Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 795-805

AENSI Journals

Journal of Applied Science and Agriculture

Journal home page: www.aensiweb.com/jasa/index.html

Investigation of Cross Shore Sediment Transport Using Physical and Numerical Methods

[1]Neshaei, M.A.L., [2]Vahid Najafi Moghaddam Gilani

[1]*Associate Professor, Dept. of Civil Eng., the University of Guilan, Rasht, Iran.*
[2]*M.Sc.Student,Dept. of Civil Eng., the University of Guilan, Rasht, Iran.*

ARTICLE INFO

Article history:
Received 19 October 2013
Received in revised form 16 November 2013
Accepted 19 November 2013
Available online 20 December 2013

Keywords:
Wave, shore, current, beach sediment, winter profiles, summer profile

ABSTRACT

In this paper, cross shore sediment transport and changes in bed profile due to wave are considered using two physical and numerical methods. Test results using physical model showed that in grading of sediment materials, when D50 of used materials increases, intensity of beach erosion is decreased and the made bar becomes inclined towards the shore and its height is also decreased. Also, by increasing slope of the simulated shore, intensity of the shore beach erosion becomes more serious and the bar becomes inclined towards the sea and also its height decreases. In most cases, depending on the grading of materials and the beach slope, winter storm profiles were formed; whereas, because of wave height effect, summer profile was also formed.In the numerical method, the Litpack program was used and comparing its results with physical model showed that this model predicts real conditions and its precision in conditions of physical model due to the effects is not decisive.

To Cite This Article: Neshaei, M.A.L., Vahid Najafi Moghaddam Gilani., Investigation of Cross Shore Sediment Transport Using Physical and Numerical Methods. ***J. Appl. Sci. & Agric.,*** *8(6): 795-805, 2013*

INTRODUCTION

Coasts are permanently subject to waves attacks, so their beach profiles is alternatively changing. These changes mainly happen near surf zone where effects of waves breaking are more apparent. Surf zone means the region after which the progressive wave made in deep water enters shallow regions of the shore and effects of bed surface on wave is tangible. Width of surf zone in which the waves breaking happen is a function of wave height and morphology of the sea bed.

Since profiles of sandy shores are permanently changing because of waves attack, observing a balanced profile in stable mode for these kinds of shores is impossible. Nevertheless, Deans'(1991) studies show that an equilibrium profile can always be defined for sandy beaches around which fluctuation of sea bed take place. It stands to reason that such a profile does not exist at all and only shows average situation of bed behavior affecting by waves attacks. In determining profile equations of sandy beaches, following conditions are assumed:

-Beach is of sandy type so that average settlement velocity of particles is between 1 to 10 centimeters per seconds.

-Balanced from of shore should be supposed proportional to the loss of energy caused by waves breaking.

-Wave height in the surf zone after breaking should be a constant percentage of the water depth. Using above-mentioned assumptions, the sandy beach profile equation can be defined as:

$$h=Ax^{2/3}$$

In which h is water depth in any point with distance x from the shore line and parameter A is a coefficient that follows this equation:

$$A=2.5\left(\frac{W^2}{g}\right)^{1/3}$$

In this formula, w is the settlement velocity of bed particles and depends on the average diameter of particles i.e. D50 and is calculated by following equations:

$$0.001^{\text{ mm}} < D_{50} < 0.1^{\text{ mm}} \qquad W=\frac{(s-1)gD_{50}^2}{18\upsilon}$$

Corresponding Author: Neshaei, M.A.L., Associate Professor, Dept. of Civil Eng., the University of Guilan, Rasht, Iran.

0. 1 mm< D_{50} < 1 mm $W=\frac{10\upsilon}{D_{50}}\left[\left(1+\frac{0.01(s-1)gD_{50}^{3}}{\upsilon^{2}}\right)^{0.5}-1\right]$
D_{50} > 1 mm $W=1.1[(s-1)gD_{50}]^{0.5}$

In these equations, g is the gravity acceleration, s is the density of bed materials and v is the kinematic viscosity of sea water.

Studies of researchers such as Dean (1991) and Lashteh Neshaei et al. (1997 , 2000 , 2001) show that beaches profile in different seasons of the year changes as follows:

In winter, shore is subject to stormy waves with relatively large height, it is eroded due to turbulence caused by waves breaking in surf zone and shore sediment near shore and because of returned current caused by wave, it moves toward sea. These sedimentin a region near to wave breaking zone faces with sediment transferred to the shore in opposite direction (due to wave movement towards the shore) and from their interference and settling of these sediments, a longshore bar nearly parallel with the shore line and around the region of wave break is created.

In summer when wave are relatively mild, opposite case of winter profile happens. That is due to small wave height entered to the shore and shortage of energy loss due to breaking of big waves, direction of shore sediments are generally towards the shore and settled sediments near region of wave break advance gradually towards the shore and so forming a relatively sharp slope next to shore line is probable.Therefore, if wave height is increased, it is more probable that winter profile happens.

Iran has long and important shores in northern and southern frontiers. Therefore, exact knowledge of shores behavior, change of seasons and their reaction with shore structures in planning marine structures such as wharves, seawalls and breakwaters have great importance. Also, for exact calculation of sediment transport and sediment balance in shores, serious need for exact knowledge about mechanism of cross shore sediment transport exists. With regard to the lack of information in this respect and importance of this phenomenon, the main aim of present study is obtaining a better understanding and exact knowledge about it. For this purpose, utilizing one of the famous numerical models in this field (Litpack model) and comparing the results in predicting transformation of shore bed after storm with obtained results from performed tests, it has been tried to present a better knowledge of shore behavior.

2. Experimental Setup:

2.1. Plan of physical model profile:

Existence of laboratory limits, scale effects and measurement errors accompany results obtained from the measurement samples of shores and its fluid conditions with typical particularities among which the following cases can be referred to:

1-Limitation in complete simulation of the phenomenon
2-Physical approximation and replacement of dominant forces
3-Limitation in complete creation of environmental conditions and fluids such as temperature of water and air, water density, conditions of bed, etc.

The most important physical variables considered in shore sediment transport are in four groups of fluid, current, geometrical and sediment variables, according to table 1.

Table 1: Description Of physical Variables.

Geometrical Variables		Fluid Variables		Current Variables		Sediment Variables	
H	Water depth	ρ	Fluid density	N	Roughness of bed level	d	Diameter of sediments particles
λ	Liner Length index	υ	Fluid kinematic viscosity	G	Acceleration of gravity	ρ_s	Density of sediments particles
x,y,z	Coordinate axis			t	Time index	ζ_b	Bed shear stress
				T	Wave period	W_s	The fall velocity
				H	Wave height		
				L	Wave length		

The physical simulation is based on dimensionless parameters depicted in table 1 and, choosing suitable combination of these proportions without dimension is important. In making the model, the following combination is used (kamphuis, 1991):

$$\pi_H=f\left(\frac{H}{L},\frac{h}{L},\frac{x}{L},\frac{y}{L},\frac{z}{L},\frac{n}{L},t\sqrt{\frac{g}{L}},\frac{v}{L\sqrt{g^L}}\right)$$

In measuring physical specifications, the Froude criterion and in dimensional simulation of the study region, geometric model is directly used. So, dimensional specifications of the physical model are considered as follows:

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 795-805

1-The beach profile is a combination of fixed and formable sections and the fixed part decreases the levee volume of the model and at the same time facilitates stages of shore reconstruction and repeated performance of tests. Dimensions of this section of the model are determined and chosen according to supplying the bed thickness in eroding section of the profile. Also, part of the fixed bad as an artificial slope separates the primary boundary of the formable bed from the flume region as can be seen in Fig.1.
2-The longest length of the model profile(along with the flume axis) is 8 meters, of which 5 meters of the formable zone of the bed is in the visible part of the flume as can be seen in Figs 2 to 4.
3-Quality effect of the shore is considered by simulation of profiles with three different sloped. Due to the length limitation of visible part of the flume and also optimizing operations for making shores, slopes of 1:8, 1:10 and 1:12 are chosen.

Water level and Directional wave:

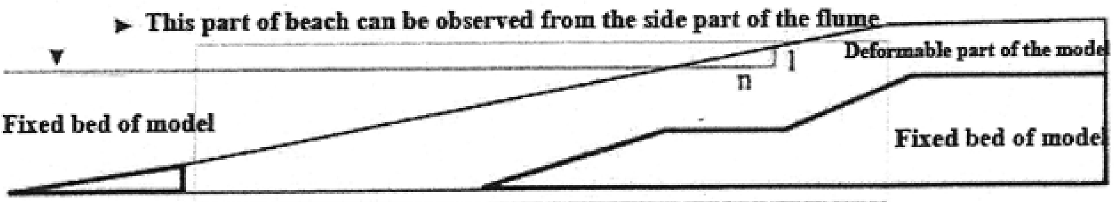

Fig.1: Geometrical profiles of the physical model made in the laboratory.

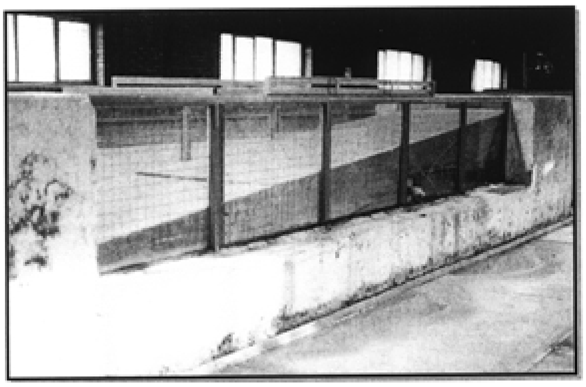

Fig. 2: Initial bed profile.

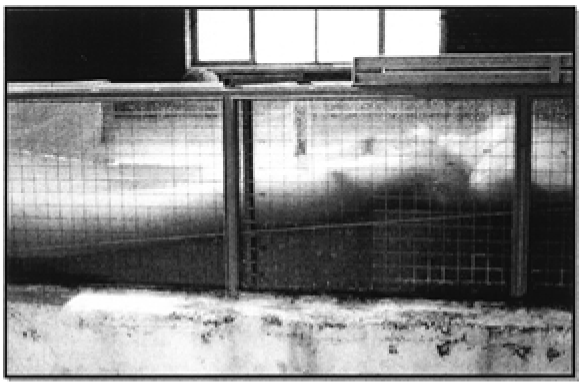

Fig. 3: Mode of reaction of wave with bed and type of wave breaking on the beach slope during the test.

2.2. Grading of sediment materials:

Considering aim of relative conformity of laboratory conditions with general situation of northern coasts of the country (Lashteh Neshaei&asano,2000),natural dimensions of granule sediment will be fine particles. In this situation, implementing direct measuring on average diameter of fine sediment particles, in addition to difficulties and limitation that preparing of sediments will lead to intensity of measuring error effect caused by increasing in viscosity effect in sedimentation of the model granules. To prevent these two difficulties, sediment dimensions of fine granules is determined through modeling of fall velocity of particles between the model and

Journal of Applied Science and Agriculture, 8(6) November 2013, Pages: 795-805

prototype. In this situation, according to Froude similarity rule, the following relation between main and laboratory quantities of fall velocity will exist, (Short,1999):

$$(W_s)_\gamma = \sqrt{\lambda_\gamma}$$

In table 2 average diameter of model granule sediment for quantities of natural dimensions of sediment which is obtained by the above method is shown. Also Fig.5 shows the aggregation distribution curve of sediment materials used in the experiment.

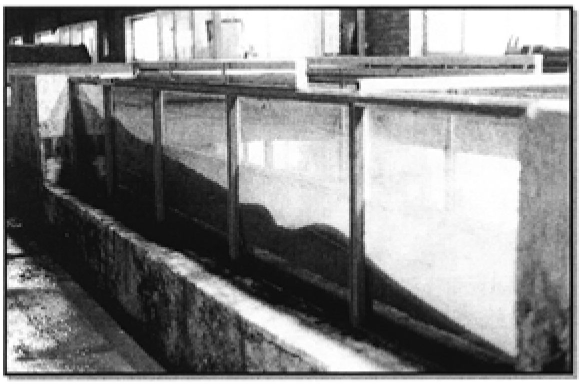

Fig. 4: Transformed mode of the simulated beach after the test period.

Table 2: Average diameter of used materials in the laboratory.

5.5	1.41	0.47	Average diameter of sediment materials in nature (mm)
27.5 × 10 -2	1.33 × 10 -2	5.69 × 10-2	Amount Of fall velocity of granules sediment in nature (m/s)
8.70 ×10 - 2	4.20 × 10-2	1.80 ×10-2	Average velocity of particle according to model measurement (mm/s)
0.87	0.35	0.16	Average diameter of sediment materials in laboratory (mm)

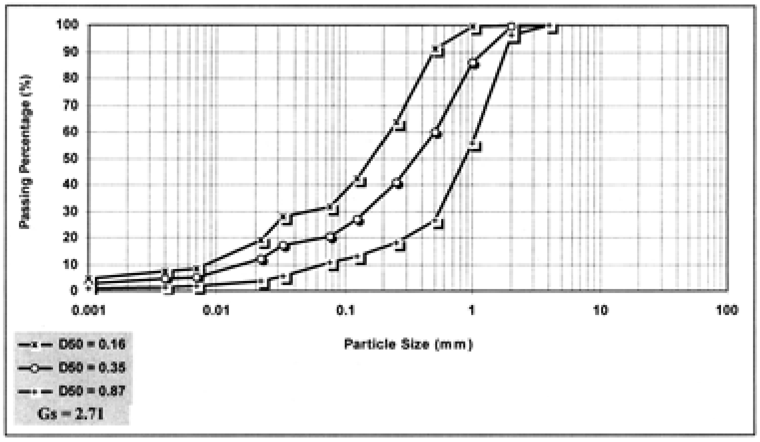

Fig. 5: Aggregation distribution curve of sediment materials used in the laboratory.

2.3. Simulation of waves conditions:

In two-dimensional progressive waves, variable specifications (parameters) in the most complete form are a function of x,y,z and t (soresen, 1993). Simulation of mentioned waves in zones with fixed depth need information such as wave height, wave frequency, wave length, wave number, gravity acceleration and wave velocity. From these parameters, four independent specifications for simulation of wave movement method are enough. Three quantities of wave height, water depth and acceleration of gravity with one of three dependant specifications to wave length, wave number and /or frequency constitute the most general four members that are chosen from complex of above specification. Therefore, the dimensionless from of wave force F = F (p,g,H,L,h,D) using dimensional analysis can be rewritten as follows:

$$\frac{F}{pgHD^2} = F(\frac{h}{L}, \frac{H}{L}, \frac{D}{L})$$

With regard to flume dimensions and also capacity of wavemaker which generates waves, the chosen scale for changing shore parameters to laboratory conditions is 1:10. Consenquently, waves with height of 10,15,20,25 and 30 centimeters and period of 2 seconds and frequency of 0.5 , 1.5 and 3 hertz are simulated.

2.4. Laboratory apparatus and measuring equipments:

According to type of study and considering existing facilities, a wave flume with dimensions of 35×1×1 meters equipped with regular wavemaker was used. The considered flume had a paddle wavemaker (a piston type) which had maximum replacement radius of 0.45 meters and capacity to produce wave up to 0.35 meters high in maximum water depth of 0.75 meters. Also, frequency of producedwaves could be arranged by subsidiary engine installed on main electromotor so that range of laboratory waves with different amounts of (H,T)could be remade by the mentioned wave-maker.

In performing tests, in order to consider the sensitivity of results, observational results of every stage on the whole three different variables have been measured as following:

- Measuring wave specifications using wave-recorder equipment with ability of momentary inputting and digital sensors was performed. This measuring through 2 entrance routes (according to need), recorded and determined specifications of water level on two points along flume at each moment. Measuring precision of these equipments was $\pm$ 1mm.
- Measuring time duration of waves generation in laboratory using chronometer was performed.
- Length profile of shore line in every stage using digital profile meter was taken.

2.5.Instruction of physical model tests:

In every stage of physical modeling, the variables which are considered for cross shore sediment transport include:

- Wave height
- Grading of sediment materials
- Beach slope

By considering every one of the above 3 cases as variant, tests of physical model of this phenomenon are totally divided into 3 stage which are shown in tables 3 to 5.

2.6. Procedure of numerical model tests:

Similarly , in stage of numerical modeling, like the physical model tests, wave height, grading of sediment materials and beachslope were considered as variable parameters. Specifications of tests are indicated in tables 3 to 5. Litpack program and subsidiary program Litprof in numerical model were used. Most of existing numerical models including Litprof which is developed to predict changes of shore beds influenced by cross shore sediment transport have the structure outlined in Fig.6.

- Program domain of solution is zones of shore in which no alongshore current exists (assumption indicating lack of alongshore current existence in the region of solution).
- Lines parallel with bed level in every mode are parallel with shore line. Consequently, shore morphology at any moment is conforming to width of the cross section profile of bed.

  Since rate of sediment transport, in practice, changes with distance of point from shore, difference of erosion volume and sedimentation in different locations will cause change of bed profile. So, Litprof program is a time dependant model through which any changes in the surfzone (change in wave breaking point) and also pattern of final sedimentation are calculated step by step. Limit of this program is, not being able to distinguishing behaviors of sediments with more than one size of granule. In other words, the program lacks ability of diameter classification and granules sediment in a compound shore.

  Some special functions of subsidiary program Litprof are as follows:
- Evaluating and predicting response of shore profiles compared with different fluid conditions
- Consequences of shores nourishment (result of nutrition processes of shore)
- Determining zero points situations in shore structures

Also, this program is a tool for better understanding of coastal process of cross shore sediment transport and determining amount of retreating and advancing sediment transport in different conditions of shore.

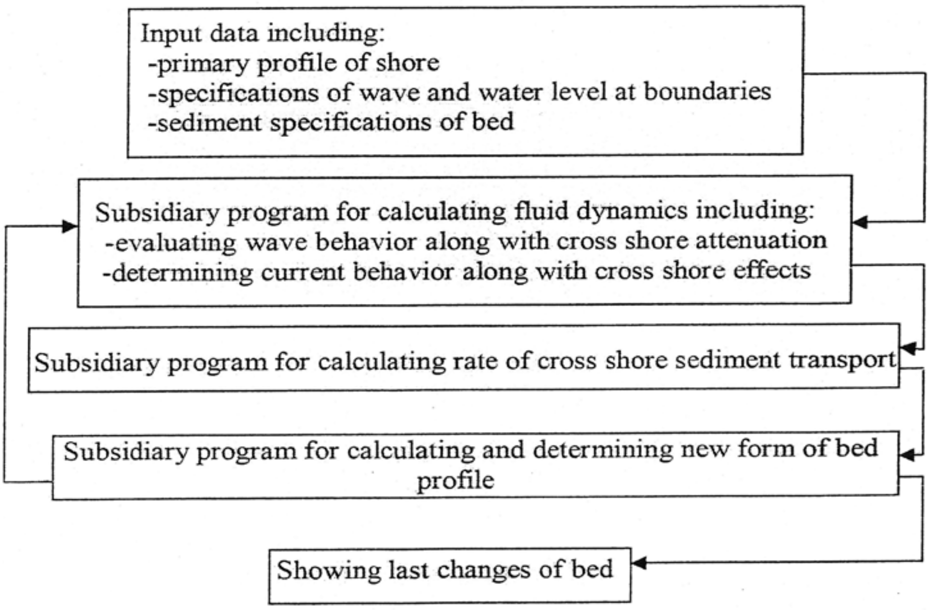

Fig. 6: Structure of litprof program.

Litprof program describes changes of bed profile influenced by process of cross shore sediment transport (caused by field effect of shore waves). Main assumptions of the program include:

Table 3: Tests specifications of physical and numerical models by changing grading of sediment materials.

Test Number	D50 (mm)	Slope	H_s (m)	T_s (s)	Test Duration(h)
D1s1 H4-1	0.16	1:12	0.25	2.0	0.5
D1s1 H4-2					1.5
D1s1 H4-3					3.0
D2s1 H4-1	0.35	1:12	0.25	2.0	0.5
D2s1 H4-2					1.5
D2s1 H4-3					3.0
D3s1 H4-1	0.87	1:12	0.25	2.0	0.5
D3s1 H4-2					1.5
D3s1 H4-3					3.0

Table 4: Tests specifications of physical and numerical models by changing shore slope.

Test Number	D50 (mm)	Slope	H_s (m)	T_s (s)	Test Duration(h)
D2s1 H4-1	0.35	1:12	0.25	2.0	0.5
D2s1 H4-2					1.5
D2s1 H4-3					3.0
D2s2H4-1	0.35	1:12	0.25	2.0	0.5
D2s2H4-2					1.5
D2s2H4-3					3.0
D2s3H4-1	0.35	1:12	0.25	2.0	0.5
D2s3H4-2					1.5
D2s3H4-3					3.0

Table 5: tests specifications of physical and numerical models by changing wave height.

Test Number	D50 (mm)	Slope	H_s (m)	T_s (s)	Test Duration(h)
D2s1H1-1	0.87	1:12	0.25	2.0	0.5
D2s1H1-2					1.5
D2s1H1-3					3.0
D2s2H2-1	0.87	1:12	0.25	2.0	0.5
D2s2H2-2					1.5
D2s2H2-3					3.0
D2s3H3-1	0.87	1:12	0.25	2.0	0.5
D2s3H3-2					1.5
D2s3H3-3					3.0
D3s3H4-1	0.87	1:12	0.25	2.0	0.5
D3s3H4-2					1.5
D3s3H4-3					3.0
D3s3H5-1	0.87	1:12	0.3	2.0	0.5
D3s3H5-2					1.5
D3s3H5-3					3.0

3.Comparison And Analysis Of Obtained Results Of Physical And Numerical Models:

Objective study of sediment phenomena such as cross shore sediment transport influenced by wave and current, often need making scaling of the shore and mentioned fluid conditions. This is when existence of laboratory limits, scaling effects and experimental errors, and obtained results of sampling accompanied with typical limitations, among which following cases can be referred to:

- Limitation in complete simulation of the phenomenon
- Physical approximation and replacing effect of dominant forces
- Limitation in full creation of environmental and fluid conditions(such as temperature of water and air, water density, bed condition etc.)

Also, in the present modeling, considering all existing factors, beach profile of the mentioned simulation was made and tested, and results of physical model was compared with those of numerical results as follows:

3.1. Effect of grading of sediment materials on cross shore sediment transport:

Resulted profiles of tests presented earlier in table 3, are obtained from winter profiles. This is when the spectra made in laboratory implemented more destructive pressure on simulated beach and led to formation of a bar. By maintaining waves production in laboratory, the made bar was moved towards the sea and got farther from the shoreline.

By increasing D_{50} of materials used in physical model tests, intensity of shore destruction decreased and consequently the longshore bar inclined towards the shore and bar height also decreased. In this stage, maximum height of longshore bar was about 12.5 centimeters and minimum height of that was about 8 centimeters. Figs. 7 and 8 show changes of beach profile with grading of bed materials.

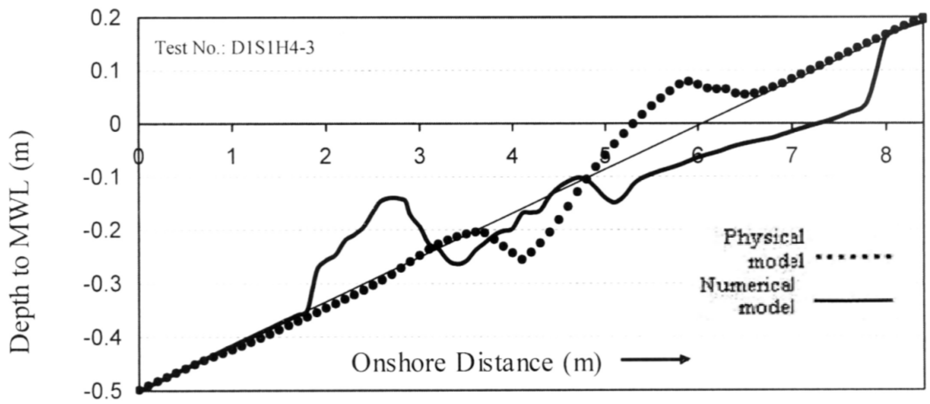

Fig. 7: Comparison of the results of physical and numerical models by changing grading of sediment materials (DISIH4-3).

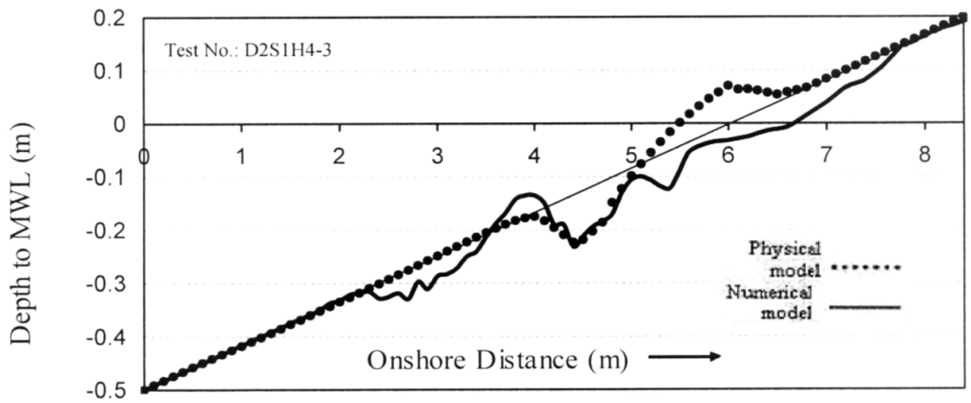

Fig. 8: Comparison of tests results of physical and models by changing grading of sediment.

Materials (D2S1H4-3):

3.2. Effect of beach slope on cross shore sediment transport:

In this stage, winter profile was obtained and by continuing production of waves in the laboratory, the longshore bar was moved towards the sea (see Nashaei et al, 2009)

By increasing the slope of simulated beach, intensity of shore destruction due to the returned current caused by breaking of waves became more intense. For this reason, water was muddy and caused retreating sediments towards the sea. In this case, the longshore bar was inclined towards the sea and its height decreased so that maximum height was about 10 centimeters and its minimum was about 7.5 centimeters. Figs. 9 and 10 show resulted change in shore bed with change of beach slope.

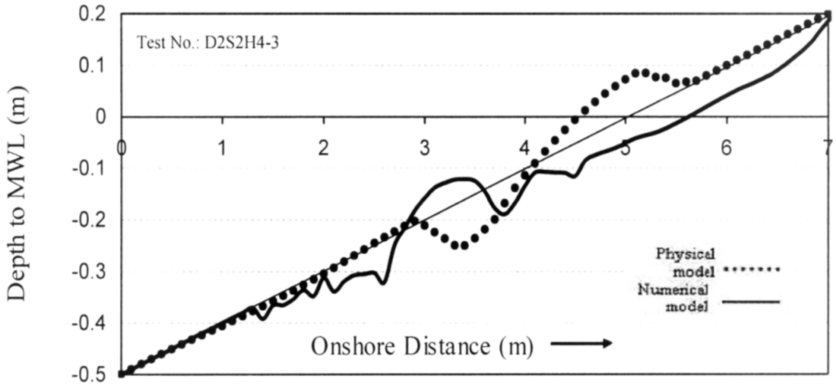

Fig. 9: Comparison of tests results of physical and numerical models by changing beach slope (D2S2H4-3).

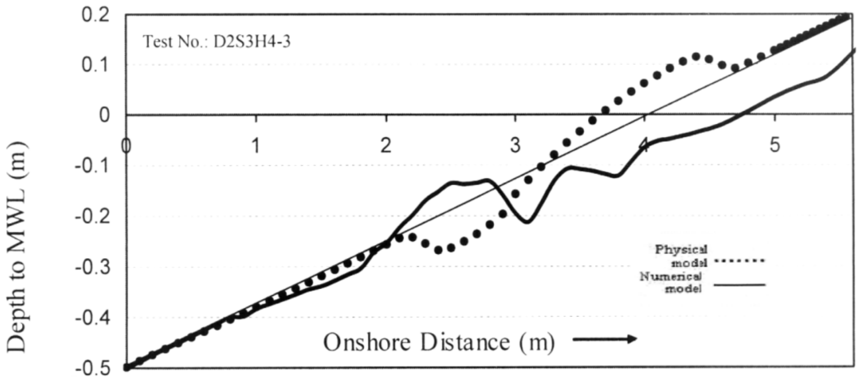

Fig. 10: Comparison of tests results of physical and numerical models by changing beach slope (D2S3H4-3).

3.3. Effect of wave height on cross shore sediment transport:

In this stage, in addition to winter profile, summer profile, was also obtained. Since occurrence condition for each one of the two profiles is mentioned, due to interaction of waves spectra with shore materials, so for materials with different specifications, occurrence condition of every one of two Profiles is probable. For mentioned tests in this stage, for D50 =0.87 centimeters, waves higher than 25 centimeters caused formation of winter profile and smaller waves caused summer profile.

In testes D3S1H4 and D3S1H5, winter profiles were formed and bar height were 8 and 10 centimeters, respectively. So, if wave heights become larger, destructive load to shore becomes more intensive.

In testes D3S1H3, D3S1H2 and D3S1H1, summer profiles were formed and the bar height was measured 9, 5.5 and 4.5 centimeters, respectively. So, by adding wave height in region of summer profile, bar height decreased. Figs.11 through 15 show how the shore bed changes by changing wave height.

3.4. Returnability of cross shore sediment transport experiments:

Phenomenon of cross shore sediment transport is a completely recursive phenomenon and shores are permanently subject to this shore line profile changes from winter profile to summer profile and vice versa.

Considering this matter, simulated shore with materials D50 =0.87 centimeters and slope of 1:12 was subjected to waves with height of 30 centimeters and period of 2 seconds and frequency of 3 Hz (test D3S1H5). The resulted profile was a winter one and led to formation of a longshore bar. In next stage, the obtained profile in test D3S1H5 was subject to waves with 10 centimeters height, period of 2 seconds and frequency of 3 Hz and with regard to tranquil nature of this wave, the bar made by the previous test was washed and the bar was formed in shore part and in other words, winter profile changed to summer profile (Fig. 16 and Fig. 17). The trivial difference in Fig.17 is because in shores, permanently due to repetition of cross shore sediment transport, density of suspending load increases and causes more erosion in beach profile.

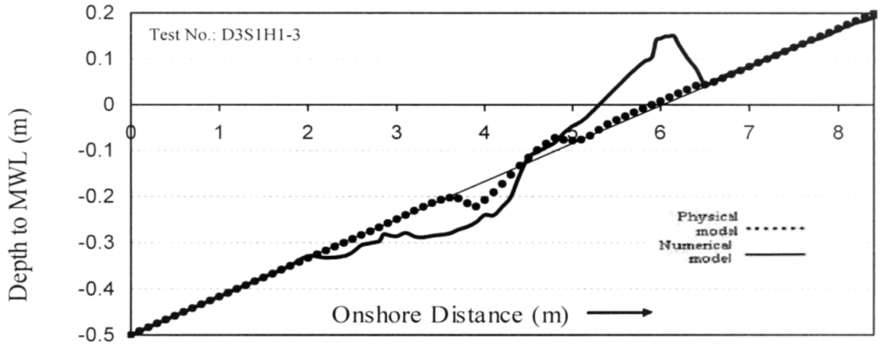

Fig. 11: Comparison of tests results of physical and numerical models by changing wave height (D3S1H1-3).

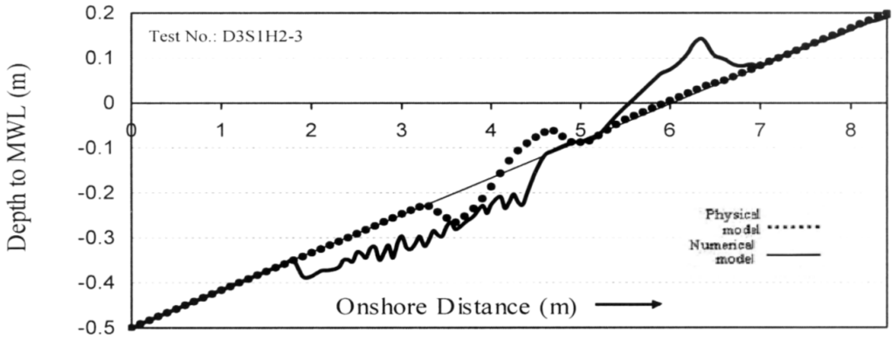

Fig. 12: Comparison of tests results of physical and numerical models by changing wave height (D3S1H2-3).

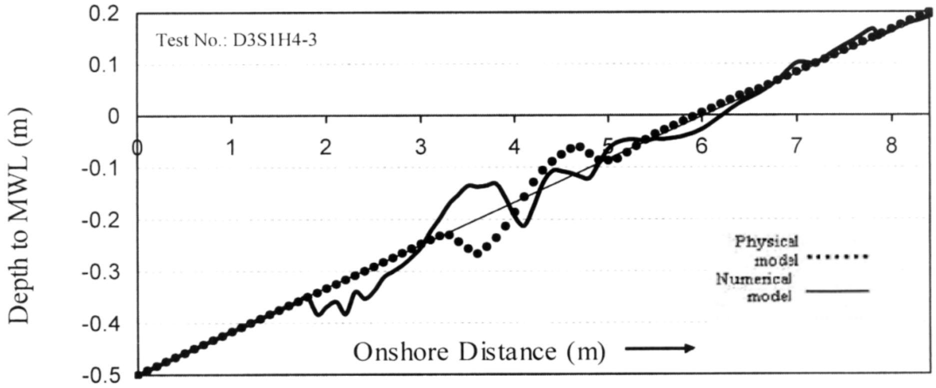

Fig. 13: Comparison of tests results of physical and numerical models by changing wave height (D3S1H4-3).

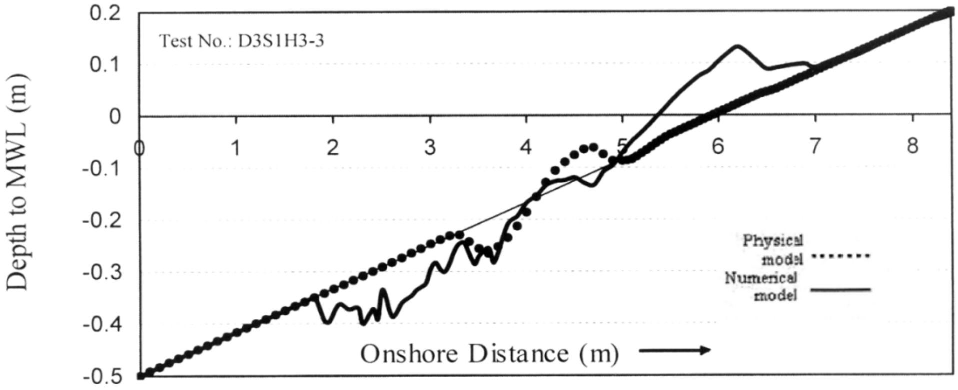

Fig. 14: Comparison of tests results of physical and numerical models by changing wave height (D3S1H3-3).

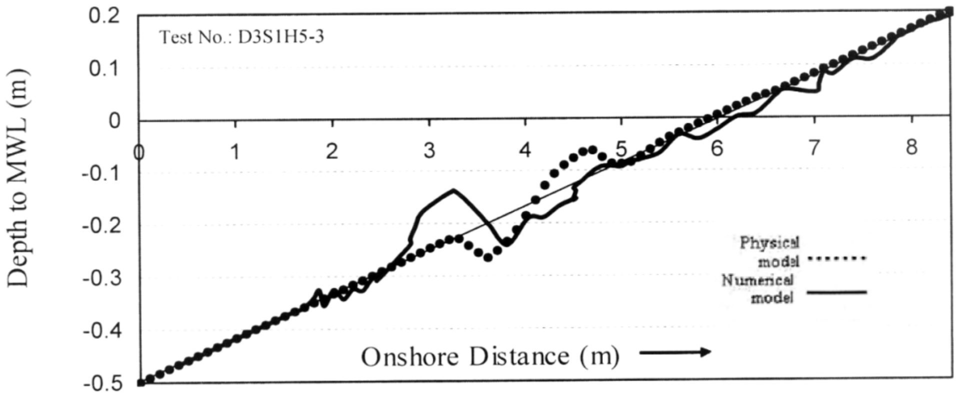

Fig. 15: Comparison of tests results of physical and numerical models by changing wave height (D3S1H5-3).

3.5. Comparison of the results of physical and numerical models:

Results of comparison of the two physical and numerical models which show the phenomenon of cross shore sediment transport are indicated in Figs. 9 through 16. All tests of numerical model have resulted in summer profile or in other words, the subsidiary Litprof program, with its simplifying assumptions, for shores with material D_{50} =0.16, 0.35 and 0.87 centimeters considers all waves of 30,25,20,15 and 10 centimeters high as summer waves. Of course, Litprof program for relatively higher waves which are similar to nature waves have resulted in winter profile, too. In this way, it seems that the mentioned subsidiary program for waves used in laboratory is not calibrated. Litpack numerical model can only predict real conditions and its precision in condition of physical model due to effects caused by scaling effects is very low. So, practical conforming of this model with laboratory conditions is not possible; therefore, other numerical models should be used. It seems that implementing coeffcients for conforming this model covered laboratory conditions, but this demands more comprehensive studies which is not the main aim of the present research.

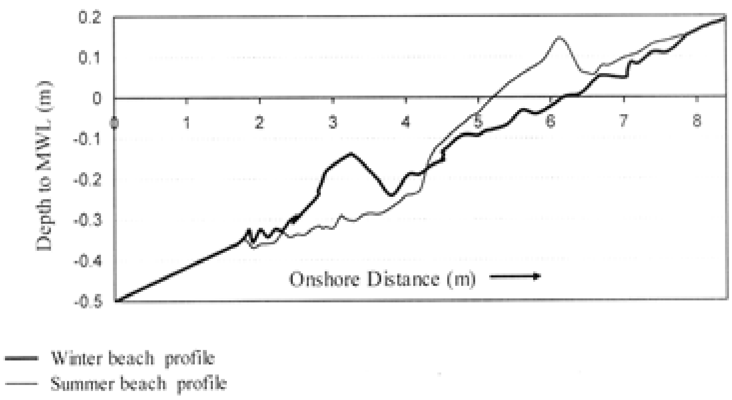

Fig. 16: Returnability of cross shore sediment transport.

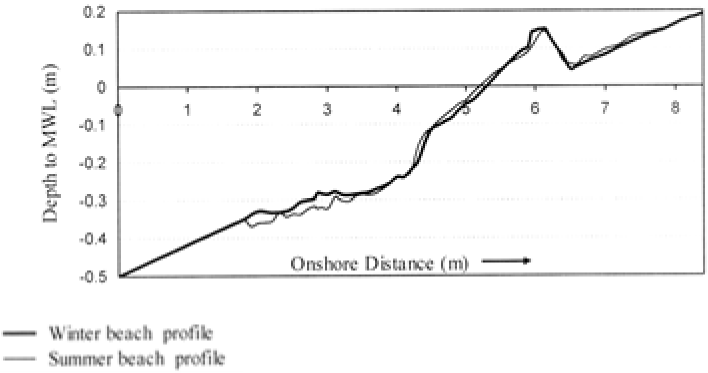

Fig. 17: Comparison of two summer profiles (the returnability of cross shore sediment transport).

4. Recommendations:

For future studies, it is recommended that in a more developed laboratory conditions by producing higher waves, winter profile are modeled and by determining bed profiles in the vicinity of protective structures such as seawalls or breakwaters, precision and efficiency of models in predicting transformation of shores bed are considered.

ACKNOWLEDGEMENT

Hereby, authors of this article express their deep gratitude of highly esteemed official managers in Water Research Center of Power Ministry that have had full cooperation in performing tests and other stages of project.

REFERENCES

Andrw D. Short, 1999. "Hand Book of Beach and shore face marphodynamics", john wiley.

Dean, R.G., 1991. "Equilibrium beach profiles: characteristics and applications" journal of coastal research, CERF, 7(1): 53-83.

Hoque, M.A., T. Asano, M.A. Lashteh Neshaei, 2001. "Effect of Reflective Structures on Undertow Distribution" , proceedings of the forth international Symposium Waves, California, USA, 2: 1042-1051.

Kamphuis, J.W., 1991. "Alongshore Sediment Transport Rate", Journal of Waterway, Port, Coastal and Ocean Engineering Div. ASCE, 701 117, 6: 624-640.

Lashteh Neshaei, M.A., T. Asano, 2000. "The Effect of Reflective Structures on the Distribution of Undertow in the Surfzone", Proceedings of 5th International Conference on Civil Engineering, Ferdowsi University of mashhad, Iran, 4: 54-63.

Lashteh Neshaei, Mir Ahmad and Pashazadeh, Ali, 2001. "Investigation of Potential of scouring in Shores of Caspian Sea", Proceeding of the International Conference of Hydraulic Structures, Shahid Bahonar University, kerman, Iran, First Volume, pages 561-570.

Lashteh Neshaei, M.A., 1997. "Beach profile Evolution in Front of Partially Reflective Structure". P.H.D. thesis, Imperial College, University of London.

Litpack, "Litpack Manual Set", (1996).

Neshaei, M.A.L., M.A. Mehrdad and M. Veiskarami, 2009. "The Effect of Beach Reflection on Undertow", Iranian Journal of Science & Technology, 33(B1): 49-60.

Shore Protection Manual, 1984. "Coastal Engineering Research Center", Department of the Army, Waterways Experiment Station, Crops of Engineering, USA.

Soresen, R.M., 1993. "Basic Wave Mechanics for Coastal and Ocean Engineers", John Wiley, F. sonsns, INC. USA.