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Using a Half Circular Section of the Pipe as a Breakwater for the Ports

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ملخص عربي

تم اختيار نموذج لحاجز أمواج نصف مغمور علي شكل قطاع من نصف ماسورة قطرها الداخلي 20 سم وسمكها 1سم. تم اختبار نموذج الحاجز المقترح معمليا وبإستخدام النمذجة العددية . حيث أشارت النتائج إلي تقارب كبير بين كلاً من النموذجين المعملي والعددي . وبمقارنة كلاً من معامل انتقال الموجة (Kt) ومعامل انعكاسها (Kr) مع عمق الماء النسبي (d/L) وجد أن معامل الانتقال (Kt) يقل مع زيادة عمق الماء النسبي (d/L) بينما معامل الانعكاس (Kr) يتخذ مساراً عكسياً تماماً . وفي حالة تثبيت القطاع بحيث يكون التجويف مقابل للموجة وجد أن معامل الانتقال (Kt) يقل عنه في حالة تثبيت التجويف عكس اتجاه الموجة بنسبة تتراح من (10 - 15)%. وأيضاً معامل الانعكاس للموجة (Kr) في الوضع المقابل يزيد عن الوضع العكسي بنسبة تتراوح من (5- 10)%. تتشتت الأمواج عند حافتي الحاجز وتتبدد طاقتها فتنتقل بارتفاع منخفض داخل الموانئ .

Abstract

A circular section of half pipe has been selected. Diameter of semicircle pipe 20 cm and thickness of 1 cm, the proposed barrier was tested both experimental and numerical. Where the results indicated a great convergence between both the experimental and numerical models. Comparing the wave transmission coefficient and its reflection coefficient with the relative water depth (h/L), the transmission coefficient was found to decrease with the relative height of the wave, while the reflection coefficient was completely reversed. In case (a) the barrier is facing the wave. But in case (b) Barrier reverse the wave. The comparison was done using the numerical model (CFD) code Flow-3D. The results indicate that with the increase in the relative water depth (h/L), the transmission coefficient decreases. In case (a) is less than the transmission coefficient (Kt) in case (b) at range (10% to 15%). While the reflection coefficient (Kr) in case (a) is Bigger than case (b) at range (5% to 10%). The waves break at the edge of the barrier and dissipate their energy and move low at ports.

KEY WORDS: *Regular wave; Semi-Submersible Barrier; numerical models; Transmission, Reflection, Energy Loss and Vortex wave*

1- Interdiction

In the ports of leisure allows the existence of water waves provided that the waves do not hurt tourists. Allows the transmission of part of the waves through the proposed barrier that gives a great view of the beach.

Several studies were done in the past, by many investigators to propose new configurations of breakwaters, to improve their performance, and to study their hydrodynamic behavior in attenuating the incident waves. Great attention was given to the development of different geometric configurations. Attempts were also made to understand the physical behavior of breakwaters action by various numerical model studies.

Many researchers have proposed breakwaters. For example. ***Mani (1991)*** studied experimentally the performance of the different types of floating breakwaters. Hydraulic model tests were carried out in 2.0 m wide, 30 m long and 1.5 m deep wave flume at the Ocean Engineering Center of the Indian Institute of Technology. The author presented dimensionless graphs indicating the variation of transmission and reflection coefficients with respect to relative depth, relative width, wave steepness and the gap to diameter ratio.

Sundar and Subbarao (2002) investigated the Quadrant front face pile supported breakwater experimentally. The transmission, reflection and energy loss coefficients were measured. In addition, the dynamic pressures were measured. Transmission, reflection and energy loss coefficients were related to different gap ratios.

Rageh and Koraim (2010) investigated experimentally the performance of a breakwater caissons supported on two or three rows of piles. The efficiency of the breakwater was presented as a function of the transmission, the reflection and the wave energy loss coefficients. Different characteristics of the caisson structure and the supporting pile system were tested. It was found that the proposed breakwater helps in dissipating about 10 to 30 % of the incident wave energy.

Elsharnouby et al. (2012) investigated the performance of double porous curtain walls fixed on two rows of vertical piles that consisted of two sets of horizontal steel strips with equal spacing. FLOW-3D software was used to examine the effect of the tested models. The research designated the effect of the model parameters on the transmission coefficient.

Koraim et al. (2014) investigated experimentally and theoretically the wave transmission, reflection and energy dissipation of double rows of vertical piles. Different wave and structural parameters were investigated. Comparison between experiments and predictions indicated that theoretical model provided a good estimate to the different hydrodynamic coefficients.

Ibrahim M. (2017a) studied the efficiency hydrodynamic performance of unsymmetrical double vertical partially slotted barriers was investigated, physically and numerically by Flow-3D. The experimental work identified the hydraulic performance of the barriers. In addition, the model provided reasonable results to the contributing variables (i.e. wave height, wave length and barrier characteristics)

Ibrahim, M., and Ahmed, H., (2017b) investigated experimentally and numerically the wave transmission, reflection and energy dissipation of Half Pipes as Permeable Breakwater. Comparison between experiments and predictions indicated that numerical model provided a good estimate to the different hydrodynamic coefficients. In this paper, the wave transmission, reflection, and energy dissipation of a circular section of half pipe are experimentally and numerically studied under normal regular waves.

The experimental model is validated by numerical model and most parameters of the proposed model are studied by numerical model.

2- Characteristics of experimental study

More than 30 experiments were conducted at the Irrigation and Hydraulics Laboratory, Faculty of Engineering, Zagazig University. See photo (1)

This section presents the details of wave flume dimensions, wave periods(T) sec, tested numerical models and how to calculate the different coefficients governing this study which including the reflection coefficient (Kr), transmission coefficient (Kt) and energy dissipation coefficient (Kd).

Photo (1) wave generator and flume

2-1. Wave flume

To investigate the interaction between regular waves and half pipes semi-submersible breakwater systems, a set of run conditions are carried out on rectangular cross-section wave flume (20.0 m long in X-direction , 2.0 m wide in Y-direction and 1.20 m deep in Z-direction) ,and in order to damp the transmitted wave, a wave absorber is installed at the end of the wave flume, keeping in consideration that the water depth is constant in this wave flume with value 0.40 m, all details of wave are shown in figure (1). The wave generator generates regular waves at different frequencies. The proposed model is installed in the middle of the flume.

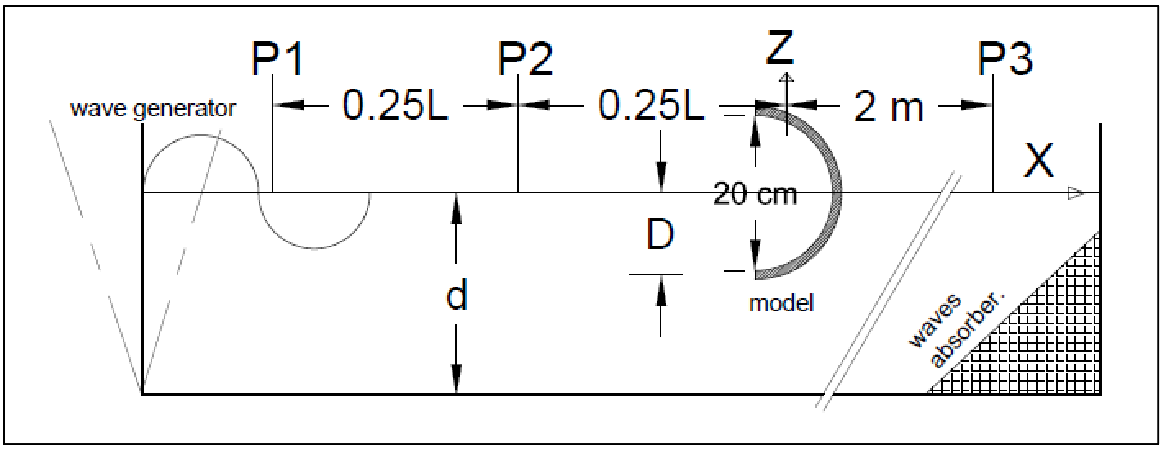

Fig. (1) Definition sketch for the model of breakwater in the wave flume.

2-2. Waves

A set of run conditions are carried out by using five different regular wave periods(T) (1.2 sec, 1.4 sec, 1.5 sec, 1.8 sec and 2 sec), where the finish time of each run based on the wavelength (L) which varies according to the wave period.

2-3. Tested Model

One half pipe fixed in vertical position with Two different cases (a & b). Case (a) facing waves and case (b) Reverse waves as in figure (2). Half-pipe used for plastic it's diameter = 0.20 m and thickness = 0.01 m

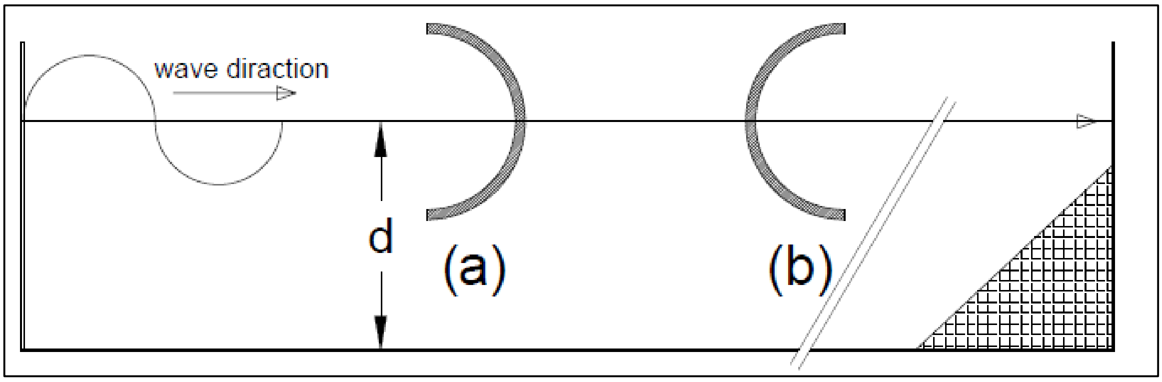

Fig. (2) Definition sketch for Two different cases (a & b) in the wave flume

2-4. Governing Coefficients

Three coefficients governing this study are discussed. Firstly, the reflection coefficient (Kr) which indicates the amount of wave reflected from the barrier, Secondly the transmission coefficient (Kt) which presents the quantity of wave transmitted after the breakwater, Thirdly the energy dissipation coefficient where the portion of the dissipated energy.

2-5. The procedure of governing coefficients calculations

The reflection coefficient (Kr) is estimated by measuring the maximum and the minimum wave heights (Hmax and Hmin) at upstream of the submerged breakwater. Incident wave height (Hi) and reflected wave height (Hr) are calculated as Hi=(Hmax+Hmin)/2 and Hr=(Hmax-Hmin)/2 respectively, where Hmax is the maximum wave height measured at antinodes while Hmin is minimum wave height measured at nodes., According to Dean and Dalrymple [1991],

The conventional method used to separate the measured wave train into its incident and reflected wave components. Two wave gauges required for measuring maximum and minimum wave heights were placed at fixed distances of L/4 (at position P2) and L/2 (at position P1) from the breakwater, where L is the wavelength. knowing that the wavelength is varied according to the wave periods. At each position (L/4) antinode, and (L/2) node) data of water surface were collected see fig (1) Where Kr is calculated according to the following equation:

$$Kr = Hr/Hi \qquad \text{(ranging from 0 to 1)} \qquad (1)$$

Where Hr is the reflected wave height, (Hi) is the incident wave height

Measuring the transmitted wave heights (Ht) using wave gauge at position (P3) are performed, this position is located at a distance 2 m behind the submerged breakwater model (from the breakwater shore side), this position is for the sake of avoiding the turbulence effect resulting from the wave overtopping on the submerged breakwater also for minimizing the effect of the reflected waves from the wave absorber which is located at the end of the wave flume. Where (Kt) is calculated according to the following equation

Kt =Ht/Hi (ranging from 0 to 1) (2)

Where Ht is transmitted wave height.

After calculating the values of Kr and Kt, the wave energy dissipation coefficient can be calculated according to the following equation

Kd = $\sqrt{1 - Kr^2 - Kt^2}$ (Thornton and Calhoun 1972) (3)

Table (1) The experimental setup parameters for the tested model

Parameter	The range of water surface level	Dimensions	Units
Water Depth (d)	0.40	(L)	(m)
Wave periods (T)	1.2 to 2	(T)	(sec.)
Wave Length (L)	2.05 to 4.1	(L)	(m)
Wave incident (Hi)	2.07 to 3.65	(L)	(cm)
Relative draught (D/d)	0.25	Dimensionless	-
Relative water depth (d/L)	0.1 to 0.24	Dimensionless	-

3-Numerical study

The investigation of the proposed breakwater achieved by numerical simulation by using the marketable (CFD) "Computational Fluid Dynamics" Code (FLOW-3D). Considering Coastal and maritime engineering, the proposed program has a developing rule where various applications are viable by its usage. The coding of this program is based on the finite volume theory in order to solve the three-dimensional Reynolds Averaged Navier Stokes (RANS) equations. Considering that the program is composed of many solid divisions, hydraulic and geometric boundary conditions are represented through this program. As a matter of validation, this program was used in the numerical study (Ibrahim, M., Ahmed, H., and Alall, M. A. (2017)) and validated experimentally which showed a good apparent agreement in results. therefore, the marketable (CFD) has been used in the implementation of this research.

The experiment was conducted without the barrier After 12 seconds the wave is formed. **wave surface profile** shows a nearly complete correspondence between the results of the numerical and physical model. This means that the numerical model can represent the wave in its entirety as shown in figure (2).

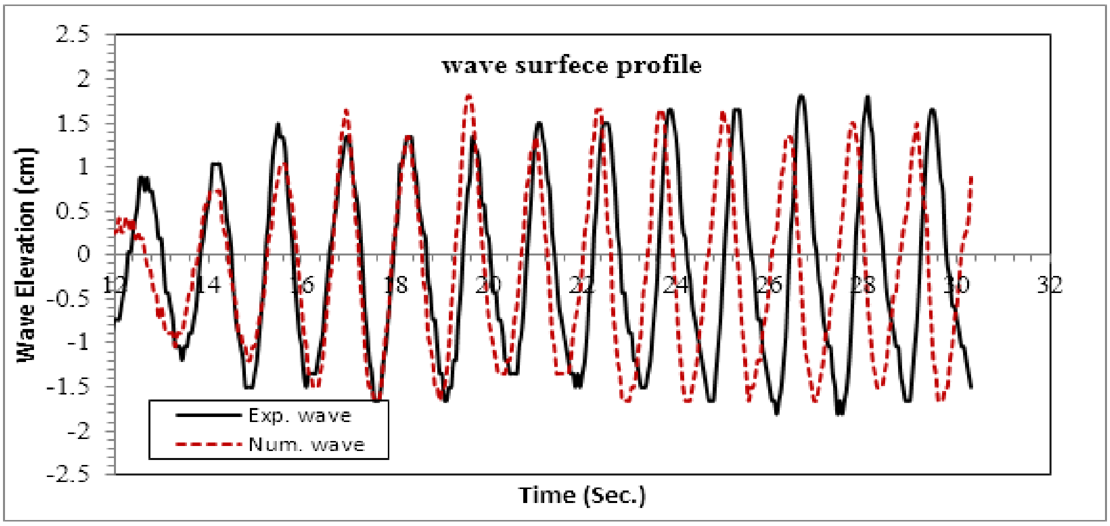

Fig. (2) Comparison between the experimental and numerical models in surface wave at wave period (T) =1.4 sec. and wave incident (Hi) = 2.8 cm

4- Analysis of the results

The experimental results which carried out experimentally on half pipes semi-submersible breakwaters are carried out numerically by (FLOW-3D) program which shown a good agreement in results where the average difference between them during fifteen run conditions = 3.0 % which ensures the efficiency of using this analysis program As in Fig. (3). the figure shows that with the increase in relative water depth (d/L) the transmission coefficient (Kt) decreases. The numerical model is capable of representing the basic features of the proposed barrier and is also reliable in similar situations.

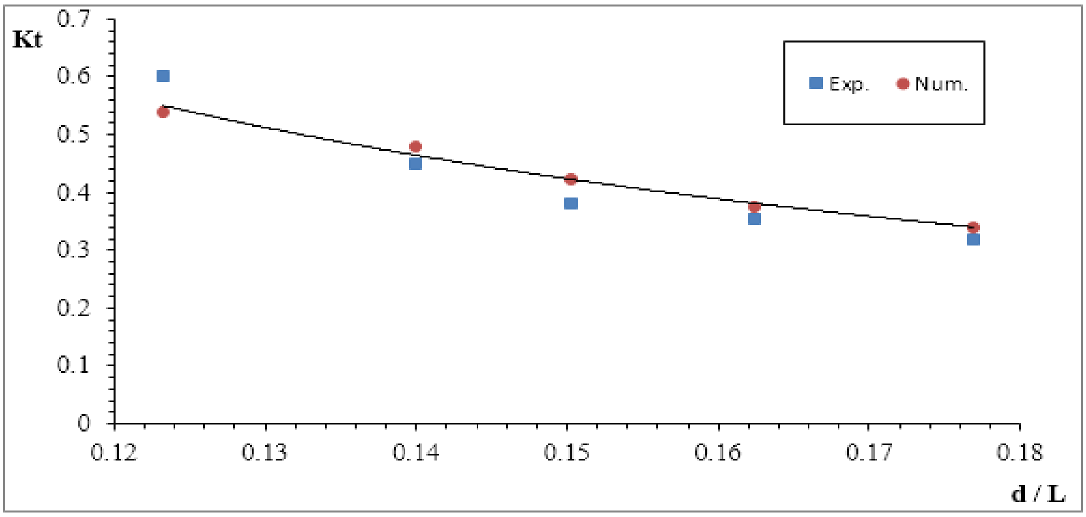

Fig. (3) Comparison between transmission coefficient and relative length experimentally and numerically.

From figure (4) Comparing the two different cases. In case (a) the barrier is facing the wave. But in case (b) Barrier reverse the wave. The comparison was done using the numerical model (CFD) code Flow-3D. The results indicate that with the increase in the relative water depth (d/L), the transmission coefficient (Kt) decreases.

Note that the transmission coefficient (Kt) in case (a) is less than the transmission coefficient (Kt) in case (b) at range (10% to 15%).

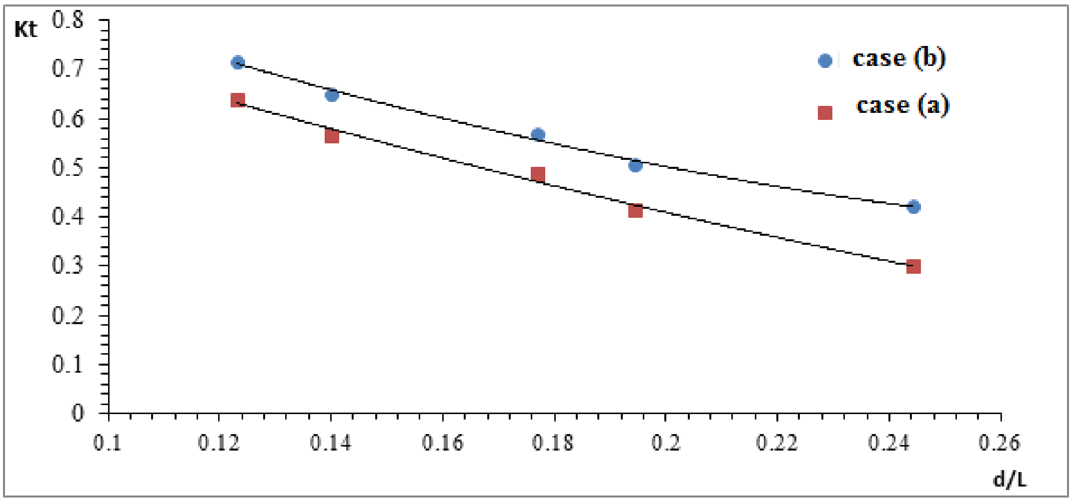

Fig. (4) Comparison of two different cases (a&b) for transmission coefficient (Kt) against relative water depth (d/L) by using numerical models.

From figure (5) Comparing the two different cases. In case (a) the barrier is facing the wave. But in case (b) Barrier reverse the wave. The comparison was done using the numerical model (CFD) code Flow-3D. The results indicate that with the increase in the relative water depth (d/L), the reflection coefficient (Kr) increases.

Note that the reflection coefficient (Kr) in case (a) is Bigger than the reflection coefficient (Kr). In case (b) at range (5% to 10%).

Summary of figures (4) and (5) show that when circular section of half pipe facing the waves, the wave's energy dissipates more than the inverse state of the barrier, the reason is due to the semicircle edge of the pipe. The transmission of the wave in case (b) is less than the case (a) due to the difference in the position of the barrier and the surface area of the barrier facing the wave

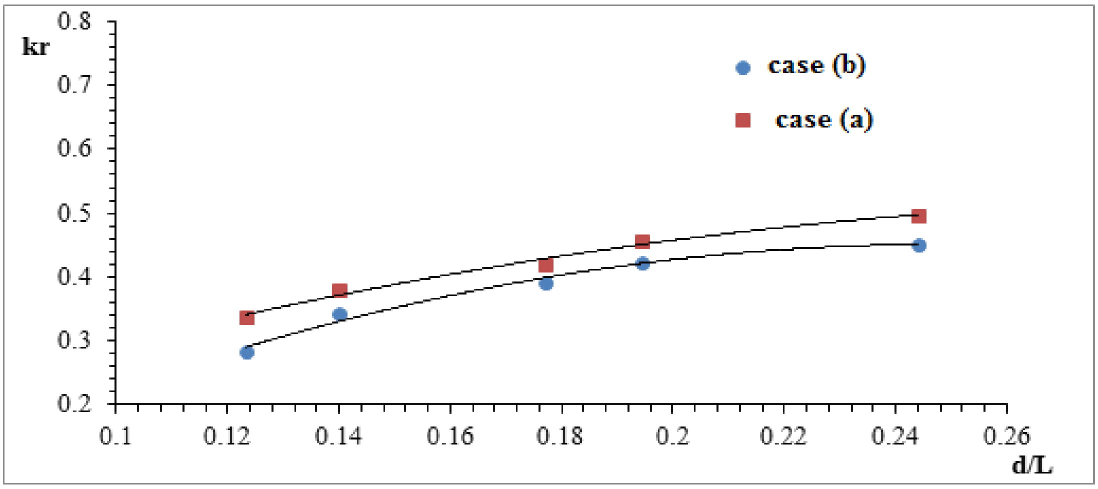

Fig. (5) Comparison of two different cases (a&b) for reflection coefficient (Kr) against relative wave length (d/L) by using numerical models.

5- vortex distribution and velocity of waves

The circular section of half pipe suspended on spaced vertical piles. By using the numerical model, the wave velocity can be measured in front of and behind the barrier. The distribution and direction of vortices can be seen in the numerical model. Figures (6a) and (6b) show that the velocities in front of the barrier are large while the velocities behind it are small. It is noted that the waves are scattered at the edge of the barrier, which helps to disperse the energy of the waves.

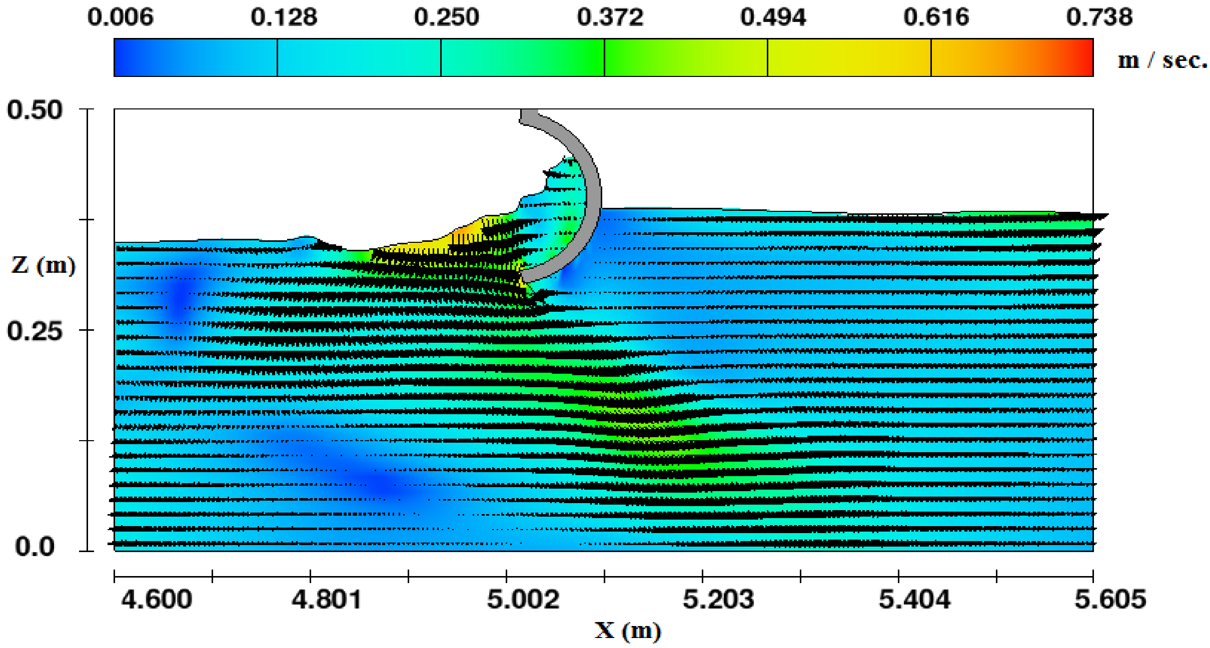

Fig. (6a) Shows vortex distribution and velocity of waves by (flow-3d)

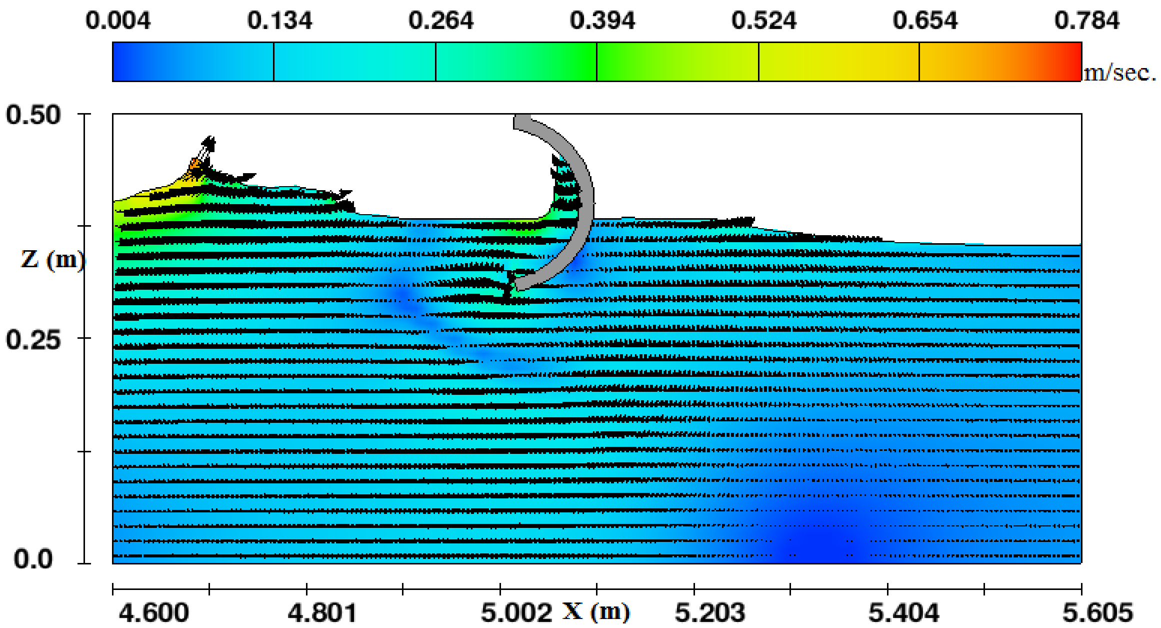

Fig. (6b) Shows vortex distribution and velocity of waves by (flow-3d)

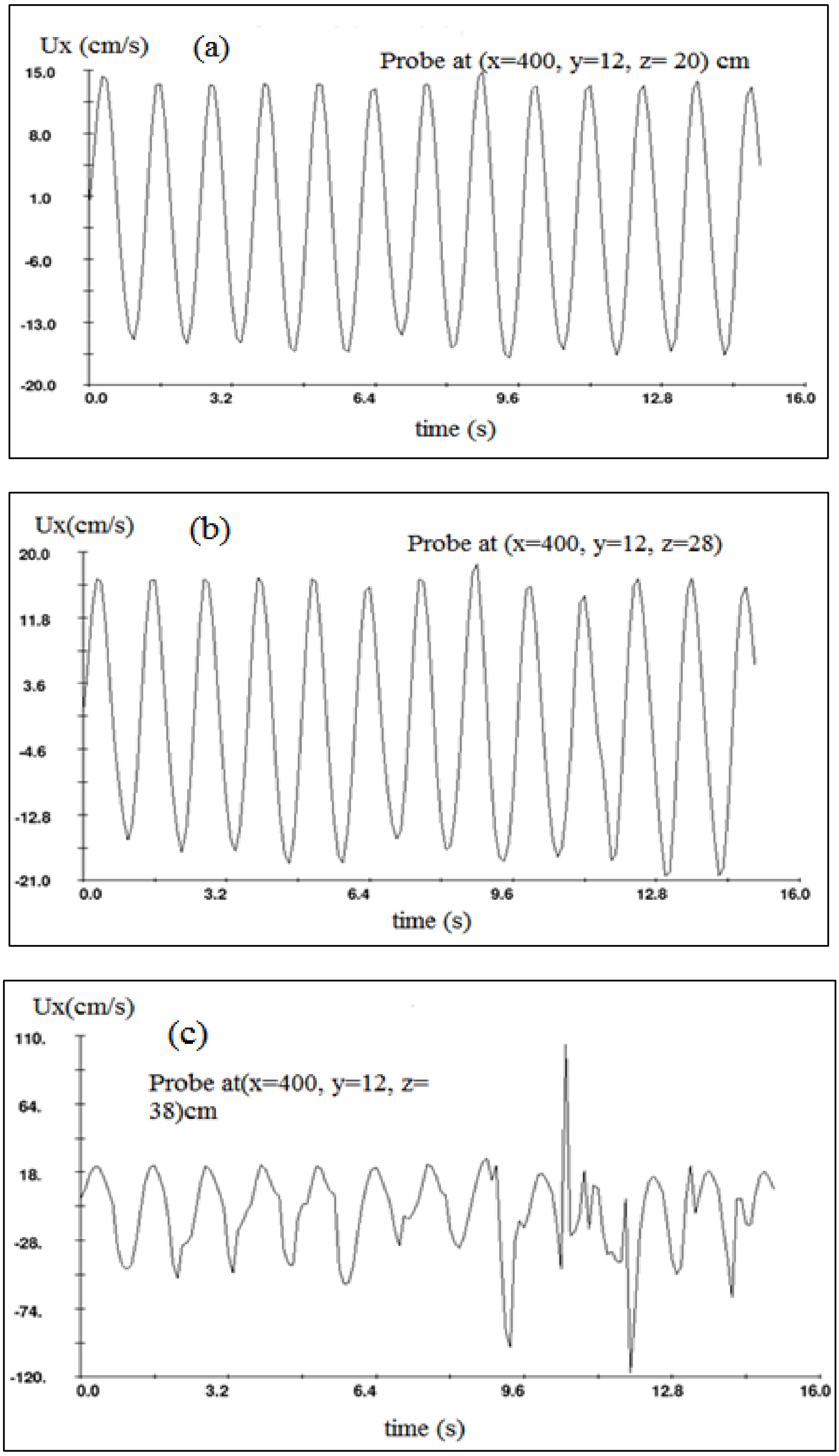

Fig (7) Comparison between velocities of wave at three different probes front at breakwater (a) z=20cm, (b) z=28 cm and (c) z= 38 cm.

Figure (7) shows that the velocities in the direction of the X axis change with the depth change in the direction of Axis z. Also the velocity of the waves near the surface of the water is as large as possible.

6- CONCLUSION

The present research could be concluded in the following points:

- The tested model of innovative barrier reduces the transmission of waves within harbors.
- The model in case (a) is better than that in case (b) in reducing the waves and dissipating the wave energy.
- There is a high correlation between the results of both experimental and numerical models.
- The proposed numerical model may be used for predicting the pile breakwater efficiency.
- The velocity of waves and vortexes can be indicated numerically.

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