FLOATING WAVE BREAKER

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Abstract - *This project is an experimental study of the performance of a floating breakwater with and without barriers at its bottom portion. Unlike other floating breakwater system, Floating wave breaker deals with the underwater current speed reduction as well. Basically what we see on the ocean surface is an up and down motion or a to and fro motion that is caused by the wind energy. Studies proven that the effect of a wave is critical up to half the depth of the area. So breaking just the surface energy will not be a adequate criteria for floating breakwaters. The two layer provided in floating wave breaker will also helps to reduce the wave energy at bottom. The top portion will be a pontoon type floating breakwater and below it, their will be geogrid cages. Bottom layer cages is filled with air tight plastic bottles. When the wave strikes, wave energy on the top portion will be reduced by the pontoon and Subsurface energy below it will be reduced while passing through the geogrid cages filled with plastic bottles. Thus a combination of floating as well as perforated type of breakwater are created. The amount of buoyant force required to keep the structure floating is not independently depends on the pontoon, air tight plastic bottles also contributes to the buoyancy requirement. So it can provide a safer wave generation at the coastal regions.*

Key Words: **Floating breakwaters, Floating wave breaker, Reduction, Geogrid cages, Bottles, Pontoon, subsurface energy**

1. INTRODUCTION

Floating breakwater like Drum type floating breakwater ,Box type floating breakwater etc are mostly used only in mild environmental conditions such as boundary markings, in the entrance of harbours and so on and to break only the surface energy, but if we are able to break subsurface energy to, its efficiency will be improved and can be used in aggressive sea conditions also and it can also provide a safer wave generation at the coastal regions. This setup does not affect the ecosystem of coastal area since there is least contact with the sea bed. The project is sustainable as the major components are reused plastic bottles. Conventional types of Submerged breakwaters can break the waves but can cause damage to natural ecosystems of sea since most of them have large contact with sea bed. Studies have also proven that on shore breakwaters won't encourage the further deposition of sand on the shore. In principle, the floating breakwaters are the most suitable ones, as the submerged ones resting over the sea bottom are limited to a few meters in heigth to make it economical. Another main advantage of the project is that we can easily control the amount of energy to be broken by fixing up the number of geogrid cages at the bottom portion of floating concrete pontoon. This design is sustainable as the major components are reused plastic bottles and thus an effective plastic waste management with proper maintenance.

Chen and Zou studied the presence of subsurface wave energy and proven that the effect of the energy will be critical up to half the depth of the area .According to that it is very much important in the design procedures of a floating breakwater[1].

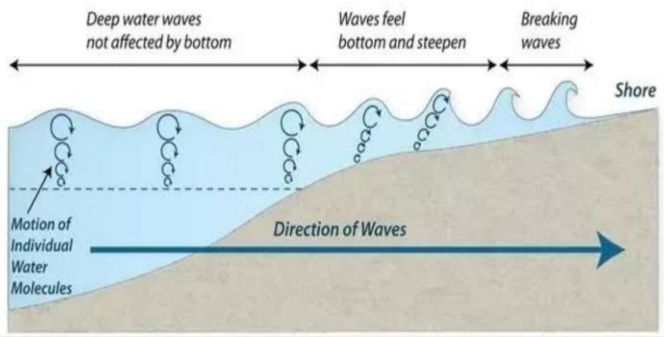

Fig-1 Presence of subsurface energy

2. PARAMETERS USED IN EXPERIMENTATION

Lafon and Younes studied the different parameters used to prove the efficiency of new designs of floating breakwaters and are mentioned below[2]:

2.1 Wave Energy

The initializing disturbance forces acting on a body in water transfer energy to the resultant wave. **Nicholas and Kraus** studied that the energy is reduced due to effects of friction and viscosity in the fluid as the wave propagates from the origin. Additional disturbance forces acting on a wave during the duration of propagation compounds with the initial force, can either results in increasing or decreasing the total energy in a wave the total energy in a wave is the primary factor which influences the consequential wave height, the equation to calculate wave energy using wave height is given below[3].

$$E = \frac{1}{8} * \rho g H^2 \quad \{1\}$$

where, E - energy per unit surface area of a wave ρ - water density g- gravity H - wave height.

The wave energy of a propagating wave is only reduced as a result of the interaction if wave with an object, eg. A coastline or change in underwater bathymetry, or a fluid of a different density etc.

2. Wave Motion and Sediment Transport

Leo and Rijin studied that Wave energy dissipation on a shoreline can creates a shear force on the sediment and which when give enough results in particle suspension and redistribution corresponding to the horizontally driven, cross-shore orbital motion in shallow waterWater motion in shallow water creates shear stress on the bottom sediments, which when high enough will suspend the sediment particles. In a perfect system, the net amount of sediment remains the same; however, due to the currents and irregular waves and forces, sediment accretion or erosion occurs[4].

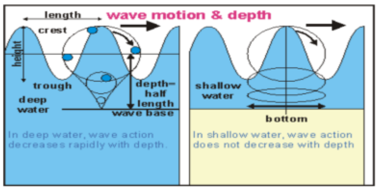

Fig -2 Difference of wave motion according to depth

2.3 Transmission coefficient

Van et al. from his study, the transmission coefficient quantifies the breakwater efficiency, that is representing the ratio between the transmitted wave height and incident wave height[5],

$$C_t = \frac{H_t}{H_i} \quad \{2\}$$

Where C_t =the non-dimensionalized transmission coefficient H_i= the incident wave height H_t=the transmitted wave height.

The transmission coefficient allows for a comparison of the effectiveness between different breakwater designs by evaluating how well each FB design reduces the incident wave height[2]

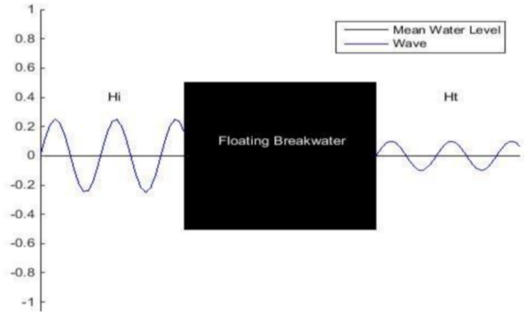

Fig-3 Common testing mechanism

2.4 Wave length

Generally waves that appear on the oceans are similar to sin waves with crests and troughs. Wave length can be simply defined as the distance between two consecutive crests or troughs.

2.5 Wave period

It can be defined as the time taken by two consecutive crests or troughs to pass a fixed point. It can be expressed in seconds and notated by T_S.

2.6 Bathymetry

The term bathymetry originally referred to the ocean's depth relative to sea level ,although it has come to mean "submarine topography", or the depths and shapes of underwater terrains. In the same way topographic maps represents three dimensional features on the land, bathymetric data represents land that lies underwater.

2.7 Mooring Force

Floating breakwaters are always moored in order to fix the breakwater in position. Thus the force experienced in each mooring system is called mooring force. **Ferreras et al.** provides the relationship between mooring force and efficiency in floating breakwaters .According to it if mooring force increases, amount of energy reduction will be high. It can be obtained using following equation[6].

$$M = \frac{1}{\sqrt{1 + \left[kw \frac{\sinh kh}{2\cosh(kh_1 - kh_2)} \right]^2}} \quad \{3\}$$

Where,
M- Mooring force in Newton k- Wave number

h-water depth
h_1-Incident wave height
h_2- Transmitted wave height

3. PROPOSED DESIGN

In order to study the performance of the new design , the model will be constructed as a design which can be assembled. That is the pontoon on the top and geogrid cage with plastic bottles will be separate pieces. The mooring line will be cross moored in its equilibrium position as shown below. Mooring line will be stainless steel. Instruments are available in the flume tank to measure the wave height after and before coinciding the wave breaker. Top pontoon will be made by steel in case of testing model .Bottom cages will be filled up with 5 ml plastic bottles. Depth up to the wave energy is to be broken depends up on the type of wave required in the shore. More number of cages and depth required if mild condition is needed in the shore and vice versa.

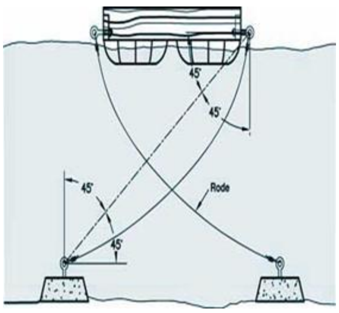

Fig -4 Cross anchorage system

3.1 Configuration Design of Floating Wave Breaker

The structure of floating wave breaker consists of two parts a main body of rigid breakwater floating on top and a geogrid cage containing a number of freely positioned perfectly airtight plastic bottles that are intended to reduce the wave energy. The rectangular concrete pontoons structure on top will considerably breaks the wave on the surface. The water reaching on the outer will have considerably lesser energy as shown in the figure.

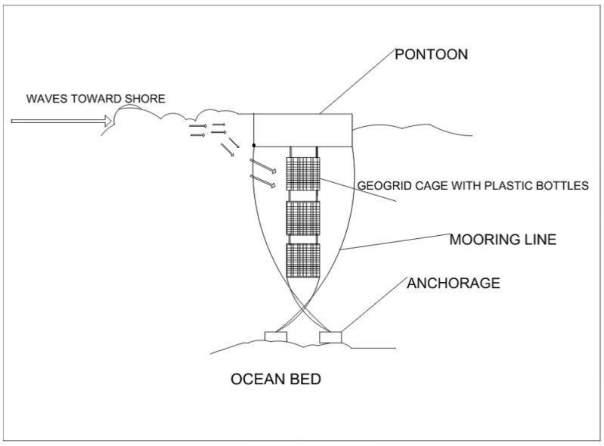

Fig-5 Design of Floating wave breaker

3.2 Experimental Facilities and Instruments

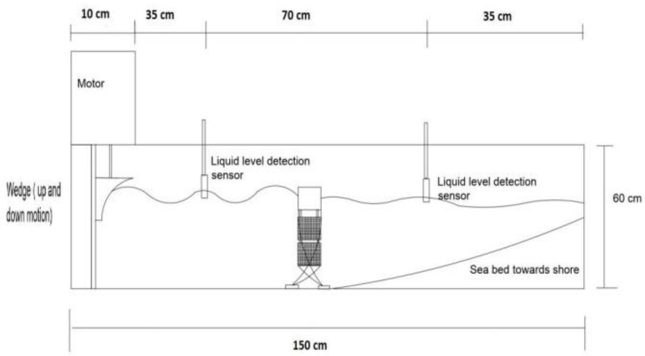

Fig-6 Wave tank

The experiments were conducted in two dimensional wave flume tank of size 1.5 m X 0.5 m x 0.6 m as shown below. A wedge shaped portion having 0.40 m length and 0.2 m height connected by a motor creates an up and down motion. Continuous pushing into the water makes desired wave condition that stimulates the similar sea conditions. Two water level sensors which will be attached before and after the floating wave breaker records the readings and get transferred into numerical values and displayed in computer using Audrino software.

3.3 Model Scale

Pereira et al. provides the information's such as the dimension to be used for the perforated type of floating breakwaters and the adopted dimensions are as follows[8]

i-Floating pontoon with 0.45 m x 0.15 m x 0.1 m. ii-Geogrid cage with 0.11 m x 0.11 m x 0.11 m . iii-Mooring chains with stainless steel of 0.6 m.

Fig-7 Floating pontoon and geogrid cage

3.4 Experimental models

Experiment 1 will be conducted with the pontoon only which resembles the present design. Experiment 2 will be conducted with pontoon attached with the cage at its bottom up to one layer and Experiment 3 with two layers. The mooring line will be cross moored in its equilibrium position.. To measure the wave strength reduction, there will be two water level sensors at preferred distance as required [7].

3.5 Experiment conditions

For regular waves of 20 meter height with model 2.5 meter to 4 meter height, the wave period is 4.02 seconds to 6.26 seconds. For our model with 0.45m x 0.15 m x 0.21 m(including pontoon and cage) will have wave period of 0.15 to 0.4 seconds and 0.05 to 0.1 meter height. Several wave heights will be adopted and inserted in the test equipment using the RPM controllable motor by using L239D and a potentiometer(BS 6349 part 1-7).

4. EXPERIMENMTATION

Experiments were done with on the proposed design under various parameters like wave energy and transmission coefficient to prove its efficiency.

4.1 Equipment and Setups

As described before, floating wave breaker and wave tank is built and calibrations were conducted. Test conditions are fixed and outputs are obtained after several experiments. Following are the different equipment used

4.1.1 Wave Generator

Wave generator consists of an 100 RPM Johnson motor and a wedge of 0.45 m length, 0.1 m height and 0.1 m breadth. As the motor starts rotating, the wedge is arranged to move up and down using a slider. The maximum stroke length of motor is kept at 5 cm so that it can create a maximum of 10 cam height of waves.

4.1.2 Water Level Sensors

Water level sensors work on the principle of short circuiting. when water touches on the different stripes given in the surface, it will be powered up and starts reading the levels. Sensors have a length of 7 cm.

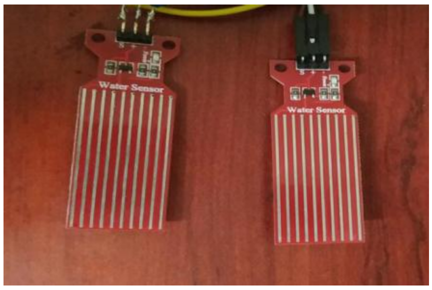

Fig-8 Water level sensors

4.1.3 Arduino Program

Arduino program helps to display the corresponding water levels and output scren is shown below. This program was developed with the help of Mr. Arun Prasad from department of Applied Electronics and Instrumentation, Saintgits College of Engineering, Pathamuttom ,Kottayam.

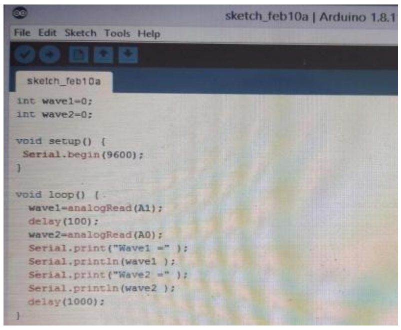

Fig-9 Output from Arduino program

4.1.4 Placing and Setup

Floating wave breaker is fixed at 0.75 m from the wave generator. Two water level sensors were kept in such a way that one to measure the wave height before the breaker and one more sensor to find the wave height after hitting the breaker. Water level sensors are equipped with magnet so that it can be fixed at any height. First water level sensor is kept at 0.35 m from wave generator and is named as wave 1. Second water level sensor is kept at 0.35 m from right side of the tank and is named as wave 2.

4.1.5. Anchoring

Anchoring is done using steel wires of 0.4 m in length. Two anchoring points are kept at 0.6 m such that at that distance the structure is in most stable equilibrium. Different wave height were maintained using wave generator equipment which is made using an rpm controllable motor.

4.1.6. Water Level

Water is to be kept at a height of 0.4 m to make a wave of 0.1 m maximum height. Wave tank filled up to 0.4 m height is shown in below.

Fig-10 Wave tank creating waves up to 0.1 m height

Fig-11 Wave tank with still water

5. RESULTS AND DISCUSSIONS

The results and its discussions from the experiments that were conducted are mentioned below,

5.1 Wave Energy

Tests were performed using conventional floating breakwater and newly designed floating wave breaker. Comparison of result were made as in the table form, Wave energy for different wave height have been calculated using the equation[3]

$$E = \frac{1}{8} * \rho g H^2$$

5.1.1 Tested Conditions

Different test conditions were as follows

1. Experiment 1-test with top pontoon only. (Table 1)
2. Experiment 2-test with top pontoon and one layer of geogrid cages which includes 3 cubes (Table 2)
3. Experiment 3-test with top pontoon and two layers of geogrid cages which includes 6 cubes (Table 3)

5.1.2 Relationship between H_t, H_i and Energy

Table-1: Results of Experiment 1

Experiment 1			
Wave Height Before Breakwater H_i(cm)	**Energy**	**Wave Height After Breakwater H_t(cm)**	**Energy**
10	12.262	5	3.065
9	9.932	5	3.065
8	7.484	4.9	2.944
7	6.008	3	1.103
6	4.414	2.6	0.828
5	3.065	2.1	0.540
4	1.962	1.9	0.442
3	1.103	1.5	0.275
2	0.490	0.9	0.099
1	0.112	0.5	0.030

Table-2: Results of Experiment 2

Experiment 2			
Wave Height Before Breakwater H_i(cm)	**Energy**	**Wave Heigth After Breakwater H_t(cm)**	**Energy**
10	12.262	3	1.103
9	9.932	3	1.103
8	7.484	2.9	1.031
7	6.008	2.7	0.893
6	4.414	2.5	0.766
5	3.065	1.8	0.397
4	1.962	1	0.122
3	1.103	0.8	0.078
2	0.490	0.3	0.011
1	0.112	0.1	0.001

Table 3. Results of Experiment 3

Experiment 3			
Wave Height Before Breakwater H_i(cm)	Energy	Wave Height After Breakwater H_t(cm)	Energy
10	12.622	2.9	1.031
9	9.932	2.8	0.961
8	7.484	2.6	0.828
7	6.008	2.4	0.706
6	4.414	2.2	0.593
5	3.065	1.5	0.275
4	1.962	0.9	0.093
3	1.103	0.4	0.019
2	0.490	0.2	0.004
1	0.112	0.1	0.001

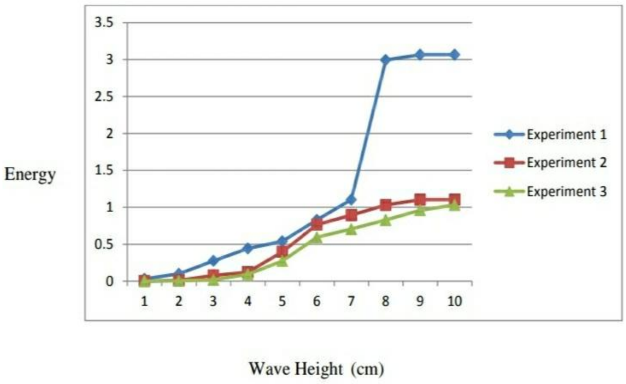

Chart-1 Energy vs Wave Height Graph

Chart-1. Graph showing relationship between number of cages and amount of energy transmitted

5.1.3 Summary

From the experiment 1,2 and 3, it is clear that the energy of wave transmitted after the structure is least for the one with a greater number of geogrid cages at the bottom. This indicates the presence of subsurface energy. Experiment 1 with pontoon only shows that the energy of transmitted waves is having the highest value. Experiment 2 with one layer of geogrid shows that a decrease in transmitted wave energy than experiment 1. Experiment 3 with two layer of geogrid cages shows the minimum transmitted wave energy. chart 1 indicates that as the number of cages and layers increases leads to more breakage of energy.

5.2. Transmission Coefficient

Transmission coefficient for different waves have been found and the values have been compared and the test conditions were as follows. With the help of this ratio, that is the ratio of transmitted wave height to that of the incident wave height, we will be able to understand the motion response characteristics and amount of subsurface energy[5].

$$C_t = \frac{H_t}{H_i}$$

5.2.1 Tested Conditions

1. Experiment 4-test with top pontoon only(table 4)
2. Experiment 5- test with top pontoon and one layer of geogrid which includes 3 cubes (Table 5)
3. Experiment 6- test with two layers of geogrid which includes 6 cubes(Table 6)

5.2.2 Relation Between Effects of cages And Transmission Coefficient

Pereira et al. studied that as the amount of obstacles which are irregularly placed increases the amount of energy dissipate. So following results will helps to understand the effect of number of geogrid cages and irregularly placed plastic bottles in it.

Table-4: Result of Experiment 4

Experiment 4		
Height of wave before incident(H_i) (cm)	Height of wave after incident(H_t) (cm)	Transmission coefficient $C_t=H_t/H_i$
10	5	0.5
9	5	0.555
8	4.9	0.612
7	3	0.428
6	2.6	0.433
5	2.1	0.52
4	1.9	0.525
3	1.5	0.5
2	0.9	0.45
1	0.5	0.5

Table-5: Result of Experiment 5

Experiment 5		
Height of wave before incident(H_i) (cm)	Height of wave after incident(H_t) (cm)	Transmission coefficient $C_t=H_t/H_i$
10	3	0.3

9	3	0.333
8	2.9	0.362
7	2.7	0.385
6	2.5	0.416
5	1.8	0.5
4	1	0.45
3	0.8	0.266
2	0.3	0.15
1	0.1	0.1

Table-6: Result of Experiment 6

Experiment 6		
Height of wave before incident(H_i) (cm)	Height of wave after incident(H_t) (cm)	Transmission coefficient $C_t=H_t/H_i$
10	2.9	0.29
9	2.8	0.311
8	2.6	0.325
7	2.4	0.342
6	2.2	0.366
5	1.5	0.44
4	0.9	0.375
3	0.4	0.133
2	0.2	0.1
1	0.1	0.1

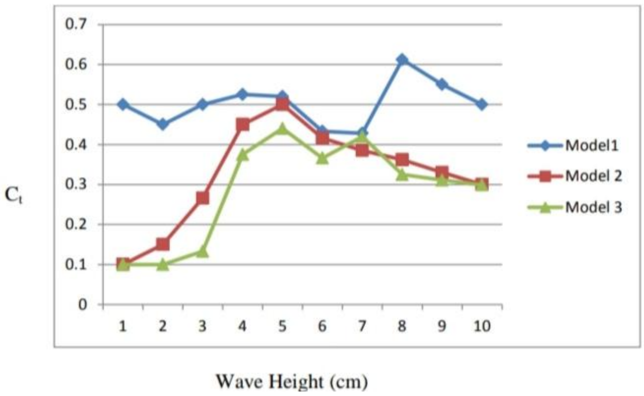

Chart-2: Ct vs Wave Height Graph

Chart 2. shows the relationship between number of cages and Transmission coefficient.

5.2.3 Summary

For better dissipation of energy, the transmission coefficient must be least. As the wave height increases, the motion responses also increases and their by producing high transmission coefficient.. Here we can see that Experiment 6 poses the least value for transmission coefficient indicates least motion responses and greater wave dissipation. And the Experiment 4 with highest value indicates lesser wave energy dissipation after the floating wave breaker. It is represented in chart 2. We can see that the Experiment 6 with two layers of geogrid cages is well below the other two models.

5.3 Mooring Force

Mooring force is the amount of energy token by the anchorage system. The relationship is that the more the mooring force, better wave energy reduction occurs. The equation to find the mooring force is as follows[6]

$$M = \frac{1}{\sqrt{1+\left[kw\frac{\sinh kh}{2\cosh(kh_1 - kh_2)}\right]^2}}$$

5.3.1 Tested Conditions

1. Experiment 7-test with top pontoon only(Table 7)
2. Experiment 8-test with top pontoon and one layer of geogrid cages which includes 3 cubes(Table 8)
3. Experiment 9-test with top pontoon and two layers of geogrid cages which includes 6 cubes(Table 9)

5.3.2 Relation Of Effects of cages And Mooring Force

Table-7: Results of Experiment 7

Experiment 7		
Height of wave before incident(H_i)(cm)	Height of wave after incident(H_t)(cm)	Mooring force(N)
10	5	0.991
9	5	0.9885
8	4.9	0.983
7	3	0.985
6	2.6	0.9801
5	2.1	0.9723
4	1.9	0.9536
3	1.5	0.9183
2	0.9	0.851
1	0.5	0.6112

Table-8: Results of Experiment 8

Experiment 8		
Height of wave before incident(H_i)(cm)	Height of wave after incident(H_t)(cm)	Mooring force(N)
10	3	0.9942
9	3	0.9923
8	2.9	0.9899

7	2.7	0.9863
6	2.5	0.9806
5	1.8	0.9748
4	1	0.9668
3	0.8	0.942
2	0.3	0.8959
1	0.1	0.7195

Table-9: Results of Experiment 9

Experiment 9		
Height of wave before incident(H_i)(cm)	**Height of wave after incident(H_t) (cm)**	**Mooring force(N)**
10	2.9	0.9941
9	2.8	0.9925
8	2.6	0.990
7	2.4	0.9872
6	2.2	0.9821
5	1.5	0.9769
4	0.9	0.9678
3	0.4	0.9503
2	0.2	0.9008
1	0.1	0.7195

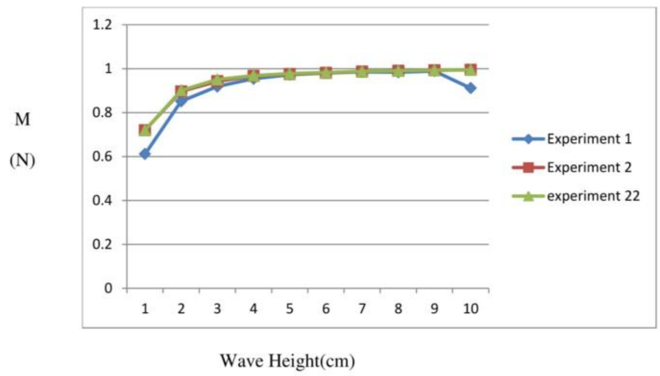

Chart-3 Mooring force VS Wave height

Chart -3. showing relationship between number of cages and Mooring force

5.3.3. Summary

It is found that the new design will be able to break more energy than conventional type floating breakwater. Because we can see an increasing trend of mooring force as the number of geogrid cages increases. From Chart.3 it is clear that Experiment 9 shows the maximum mooring force, which indicates breakage of more amount of energy by the floating wave breaker and also the presence of energy below the water surface.

6. CONCLUSIONS

- It is found that the prosed floating wave breaker is **23.55 %** more efficient than conventional type of floating breakwater with two layers of geogrid cages at the bottom of a conventional floating breakwater.
- Applicable at poor soil conditions since support is needed only for anchoring.
- Reuse of plastic bottles with proper maintenance will leads to an effective plastic waste management.
- Weight of geogrid cage does not depends on top structure ,so implementation to existing structure is easy and does not require much alterations.
- Natural soil reclamation process, that is soil erosion and soil aeration process is not interrupted since floating wave breaker is as combination of floating and perforated type of floating breakwater.
- Transportability, which enables to change the layout of port easily since the entire structure can be easily disassembled.

6.1. FUTURE SCOPE

We are proposing to implement Floating Wave Breaker in Valiathura , near Trivandrum .Because the soil erosion recorded over the area during the last decade is tremendous(fig 12). Construction of a fixed type of breakwater is not suitable over their due to the effect of altering tidal conditions.

Fig-12 . Condition of Valiathura in 2013 and 2019(NCESS)

Information collected from the National Center for Earth and Science study(NCESS) Department; Trivandrum provides sufficient knowledge about the offshore behavior of the religion Valiathura. Table 10, Table 11 and Table 12 shows the altering water levels and wave periods. Site visit also provides the current status of the beach which is shown in fig 13.

Table-10: Altering water levels in Valiathura(NCESS)

Return Period (years)	HAT (m)	Storm Surge (m)	Sea Level Rise (m)	Total (m)
10	1.2	0.3	0.04	1.54
25	1.2	0.3	0.1	1.6
50	1.2	0.3	0.2	1.7
100	1.2	0.3	0.4	1.9
200	1.2	0.3	0.8	2.3

Table-11: Future water levels Expecting in Valiathura(NCESS)

Water Depth (m CD)	Significant Wave Height, Hs (m) for various Return Period				
	10 Year	25 Year	50 Year	100 Year	200 Year
6	2.1	2.2	2.4	2.5	2.7
8	2.0	2.1	2.3	2.4	2.6
10	1.2	1.3	1.4	1.5	1.7
12	3.1	3.2	3.4	3.6	3.9
14	3.5	3.6	3.7	4.0	4.2
16	3.7	3.8	3.9	4.2	4.4
18	3.9	4.0	4.1	4.4	4.6
20	4.0	4.1	4.2	4.5	4.7

Table-12:. Altering wave periods in Valiathura(NCESS)

Return Period (years)	Wave period, T (s)
25	9.5
50	9.7
100	9.8
200	9.9

Fig 13 . Present condition of Valiathura

All the above-mentioned details prove that Valiathura may not be suitable for a conventional type of breakwater. Normal floating breakwater doesn't have much advantage over there. So, implementing Floating Wave Breaker will be the best and to save the entire area for the future.

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BIOGRAPHIES

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