of waves. It consists of an adjustable resonant circuit calibrated in frequency, with a meter or other means to measure the voltage or current in the circuit. The wave probes are connected to the wave meter. Wave probe connected to the wave meter is shown in Fig.7.
*8) Digital Storage Oscilloscope (DSO):*A digital storage oscilloscope (often abbreviated DSO) is an oscilloscope which stores and analyses the signal digitally rather than using analog techniques. The input analogue signal is sampled and then converted into a digital record of the amplitude of the signal at each sample time. The input signal from the wave meter is visualized in the DSO. These both are connected by BNC cable. Fig.7 shows DSO with Wave meters.

Fig.7 Digital storage oscilloscope with wave meter

The wave forms displayed in the DSO are saved and later analyzed in the excel sheets. The incident and transmitted data is obtained in volts. This is later analyzed by converting the data into a graph as shown in Fig.8

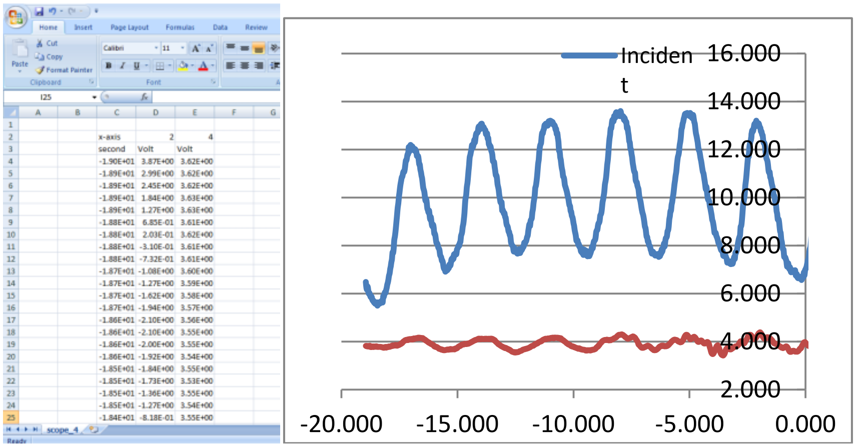

Fig.8 Analyzed data using Excel

III. Results And Discussions

A. General

The major part of the program involved two-dimensional flume tests with a single manifold. The primary objective was the procurement of information concerning the effect of wave attenuation, which is measured as transmission coefficient $K_T = H_T/H_I$ (H_I = incident wave height and H_T = transmitted wave height). Parameters which were varied include the wave length L, the wave height H, jet area *a*, and jet discharge *q*. The discharges required under various test conditions were expressed in the form of dimensionless ratio as follows:

$$q = \frac{Discharge\ per\ lineal\ metre\ of\ breakwater}{L\sqrt{gd}} \qquad (1)$$

Where "*q*" is the dimensionless discharge ratio, *g* is is the acceleration due to gravity in m/s^2 and *d* is the water depth.

B. Experimental Results

The data indicated that the discharge requirements of a hydraulic breakwater are primarily dependent upon wave length, water depth, wave steepness, submergence of the nozzles, number (or area) of nozzles. A total of 128 sets of experiments were carried out.

1)Effect of Wave Length (L): The experiments were conducted for four different wave lengths L= 3.51, 6.24, 9.75 and 14.04m. The results were plotted against non-dimensional coefficient (d/L) and transmission coefficient (K_T). It was found that as d/L increases K_T is decreases which implies that waves with shorter wave lengths are easy to break. This may be due to the reason for higher wave lengths; by the time the jet hitting the wave the wave has already travelled forward and escaped from the impact of jets. The summary of curves showing the relationship between d/L and K_T for different discharges are shown below.

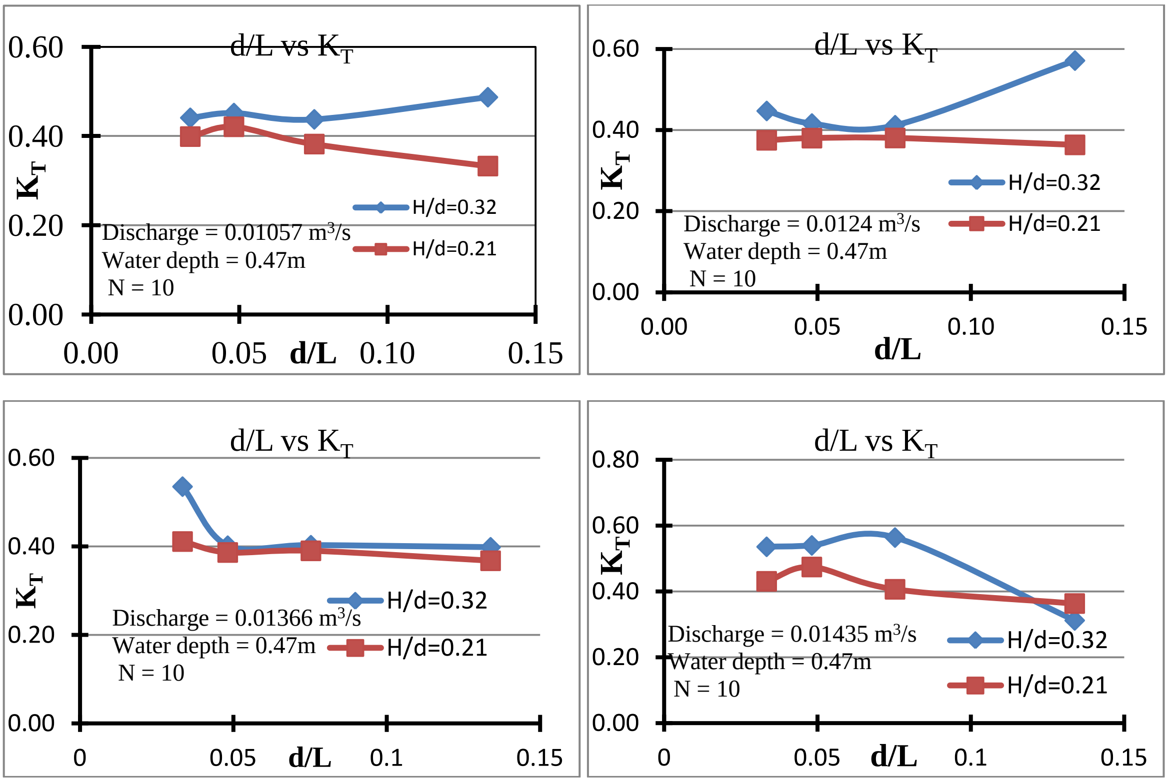

Fig.9 Variation of transmission coefficient K_T with relative water depth (d/L) for different wave heights and discharges.

2) Effect of Water Depth (d): The experiments were conducted for two different water depths 0.47m and 0.61m. As anticipated the attenuation decreased for increase in water depth. This is because as depth of water increases the distance travelled by the water from the jets increases and also hydrostatic force (γH) which is opposing the jet increases with increase in depth. For same discharge the transmission coefficient has been increased for greater depth as shown in the summary curves below.

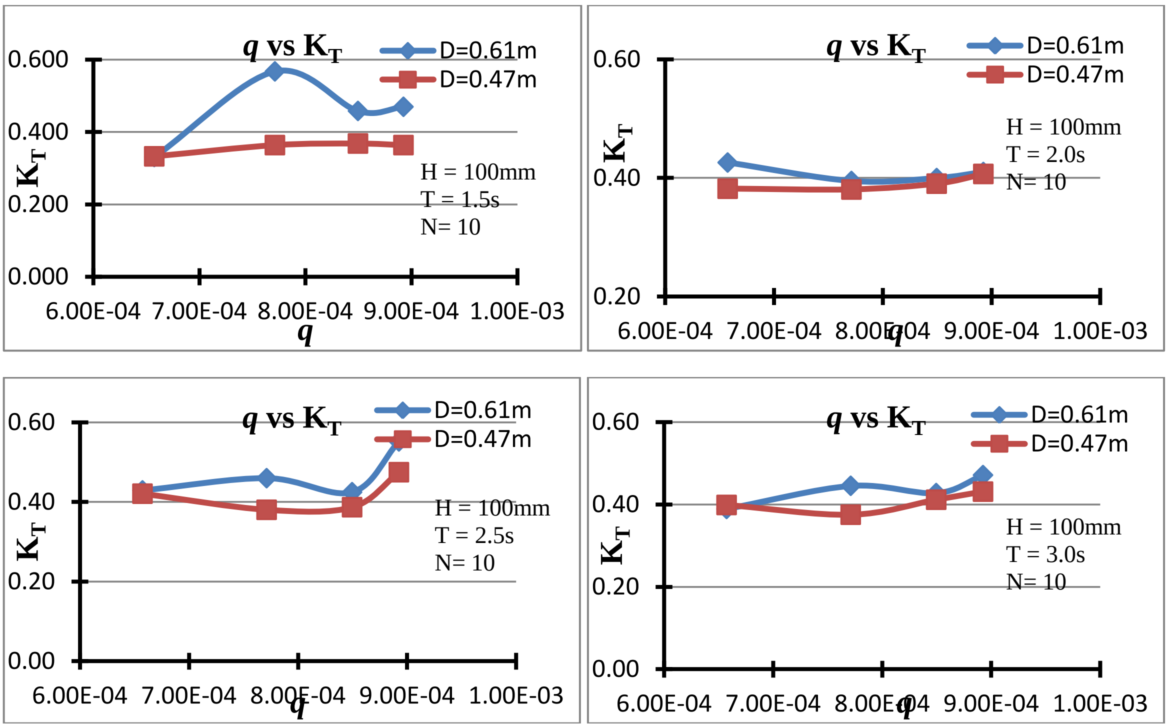

Fig.10 Variation of transmission coefficient K_T with discharge coefficient q for two depths

3) Effect of Wave Steepness (H/L): Wave steepness is the ratio between wave height (H) and wavelength (L) of a wave. To study the effect of wave steepness on attenuation of wave; a plot between *q* and K_T for different wave steepness have been plotted. The tests were done for two different wave heights 100 and 150mm. It was found that steep waves are easy to break because waves with increasing wave height and decreasing wavelength are usually unstable. The summary of curves showing effect of wave steepness is shown below.

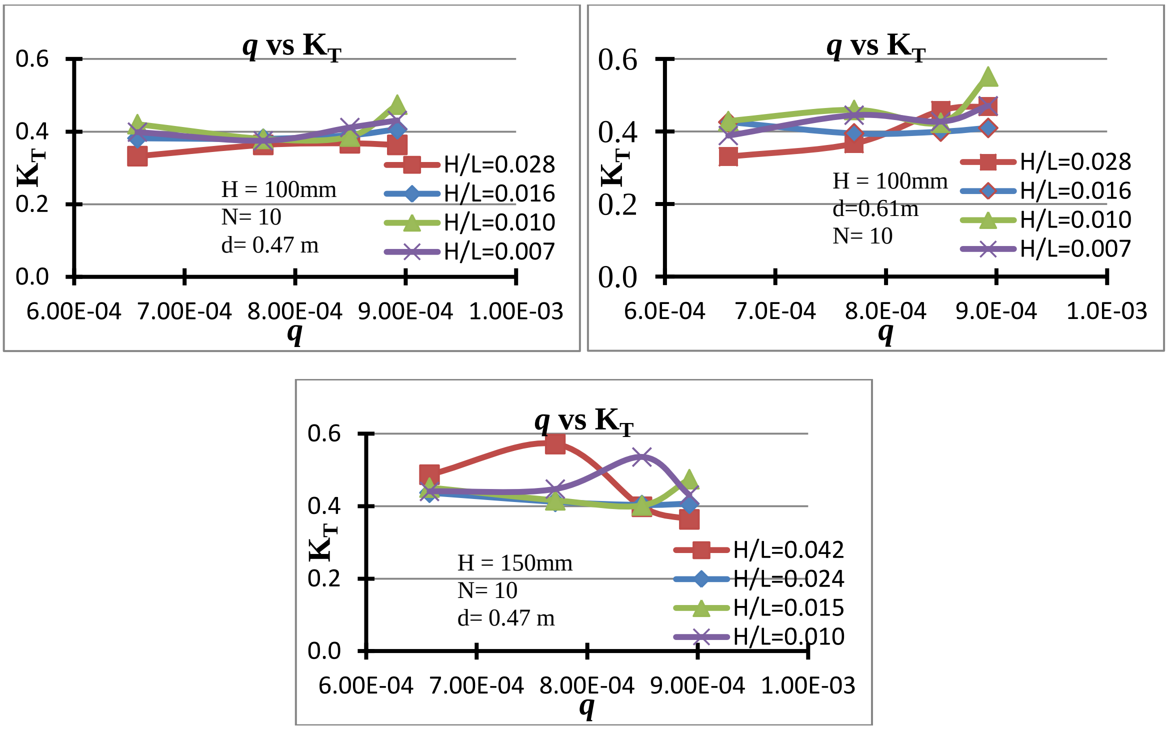

Fig.11 Variation of K_T with q showing the effect of wave steepness

4) Effect of Jet Direction: The manifold is placed in two different directions; one is placing on the bed and other placing opposite to incident wave on the surface level (Still Water Level). A drastic change has been noticed in the attenuation. The manifold faced opposite to incident waves has a great transmission when compared to manifold placed bottom of the bed. This is because when manifold is placed bottom; two currents are produced and are transferred towards both incident and transmitted sides. Due to this half of energy is being wasted. Whereas manifold placed in opposite direction does not experience such problem. The curves plotted against discharge coefficient and transmission coefficient shows the effect of jet direction.

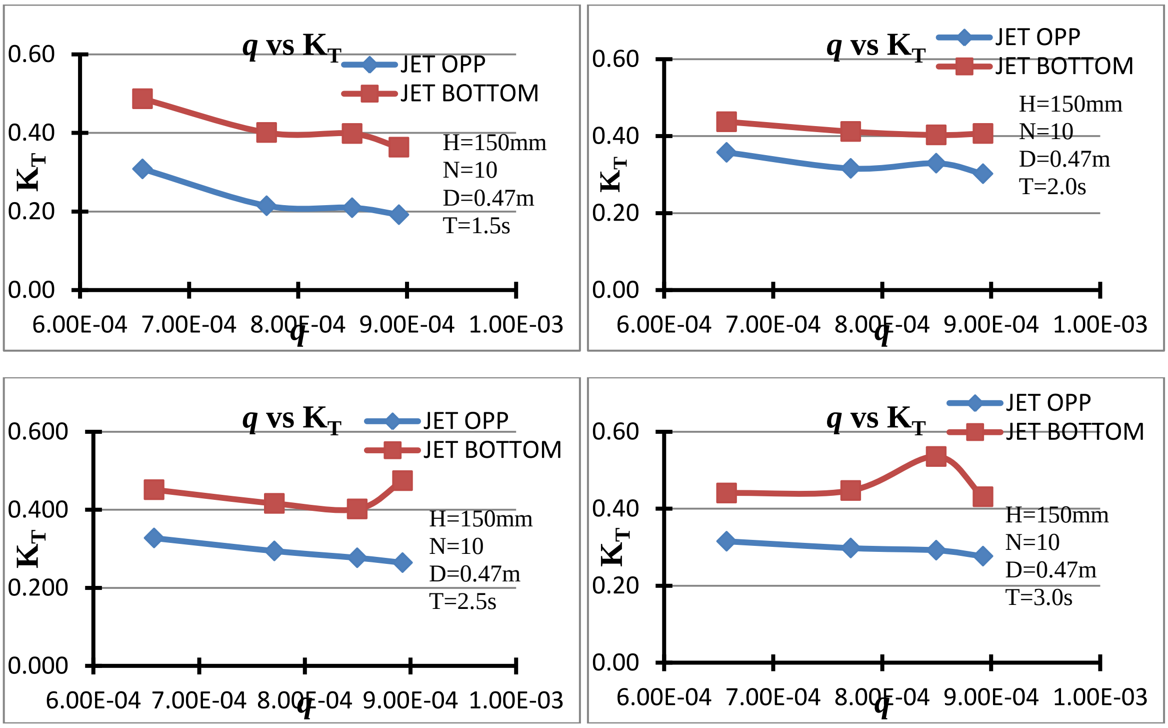

Fig.12 Variation of K_T with q showing the effect of jet direction

To know the clear effect of change of jet direction a plot between *q* and K_T for various conditions like changing wave height and time period (Fig.13). The average K_T value observed for all such set of experiments found is 0.423 i.e. the average breaking of waves is found to be 57.69 %.
Similarly a plot between q and K_T for various conditions is plotted when the jet direction is placed in opposite direction.(Fig.14). The average value of K_T was found to be 0.309 i.e. the average breaking of waves is found to 69.14% The increase in the percentage of breaking for the jet placed in opposite direction with respect to jet placed bottom is found to be 19.84 %.

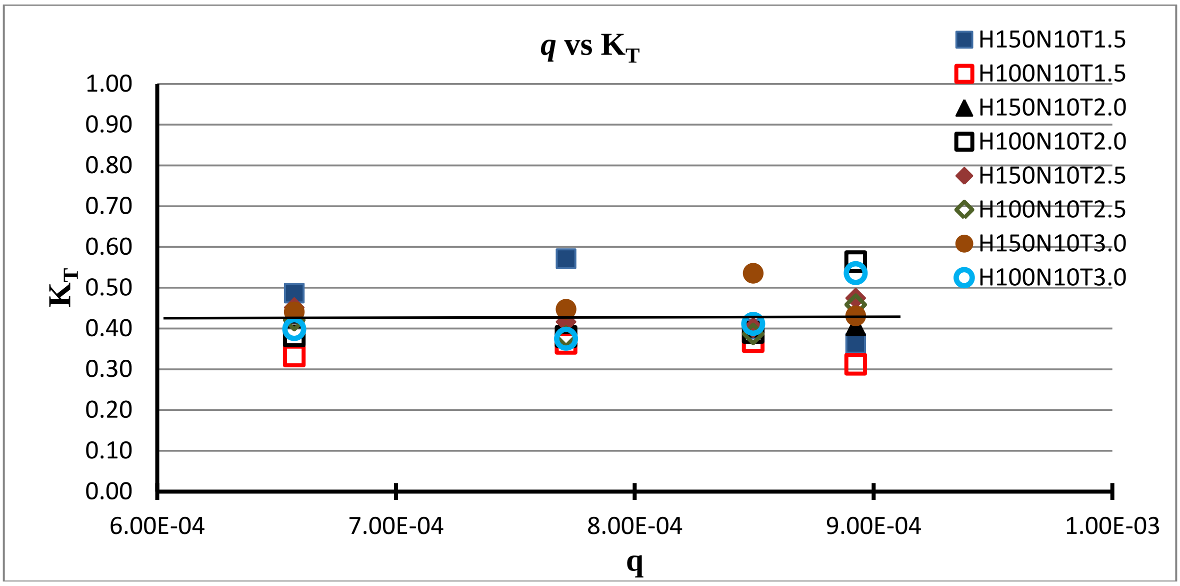

Fig.13 Variation of K_T with q for different conditions when jet placed bottom

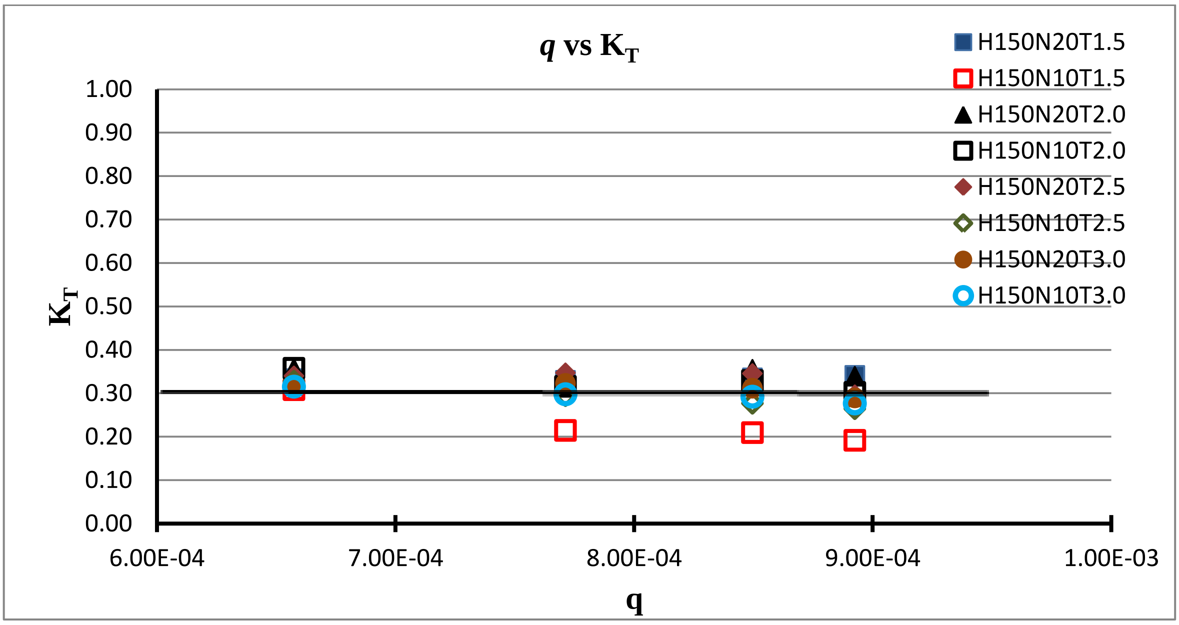

Fig.14 Variation of K_T with q for different conditions when jet placed in opposite direction.

5) Effect of Number of Nozzles (N): The manifold was mounted with 1/2 inch (1.27 cm) nozzles twenty in number. To study the effect of jet area the tests were conducted for 10 and 20 number of opening of jets. As the jet area increases i.e. number of openings increases the jet pressure (or) velocity of jets decreases and there by effect of these jets decreases on wave attenuation. The same thing has been observed from the test results. The summary of curves showing the effect of jet area (or) number of nozzles opening for jet placed in opposite direction is shown below.

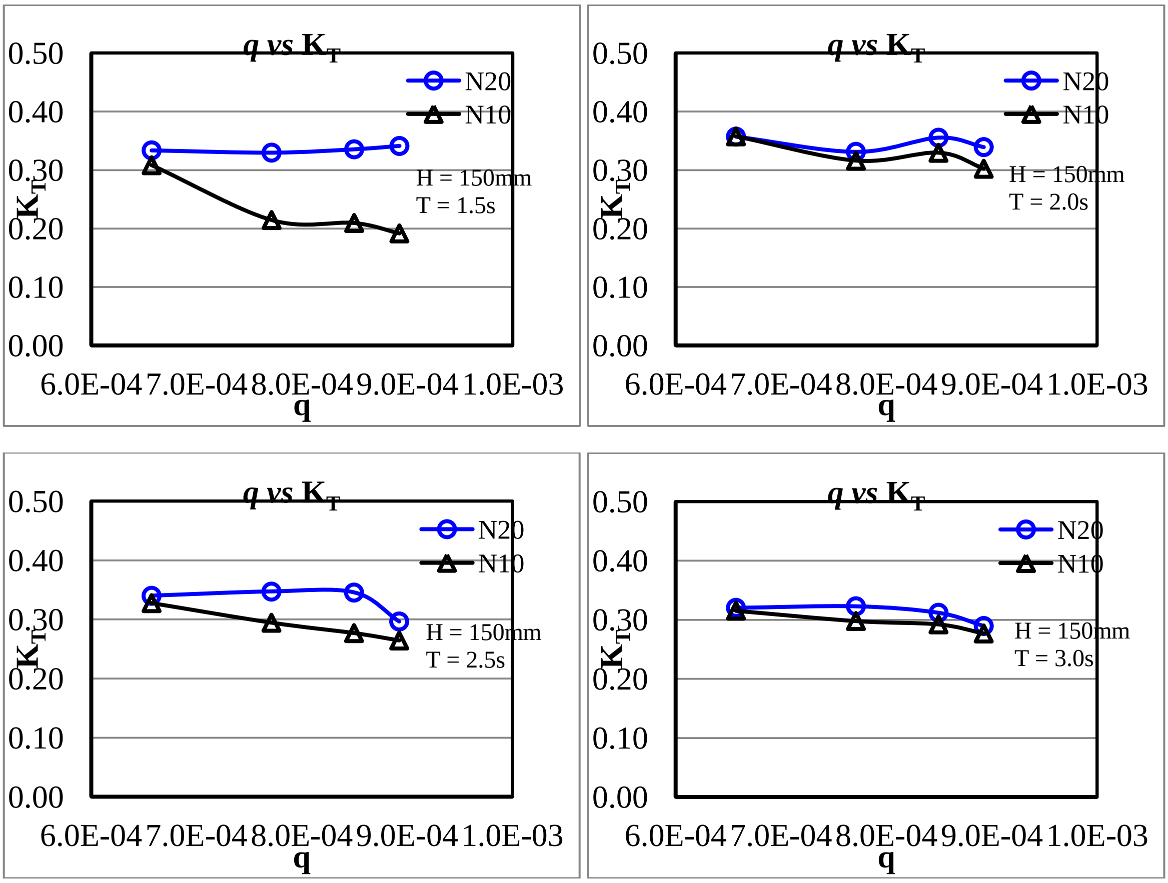

Fig.15 Variation of K_T with q showing effect of nozzles

6) Summary of Results: The idea of wave breaking thus by reducing the wave transmission was carried out experimentally. Wave breaking with hydraulic jets at free surface (SWL) and at the bottom of the bed was carried out 2D wave flume. By comparing the results of a pneumatic wave breaker from the reference [17] and present study results it was found that the air discharge required for 60% breaking of wave with wavelength 3.35m is 0.045m^3/s. whereas the hydraulic jets were able to break the wave by 60% for a wavelength 3.51m at a discharge of 0.0136 m^3/s. This shows that hydraulic jets placed bottom is very much efficient than pneumatic wave breakers.

But when jet is placed at bottom, for all varieties of conditions like changing discharge, number of nozzles, water depth and wave heights. More or less the breaking of waves for all these conditions was in the same range. The primary reason being there is not much difference in the four discharge conditions. But still there should be change observed for all such varieties of conditions. But this didn’t happen because maybe when the manifold placed bottom there are two currents produced are being travelled towards both incident and transmitted side. Due to this half of the system is being wasted and also an appreciable change has not been observed for all different conditions. But for jet placed in opposite direction the results were in agreement with the general theory.

One more advantage of jet placing on the surface and in opposite direction is; it is independent of depth. So the results obtained when jet placed in opposite direction can be compared with results of jet placed bottom for various depths and also found that breaking is more when compared with them.

IV. Conclusions

1. Discharge requirements for the hydraulic breakwater are dependent upon wave characteristics such as length, height, and water depth, and breakwater characteristics such as submergence of nozzles, number of nozzles and jet direction.
2. When jet is placed at bottom, the breaking of waves for all the conditions was in the same range. The primary reason being there is not much difference in the four discharge conditions. But still there should be change observed for all such varieties of conditions. But this didn’t happen because maybe when the manifold placed bottom there are two currents produced are being travelled towards both incident and transmitted side. Due to this half of the system is being wasted and also an appreciable change has not been observed for all different conditions.
3. For jet placed in opposite direction the results were in agreement with the general theory.
4. The advantage of jet placing on the surface and in opposite direction is; it is independent of depth and also found that breaking is more when compared with other way of placing the manifold.
5. The average K_T value observed when jet placed bottom for all set of experiments found is 0.423 i.e. the average breaking of waves is found to be 57.69 %. The average value of K_T when jet placed on still water level and in opposite direction to the incident wave was found to be 0.309 i.e. the average breaking of waves is found to 69.14%. The increase in the percentage of breaking for the jet placed in opposite direction with respect to jet placed bottom is found to be 19.84 %.

6. Installation of the pneumatic manifold on the harbor floor (for shore installations) would be easier and less subject to wave damage than a hydraulic manifold at or near the water surface. On the other hand, silt and sand may present some problems with a bottom installation.

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