NEAR EAST UNIVERSITY

COMPARISION OF BEACH PROFILE CHANGES WITH AND WITHOUT VEGETATION

Presented by

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Master thesis

DEPARTMENT OF CIVIL ENGINEERING

NICOSIA – 2009

ABSTRACT

Comparison of beach profile changes with and without vegetation

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January 2009

An experimental investigation of coastal bar and erosion generated by the action of regular and irregular waves under protection and non-protection vegetation were carried out in laboratory channels. Natural beach sand, with medium diameter of 0.38 mm and specific gravity of 2.65, was used in this study. A 1:5 initial beach slope was selected for the model tests. Different wave groups were generated over the initially flat beach, and the characteristics of coastal erosion and bar geometry such as erosion area, bar area, distance of center of masses, were measured.The relationship between wave parameters and beach morphology were analyzed and theoretically defined in relation to vegetation and non-vegetation conditions.The relationships of these functions followed good trends with the derived dimensionless number.

ACKNOWLEDGMENT

I would like to express graduate to all those who gave me the possibility to complete this thesis.

First, thanks for god.

Second, I would like to express sincere gratitude to my thesis advisor Assoc. Prof. Dr. Umut TÜRKER for his excellent guidance and advice, and his effort over this thesis.

Third, I would like to thank to Prof. Dr. Sedat Kabdaşlı, and Asst. Prof.Dr. Oral Yağcı who were involved in laboratory works and supplied the necessary data required for this thesis.

Fourth, I also would like to express sincere gratitude to my family, for gave them me all type of support to finish my master.

Finally, I would also like to thank my managers in the work, Santa Fe construction, for them support and for gave me the time to finish this thesis, and I would also like to thank all of my friends for help.

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NOMENCLATURE

H_0	Deep sea wave height
H_s	Significant wave height
L_0	Seep sea wave length
m	Beach slope (tan ß)
D_{50}	Mean sand diameter
Ω	Distance of center of masses
H/wT	Fall speed parameter
H_e	Vertical distance between the equilibrium point and still water level (swl)
X_s	Horizontal distance between the original point of The shoreline and the final shoreline
H_m	Vertical distance between the original point of the shoreline and the maximum upper erosion point
H_d	Maximum erosion depth
V_e	Volume of the erosion
G_{sp}	Dimensionless specific gravity of sand
ζ	Surf similarity parameter
D_p	Sand diameter
Ψ	Intensity
D_w	Actual energy dissipation rates per unit volume
D_{eq}	Equilibrium energy dissipation rates per unit volume
K	Transport rate parameter
D_s	Net sediment transport rate
q_s	Sediment load transport resulting from destructive forces during the wave breaking process

CHAPTER 1

INTRODUCTION

The sediment transport and corresponding beach profiles are the vital factor for any kind of coastal and seashore structures. The volume, the direction and the characteristics of sediment transport and beach profile formation depends on sea state characteristics such as wave height, period and length; morphological characteristics such as beach profile, vegetation cover and material properties; and artificial characteristics such as river basin structures and navigation purposes. Beach profiles if undisturbed usually follows stable behavior in which any external or internal interference causes erosion or deposition of the profile. The profile changes are generally monitored through physical, numerical or prototype models. The previously carried out works have shown that the results obtained by physical modeling generates better results with respect to those by the prototype model. (Murat et al., 2006). On the other hand, numerical modeling is not satisfactorily fitting due to complexity of coastal hydrodynamics and the results of the models are still not reliable. (Dean, 1985; Kamphuis, 1985; Güler, 1985; Lakhan and Trenhaile, 1989). The results of physical models presenting effective parameters with dimensionless units are easily applicable to field problems, minimizing experimental errors originated from laboratory conditions (Hallermeier, 1985; Wang et al., 1994).

Beach profiles are usually exhibiting concave shapes owning steep slopes at coastal regions followed by mild slopes towards offshore. The concavity of coastal profiles has been verified through a large number of laboratory (Waters 1939; Rector 1954; Saville 1957; Türker and Kabdaşlı, 2006) and field experiments (Bruun,1954; Dean, 1977; Türker and Kabdaşlı, 2009).

The concave beach profile is usually reached if the profile is exposed to constant wave conditions for a sufficiently long time. The cross-shore storm wave attack however, demolishes the concavity. Wave energy from open sea transfers intensive sediment to the area between the breaking zone and coastline. This causes high sediment erosion rates in onshore, offshore and long shore directions, resulting in drastic beach profile changes. One such change is well known storm profile or winter profile, which is caused by a dominant sediment transport in the cross-shore direction. This process continues along with the storm and eventually stops when sand grains, accumulating at a point offshore, form an offshore bar. A significant process during this bar formation is the transportation of sediment particles caused by intensive breaking waves. The modeling of offshore bar profile, sediment transport and evolution process is formulated in various ways in a number of different laboratory studies (Özölçer, Silvester, Günaydın etc.). Dean (1995) presented the energy dissipation related transport rates, assuming that offshore transport continues until the wave energy dissipation per unit volume of water is constant and is equal to a pre-described value over the entire surf zone. Later, Türker and Kabdaşlı (2004), assuming that the distances between the erosion and deposition profiles are directly related with the energy dissipation rate on the beach profile use Dean's model defining the position of an offshore bar with respect to its center of mass. Roelvink and Broker (1993) classified the models having cross-shore profiles according to theories, and analyzed the disadvantages of the models. Schoonees and Theron (1995) have compared 10 models for cross-shore sediment transport and beach profile and classified the models as fine, average and poor. Various researchers have carried out studies on linear and non-linear cross-shore sediment transport models for a variety of beach profiles. During the studies, new experimental and previous data were compared with previous models in the literature (Zheng and Dean, 1996; Leont'yev, 1996; Larson, 1996; Rakha et al., 1997). Silvester and Hsu (1997) analyzed beach profile parameters by non-linear regression techniques using various experimental data obtained from previous works and proposed an equation for the erosion parameter. Hsu (1998) performed experimental and theoretical studies to determine the geometry of offshore bars and suggested some equations for erosion parameters. Larson et al. (1999) studied the equilibrium beach profiles under breaking and non-breaking waves. Three different models were developed to derive the profile shapes under non-breaking waves. Consequently, it is apparent that considerable amount of research has been performed on the behavioral and geometric characteristics of erosion profiles under stable and unstable conditions pointing out that the flexible and impressible properties of coastal regions are offering storm wave protection.

The experiments and field surveys are all agreed that beach acts to absorb wave energy through the movement of countless grains of sandy particles. The remaining energy will cause erosion of the beach profile. Doing so, the beach becomes the first line of defense against storm driven coastal waves. The goal of beach protection is to increase the wave energy absorption so that the beach will have the quantity of sand needed reduce coastal erosion. The most effective ways to protect beaches include dunes, vegetation, habitat protection areas, artificial reefs, groins etc. Different protection techniques and devices have been studied and developed.

The vegetation population plays a major ecological role with beneficial effects along the oceans, estuaries and lagoon systems (Boudouresque, 2004). Meadows of vegetation shelter a high biodiversity population, contribute to improve water quality and prevent coastal erosion (Gacia and Duarte, 2001) and regulate biogeochemical fluxes along the coasts (Romero et al., 1994; Gacia et al., 2002). In the last decade there has been a growing interest in studies, which attempt to understand the impact of vegetation on coastal erosion. This surge of interest is a new approach to a concept which tries to solve coastal and hydraulic engineering problems taking ecological balance into account. One of the primary motivations of vegetation studies is to understand related transport processes in natural environments, such as the transport of pollutants, heat, sediment, etc. In current literature, it has been generally agreed that vegetation increases flow resistance, controls the mean and turbulent flow structure in channels and coastal regions and thus, modifies sediment transport and deposition (Yen, 2002; Nepf and Vivoni, 2000). Several studies have already been performed to analyze the flow resistance of rigid emergent vegetation. In all those studies the vegetation was simulated by a group of cylinders of the same height and diameter at a regular spacing (Meijer and Van Velzen, 1999; Nepf, 1999). In another approach, it was claimed that the flow resistance depends on the density of the vegetation as well as bending stiffness of the species. The density of vegetation is defined as the frontal area of submerged vegetation projected onto a plane perpendicular to the direction of flow per unit volume of flow (Dudley et al., 1998). Knowledge of interaction between vegetation and incident waves helps a better understanding of ecological and geomorphological processes in coastal waters with particular respect to coastal defence management. Kobayashi et al. (1993) proposed an analytical expression for the submerged vegetation case and tested the phenomena using experimental data collected from experiments conducted in a wave tank roughened with artificial vegetation elements. This was followed by Ostendrop (1995), who investigated the bio-mechanical resistance of lakeside Phragmites australis. Later on, the effect of different vegetation species (i.e. Laminaria hyperborea, mangrove forests) on wave propagation was studied by the other researchers (e.g. Mork, 1996; Andersen et al., 1996; Massel et al., 1999; Lovas and Torum, 2001). All these studies, while providing insight to the details of flow through vegetation, are mostly analyzed to understand the flow regime in open channels and especially in flood plains. The damping of waves by submerged vegetation and the impact of the kelp harvesting on beach erosion are the two significant contributions on coastal studies (Dubi, 1995; Lovas, 2000). Important developments in the understanding of effect of vegetation on sea bed morphology and the interaction between the waves, sediment transport and vegetated area can be achieved from extensive studies in controlled laboratory conditions. The controlled laboratory environment will allow the measurement of wave parameters that are not easily measurable at natural sea conditions. So far, in the absence of vegetated area, a great deal is known about geometric characteristics of shore erosion under the direct effect of wave climate. Here, in this thesis, the protective effect of vegetation is analyzed by comparing the rate of erosion and bar formation while the same wave climate conditions are applied to two different beach profiles, one with no protective measurements while the second one protected with emergent vegetation cover. To do so, the study presents the determination of coastal erosion and coastal bar and distance of center of masses of barred profiles under regular and irregular waves. The analyses are followed with same climate but different protection conditions, vegetation and non-vegetation.

CHAPTER 2

MATERIAL AND METHOD

2.1 Introduction

The approach consisted on a comparative experimental study, in which different environmental variables (beach erosion, offshore bar formation, distance between the center of masses of erosion and bar profiles) under different wave climate conditions were determined on a predefined beach profile receiving storm waves. To take into account the strong effect of storm waves experiments were performed in two different flumes. (vegetated and non-vegetated) under the same wave forces. In each experiment artificial storm waves possessing high energy haul the sand from the beach face of profiles and develop offshore bars. Depending on the intencity of vegetal cover protecting the beach profile, the size of offshore bar and the erosion in front of it was changing.

2.2 Experimental setup and procedure

Interactive behavior between the sea and beaches is a complex process, which is often poorly understood since the ecosystem is rare and unique. Sometimes, the coastal areas are covered by vegetation located at beaches or located in the transition zone between dunes and saline areas. This vegetal cover has protective behavior on beach profiles enlarging the complexity to understand the physical behavior of dynamic beach profile behavior. These complex analyses are better worked out under macroscale analysis, which utilizes heuristic arguments that provide reasonable solutions. The best understanding of coastal processes through macroscale analysis, including the protective behavior of vegetal cover requires effective measures on experimental studies governing the behavior of the vegetal cover, sand and the water.

The principal physical mechanism of coastal dynamics must be described in order to model the changes at a coastal zone. Erosion is one of the main by product of these dynamic activities which results due to the movement of individual grains of sand with the forces created by the storm waves. These forces are constantly changing. The effects of erosion during the storms are balanced by subsequent accretion and dune building in calmer conditions. To achieve this, it is necessary to study the profile evolution under different wave climates and vegetation densities. However, to establish cause and affect relationship between the governing factors and the profile response, it must be possible to delineate these relationships. Use of field profile data as a basis for developing a physical model is extremely difficult due to the complexity and randomness of naturally occurring conditions and cost of data collection. Laboratory facilities provide an environment where such investigations may be carried out efficiently at a temporal scale.

The experimental investigations on beach profile changes and protective effect of vegetation cover were conducted in the Hydraulics Laboratory of Istanbul Technical University. Two series (A and B) of experiments were carried out to investigate the influence of vegetation and non-vegetation on bed load transport at coastal zones under storm wave conditions. The result of bed load transport was analyzed by erosion and bar at the coastal zone. The series 'A' experiments divided for two parts were performed under vegetation and non- vegetation condition under regular waves, (i.e. constant significant wave heights and periods) consisting of fifteen tests each possessing different wave heights and periods. The series 'B' experiments divided for two parts were performed under vegetation, non-vegetation condition under irregular waves, displaying Pierson–Moskowitz wave spectrum. Fourteen tests were performed in series 'B'. In order to check the validity of the experimens irregular wave data ratios between wave height statistics obtained during the experiments (measured and analyzed) were compared with ratios between wave height statistics derived from Rayleigh distribution (Goda, 2000; Dean and Dalrymple, 1991). Ratios of wave height statistics showed that the generated waves in the flume fitted Rayleigh distribution properly. Glass-sided wave flumes with dimensions

24x1x1m and 22x1x0.8m and were used to generate irregular and regular waves respectively (Figs. 1 and 2).

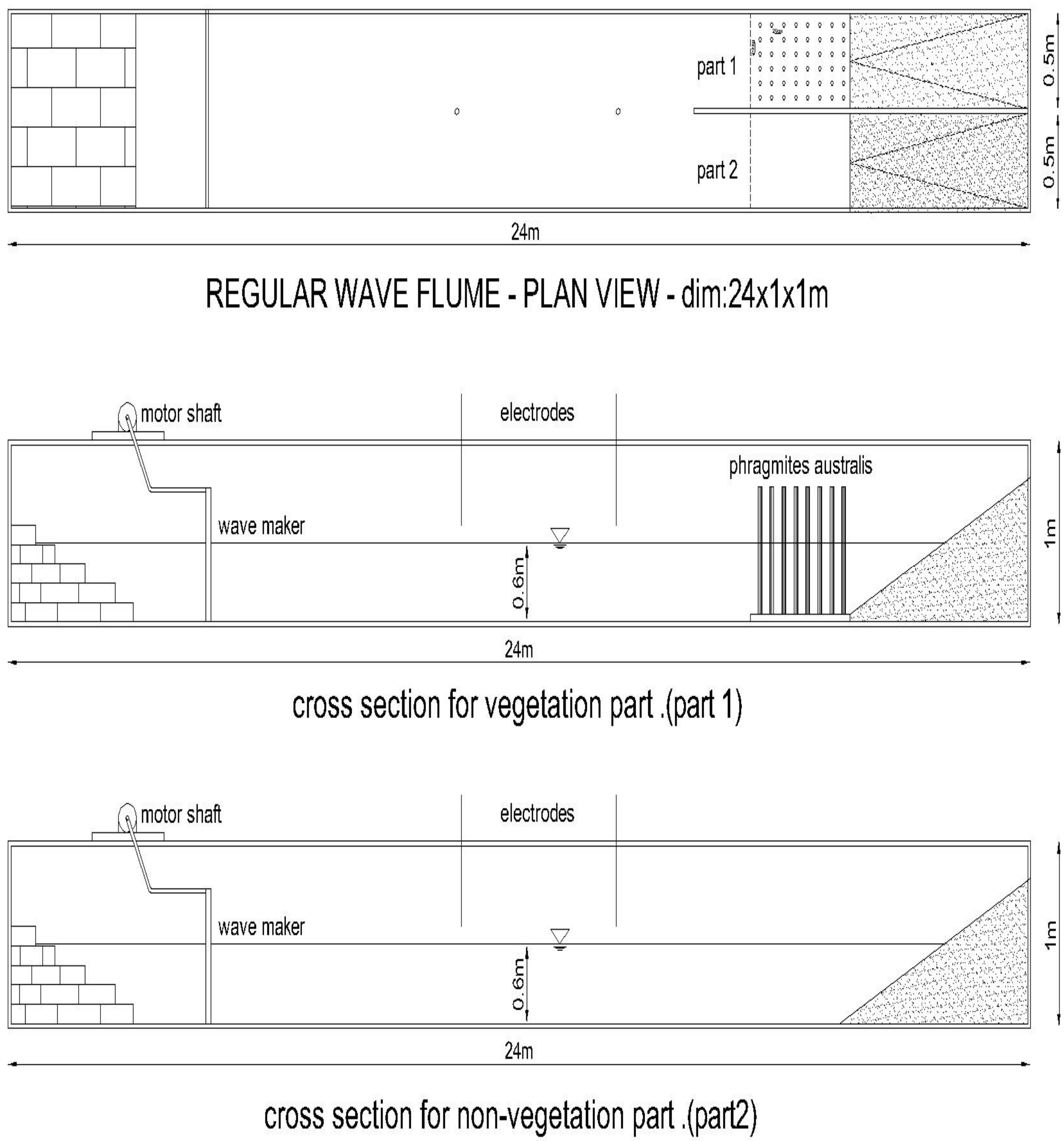
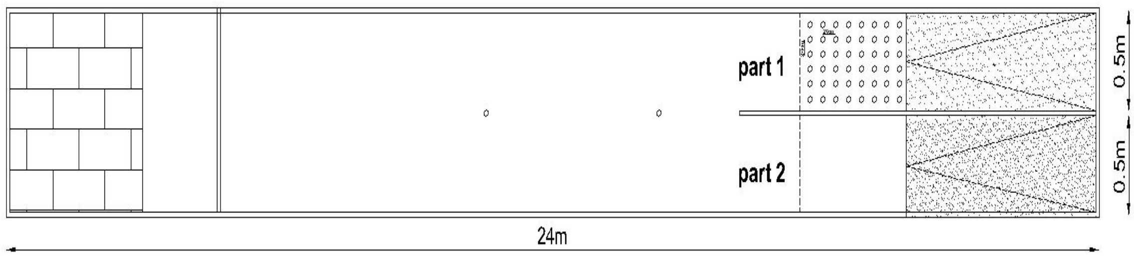
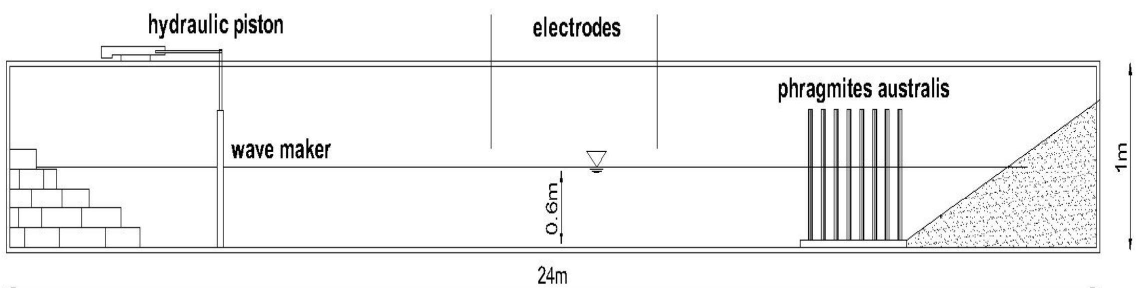


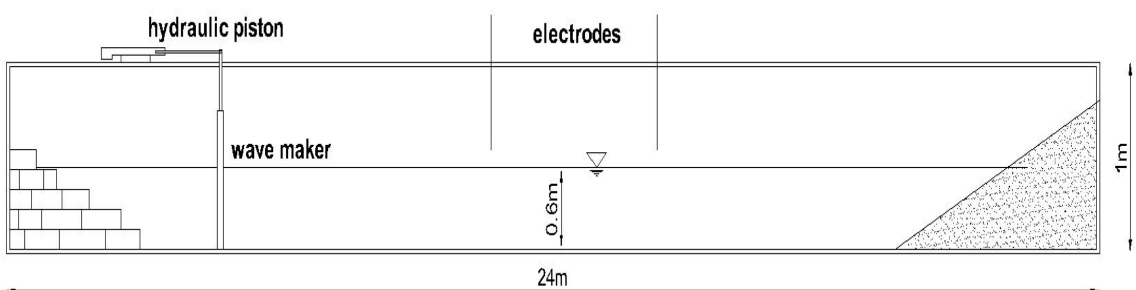
Fig.2.1 .Series A .Experimental setup of regular wave channel



IRREGULAR WAVE FLUME - PLAN VIEW - dim:24x1x1m



cross section for vegetation part .(part 1)



cross section for non-vegetation part .(part2)

Fig.2.2 .Series B .Experimental setup of irregular wave channel

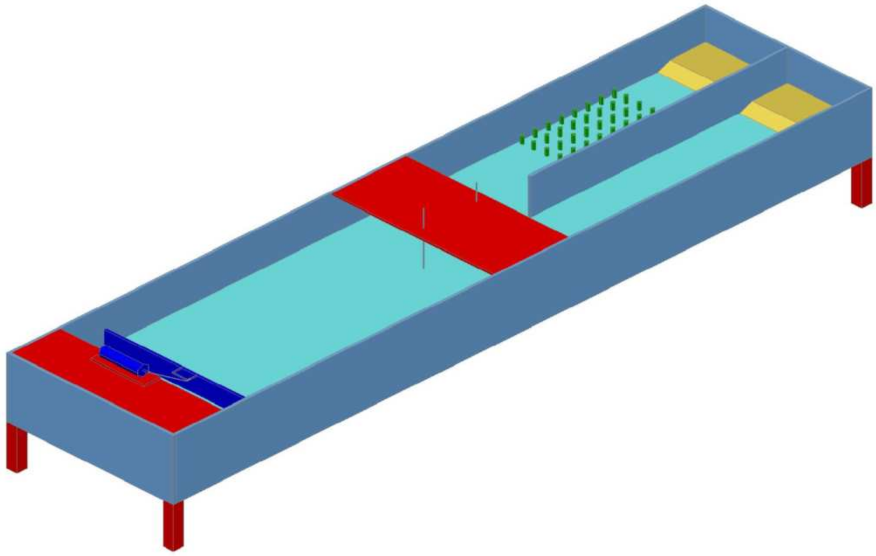


Fig.2.3. 3d .series A .Experimental setup of regular wave channel

In series ‘A’ experiments, the waves in the tank were forced by a vertical paddle installed at one end and connected through a mechanical drive to a precision motor. The paddle was oscillated with a prescribed amplitude and frequency, thus generating periodic progressive surface waves. When these waves reached the end corner of the flume they passed through the vegetated area in the first part and non vegetation area in the second part breaking and having significant loss in amplitude and frequency. The irregular waves in series B were generated by a computer controlled wave maker, which is capable of generating waves displaying the Pierson–Moskowitz wave spectrum. The still water depth of regular waves and irregular waves was 0.60 m. The sediment used in the tests was non-cohesive sand with a median grain size of 0.38 mm. The slope of beach profile prior to each test was kept constant at 1V:5H. Before starting each experiment, the sand bed was leveled and the location of the vegetated area was checked to ensure identical conditions during all the experiment stages. Real reeds (Phragmites australis—without foliage), with a diameter of 5 mm were employed throughout the experiments for the emergent case. The spacing between each vegetative element was taken as 20 mm in the cross-stream wise and 20 mm in the wave direction. In the experiments, 7, 15, 30, 45 and 60 rows (in the wave direction) of reeds were tested. A wooden array system was utilized to mount the vegetative elements (Fig. 3). The wave gauges were fixed in their assigned positions before the wave maker was turned on to generate waves. Wave characteristics were measured at offshore, before vegetation and while entering into the vegetation zone. One wave gauge was positioned 5 cm behind the vegetated area and the other wave electrode was positioned at an offshore location. The location of this electrode was in the centerline of flume cross-section and 1.5 m away from the vegetated zone. Each test started as soon as the waves were generated towards the vegetated and non-vegetation area and the primary result of each test was the final storm beach profile accomplished as long as the dynamic stability was attained.

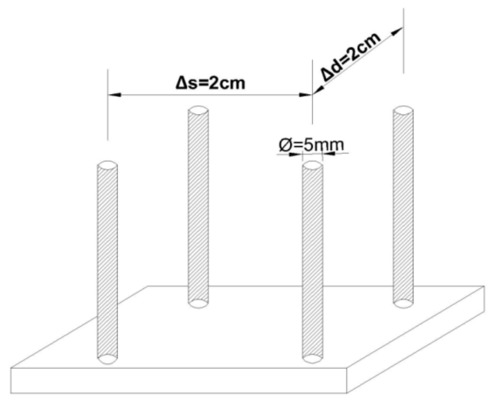


Fig.2.4 .Schematic representation of a single of vegetation distribution attached on wooden array

2.3 Characterization of vegetal cover

In order to observe the protective capability of reeds on beach profile, different number of reeds was used in front of the beach profile, in the direction of incoming waves. The physical effect of the vegetated area is described by using the number of reeds, the distances between each reads and the area occupied by the reeds. Thus, a dimensionless parameter named ‘vegetation parameter’, ψ, was developed to represent the effect of increased number of reeds on waves and coastal profile.(Turker et al.2006)

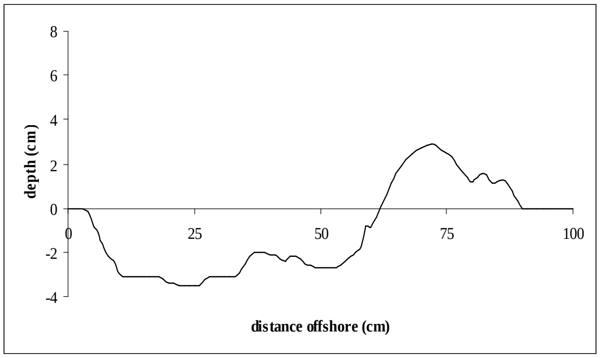
$$\psi = n\frac{\text{Ø}^2}{\Delta d \Delta s} \quad (1)$$

Based on the nomenclature given in Fig. 2.4, Ø is the mean diameter of the reeds, n is the number of reeds involved during each experiment, Δs and Δd are the spacing between two adjacent reeds parallel and perpendicular to incident wave direction, respectively. The vegetation parameter, therefore, represents the magnitude of vegetated area defined by the amount of reeds per unit grid area.

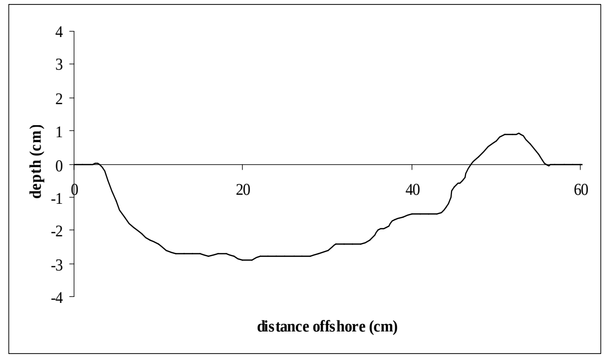
2.4 Experimental results

Storm waves approaching to the shore breaks and dissipates all their energy. The energy causes the beach to change its shape all along the experiments. To absorb the wave energy, beaches give up sand to the waves, which carry it offshore and drop it on the bottom. This raises the offshore floor and flattens the overall profile of the beach. Storm waves then shoal and break further offshore, minimize the erosive effects. This typically happens in response to shifts in wave energy. The beach profile then recovers from these natural changes when smaller waves move the sand back onto the beach, in other words, when the vegetation density is high to capture the wave energy. Following tables show the resultant beach profile after each experiment for irregular and regular wave conditions.

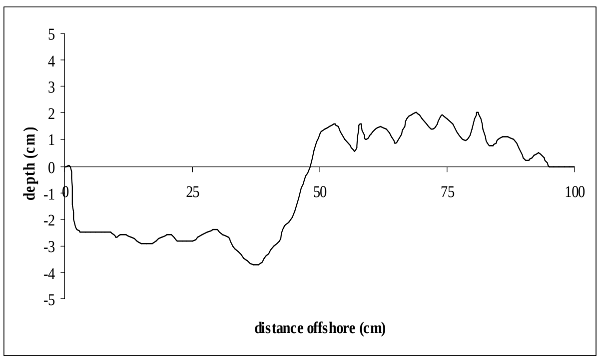
Table 2.1. The Beach Profile formations at the end of Experiments S1 to S8



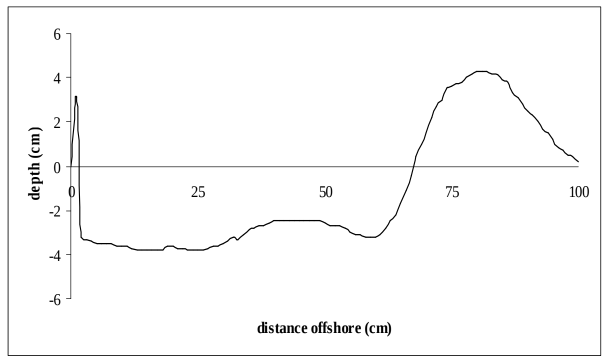
The resultant profile of Exp. S1



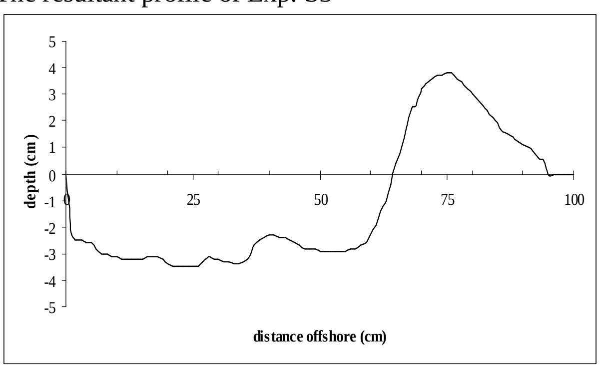
The resultant profile of Exp. S2



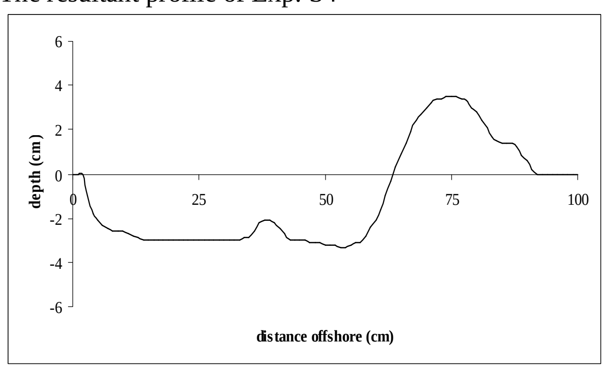
The resultant profile of Exp. S3



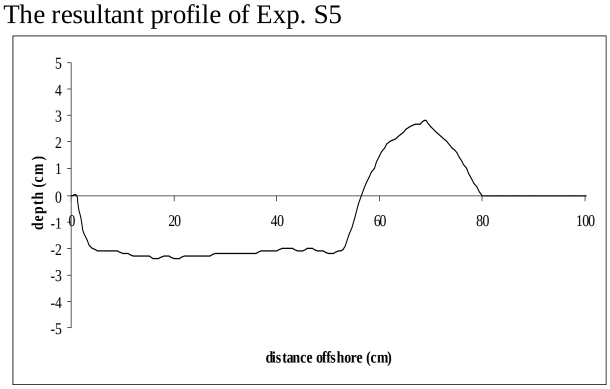
The resultant profile of Exp. S4



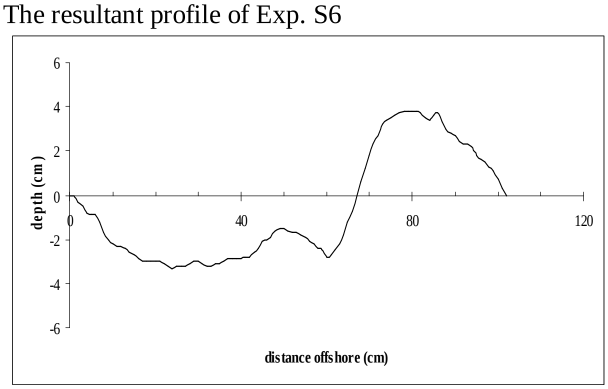
The resultant profile of Exp. S5



The resultant profile of Exp. S6

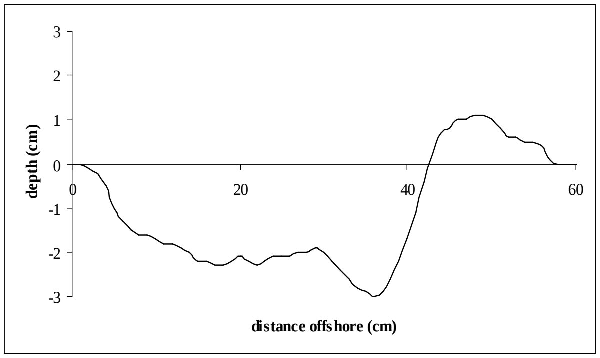


The resultant profile of Exp. S7

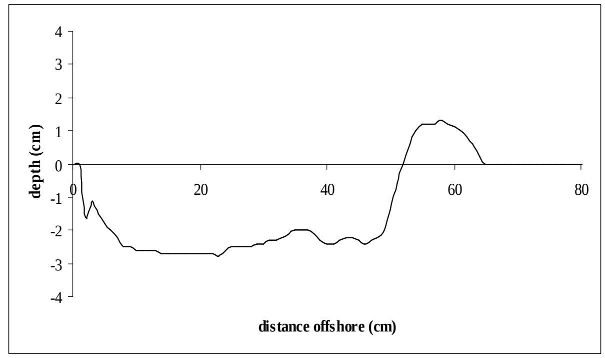


The resultant profile of Exp. S8

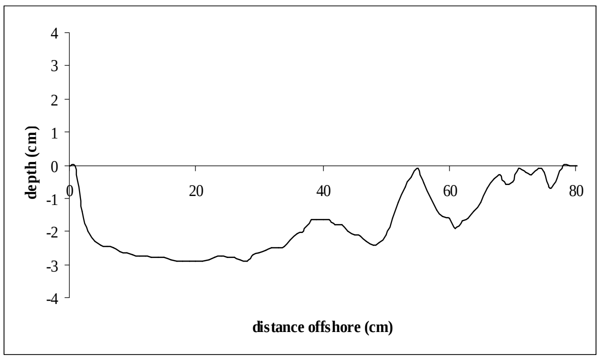
Table 2.2. The Beach Profile formations at the end of Experiments S9 to S15



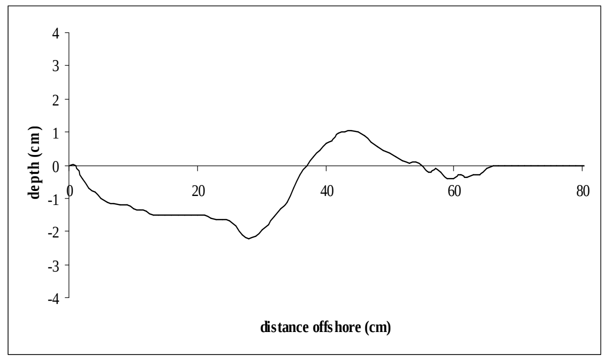
The resultant profile of Exp. S9



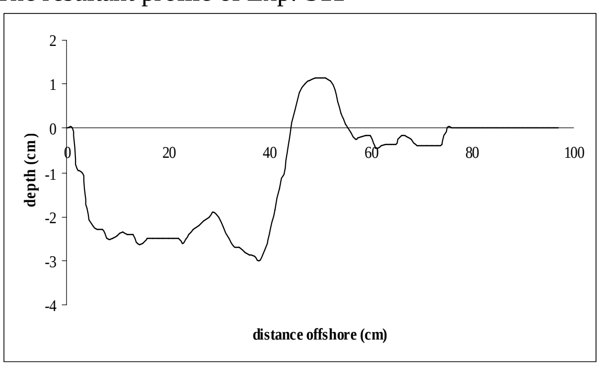
The resultant profile of Exp. S10



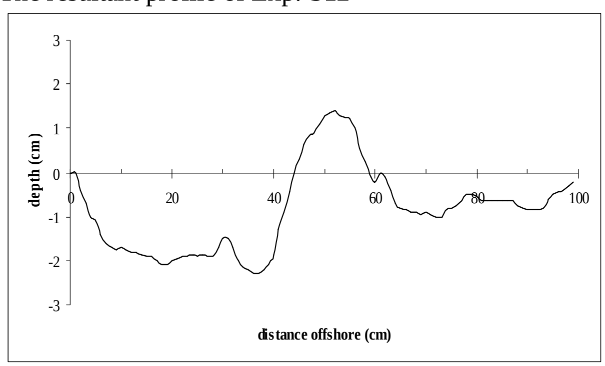
The resultant profile of Exp. S11



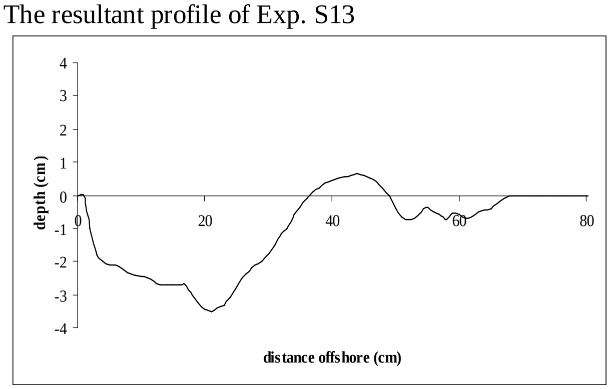
The resultant profile of Exp. S12



The resultant profile of Exp. S13

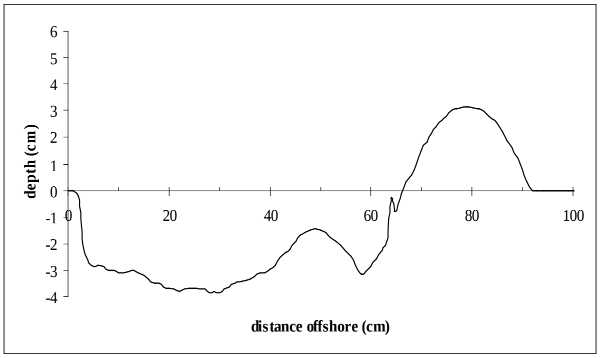


The resultant profile of Exp. S14

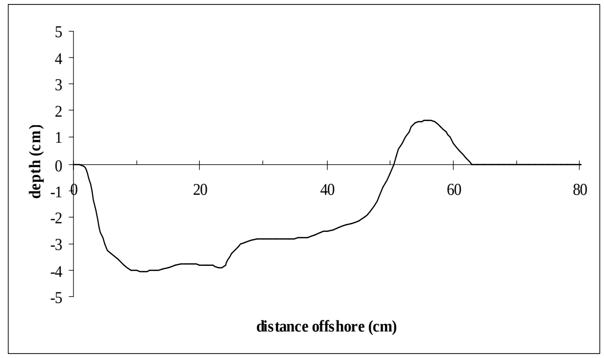


The resultant profile of Exp. S15

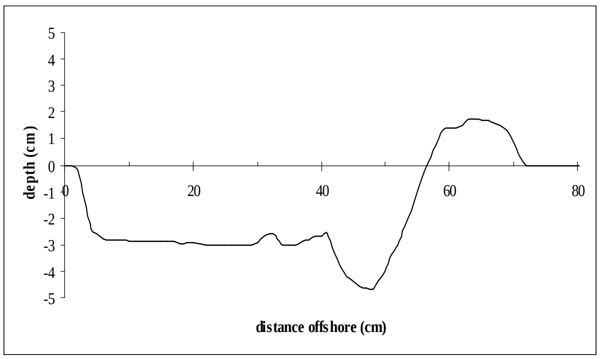
Table 2.3. The Beach Profile formations at the end of Experiments W1 to W8



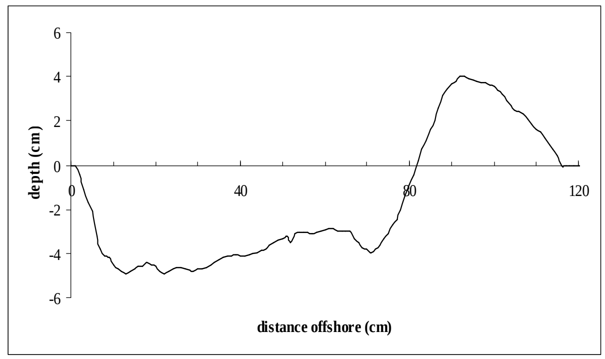
The resultant profile of Exp. W1



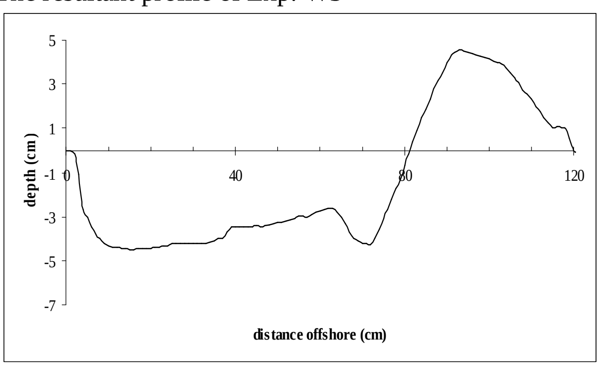
The resultant profile of Exp.W2



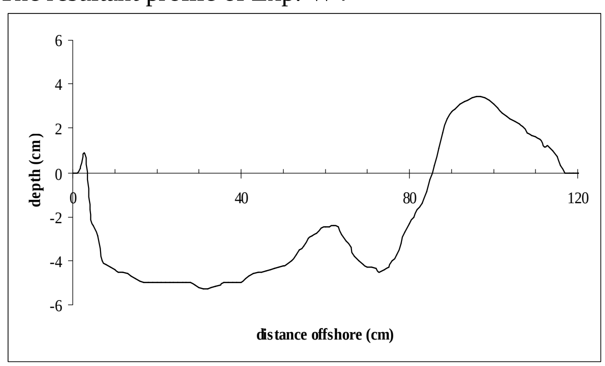
The resultant profile of Exp. W3



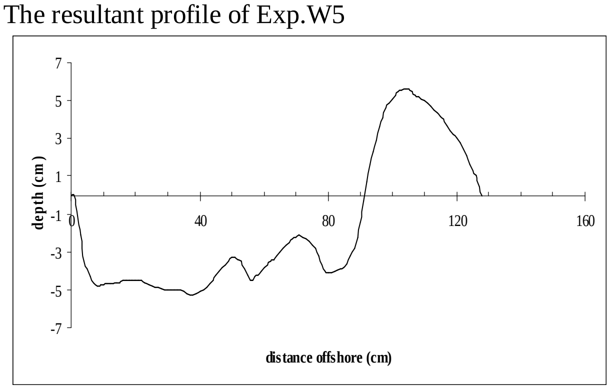
The resultant profile of Exp. W4



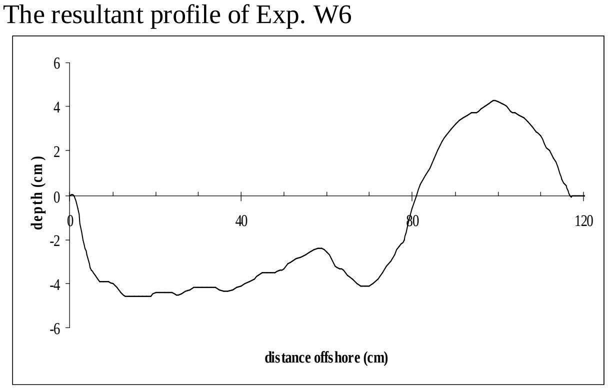
The resultant profile of Exp.W5



The resultant profile of Exp. W6

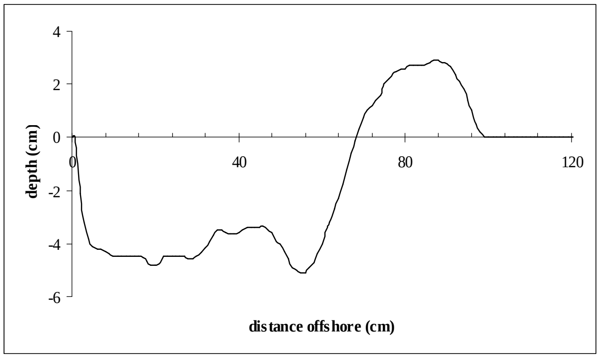


The resultant profile of Exp. W7

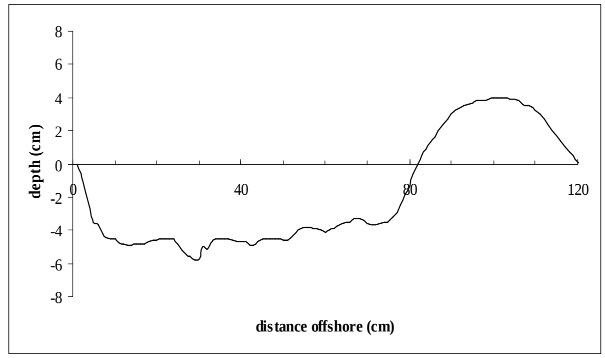


The resultant profile of Exp. W8

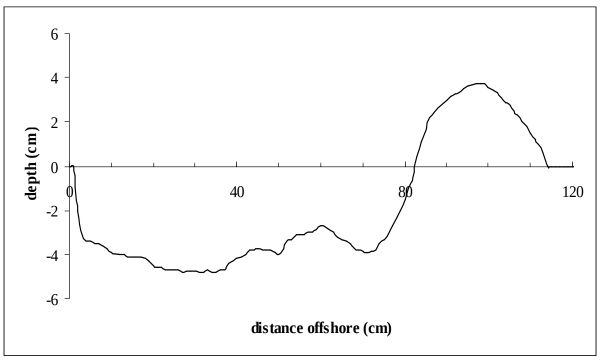
Table 2.4. The Beach Profile formations at the end of Experiments W9 to W15



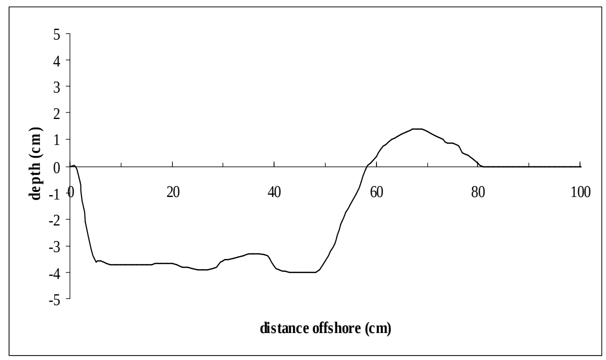
The resultant profile of Exp. W9



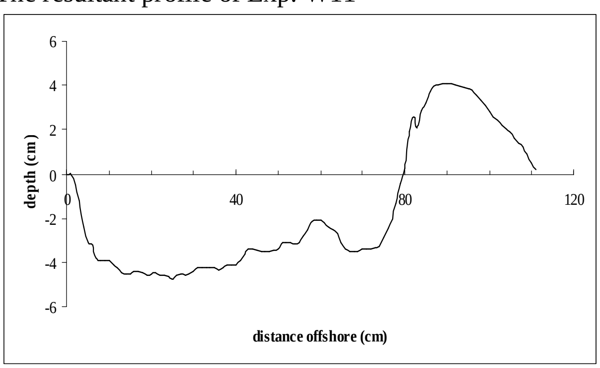
The resultant profile of Exp. W10



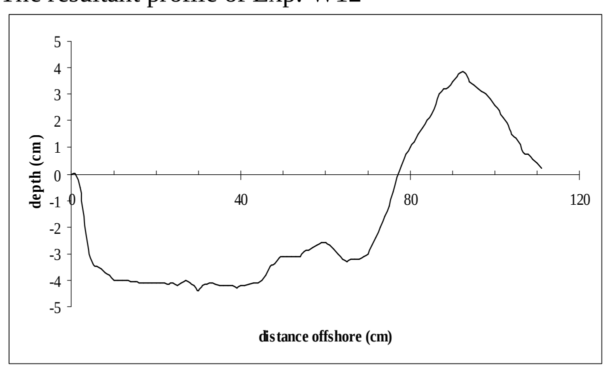
The resultant profile of Exp. W11



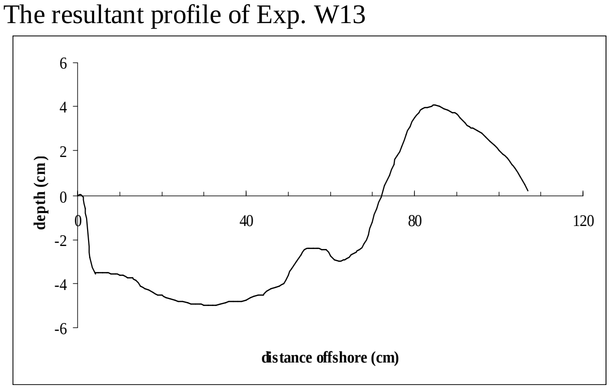
The resultant profile of Exp. W12



The resultant profile of Exp. W13

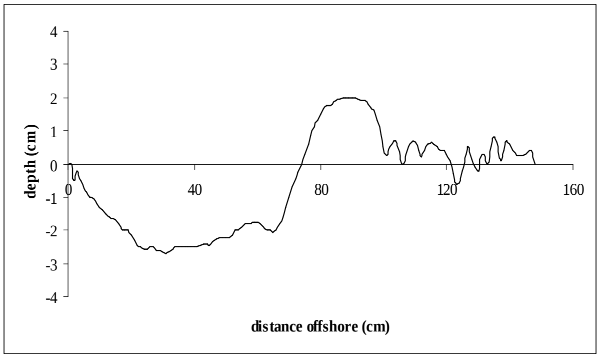


The resultant profile of Exp. W14

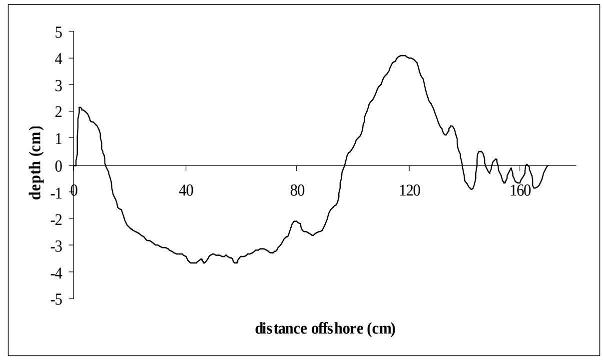


The resultant profile of Exp. W15

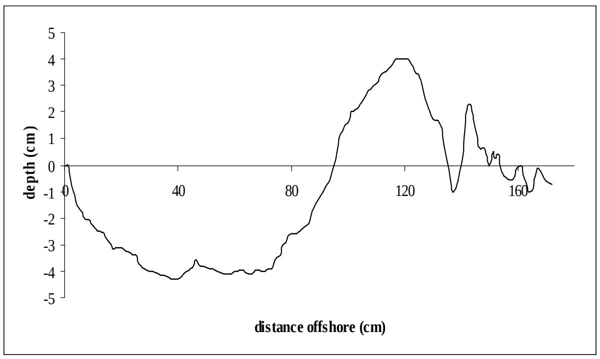
Table 2.5. The Beach Profile formations at the end of Experiments S101 to S108



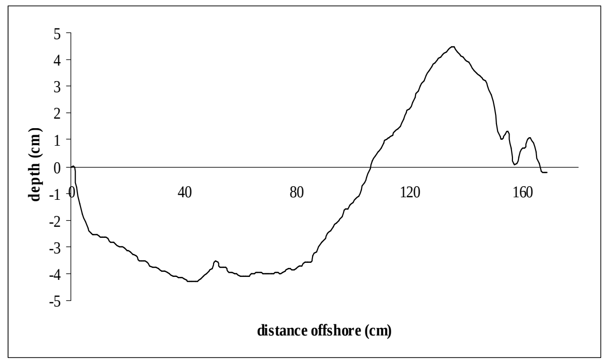
The resultant profile of Exp. S101



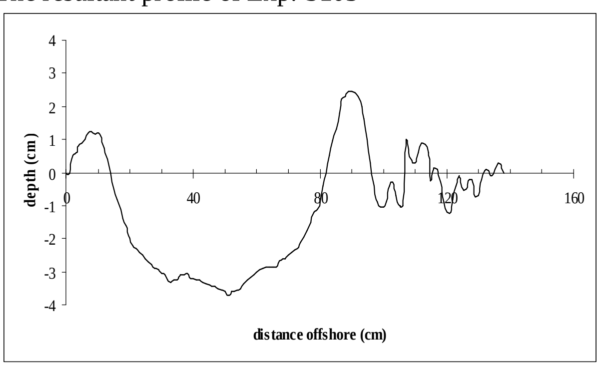
The resultant profile of Exp. S102



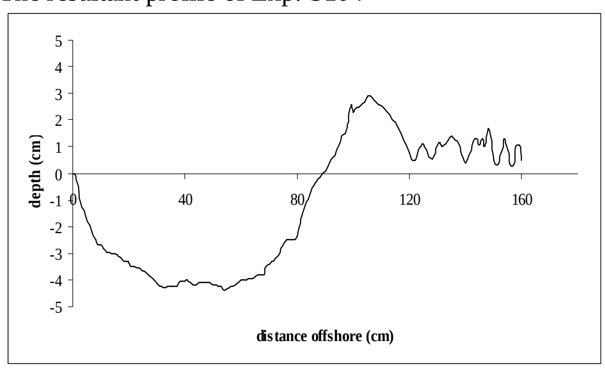
The resultant profile of Exp. S103



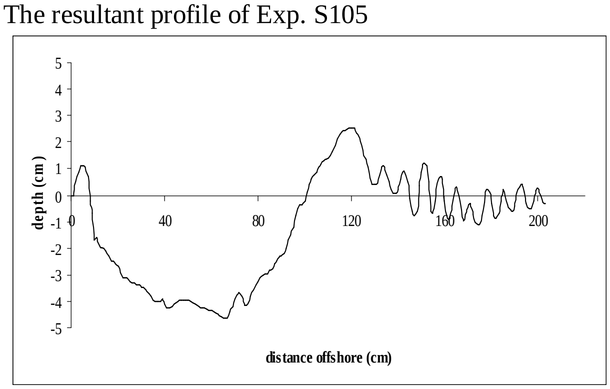
The resultant profile of Exp. S104



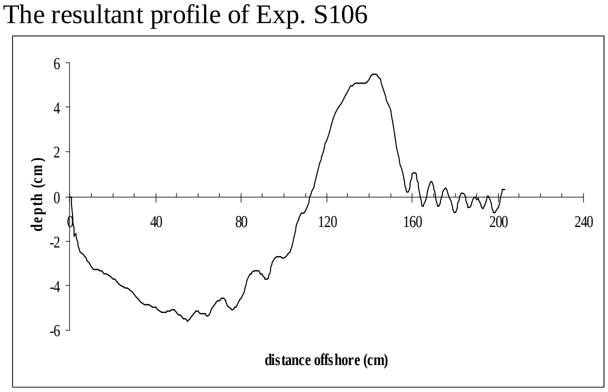
The resultant profile of Exp. S105



The resultant profile of Exp. S106

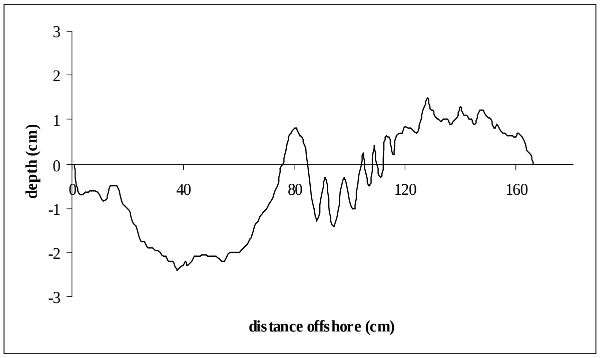


The resultant profile of Exp. S107

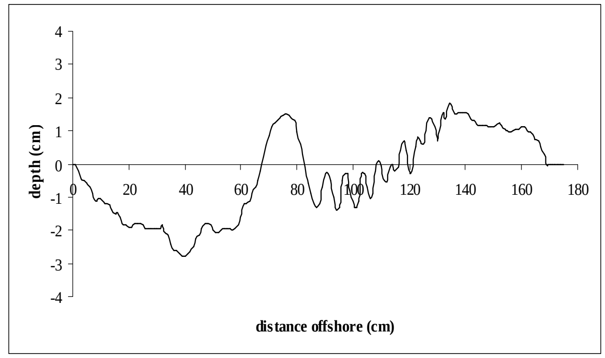


The resultant profile of Exp. S108

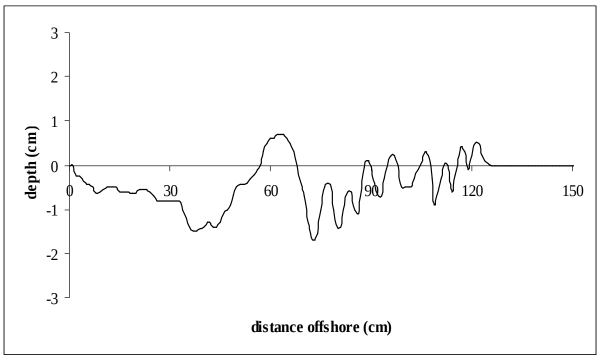
Table 2.6. The Beach Profile formations at the end of Experiments S109 to S114



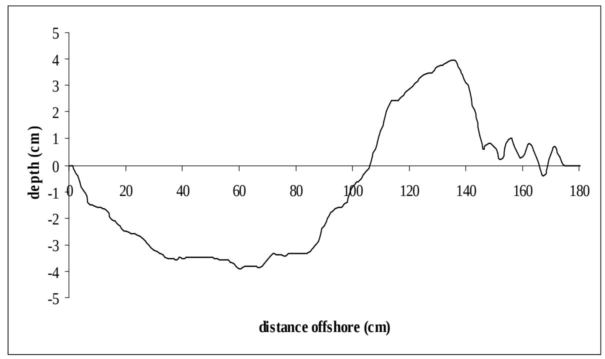
The resultant profile of Exp. S109



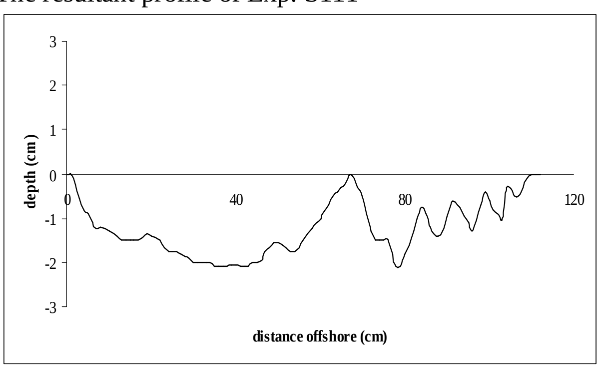
The resultant profile of Exp. S110



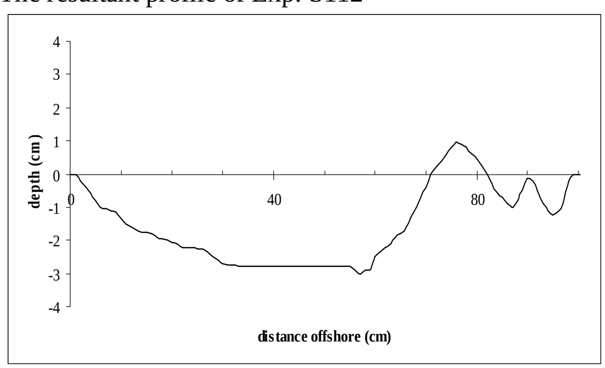
The resultant profile of Exp. S111



The resultant profile of Exp. S112

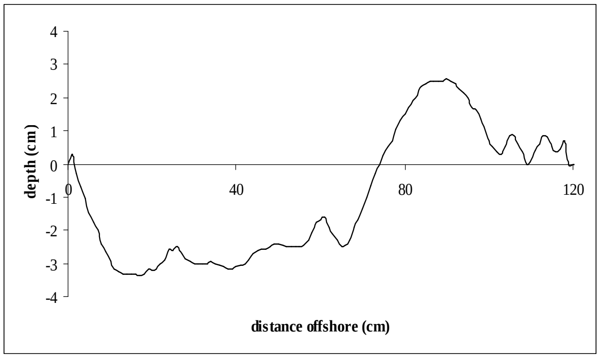


The resultant profile of Exp. S113

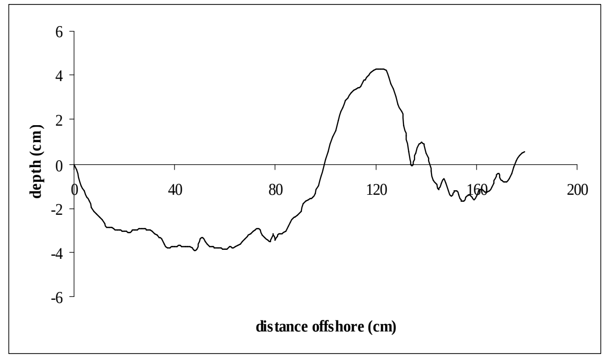


The resultant profile of Exp. S114

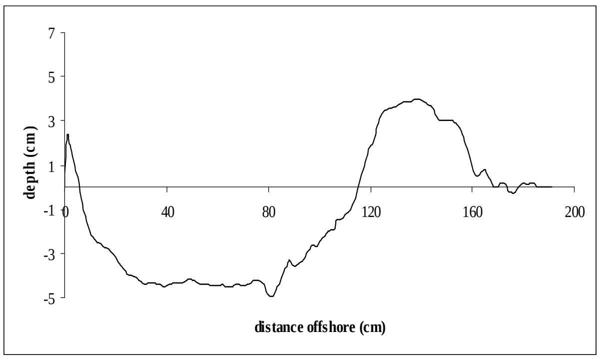
Table 2.7. The Beach Profile formations at the end of Experiments W101 to W108



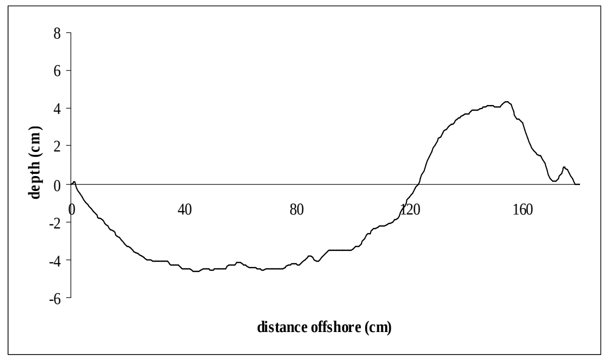
The resultant profile of Exp. W101



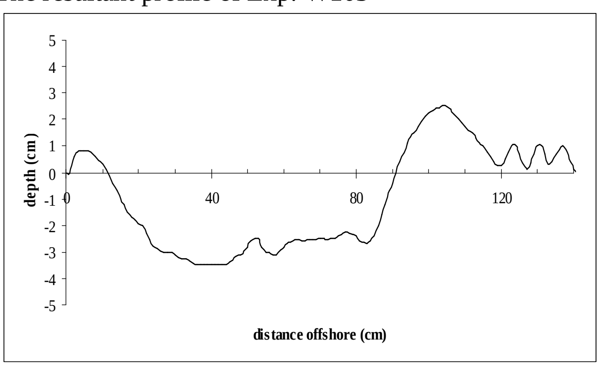
The resultant profile of Exp. W102



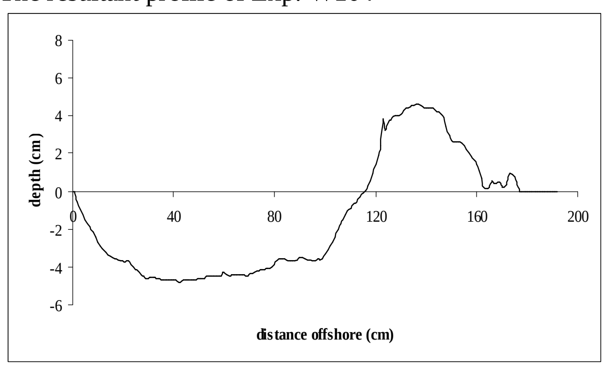
The resultant profile of Exp. W103



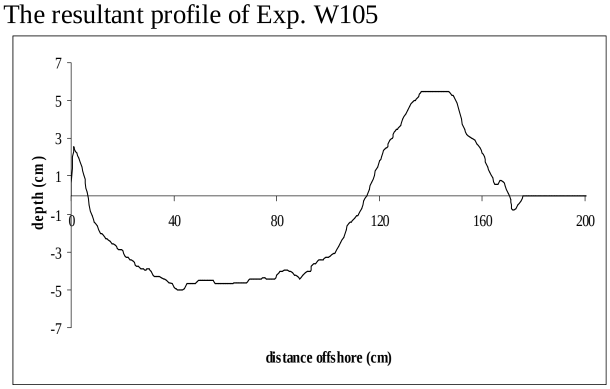
The resultant profile of Exp. W104



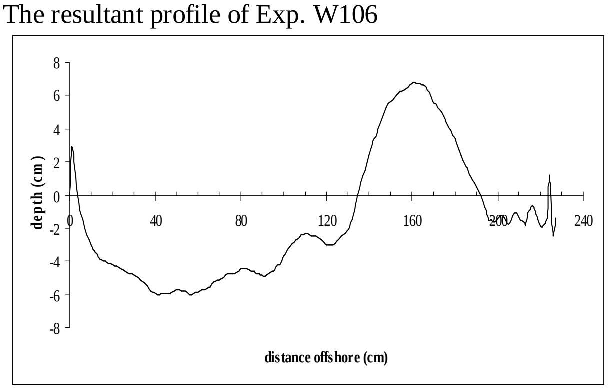
The resultant profile of Exp. W105



The resultant profile of Exp. W106

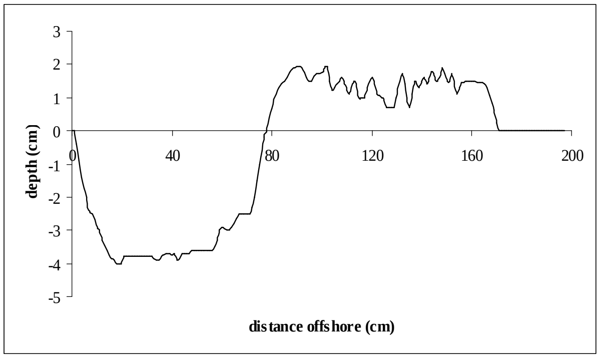


The resultant profile of Exp. W107

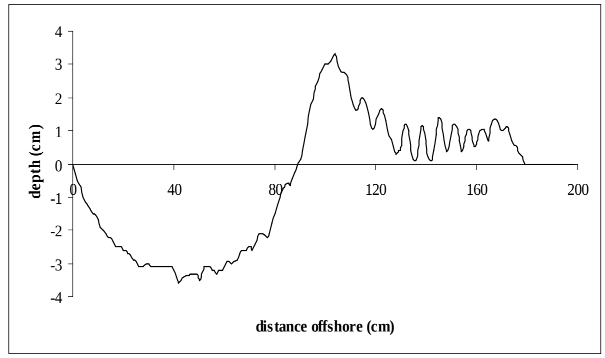


The resultant profile of Exp. W108

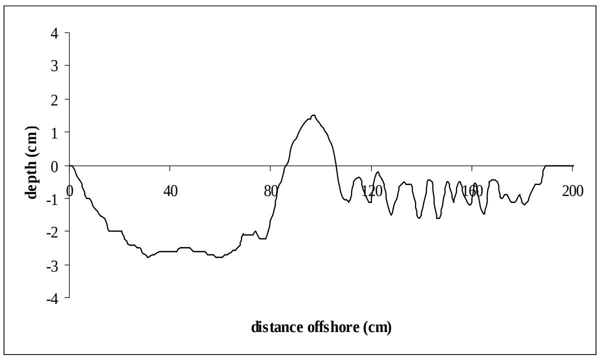
Table 2.8. The Beach Profile formations at the end of Experiments W109 to W114



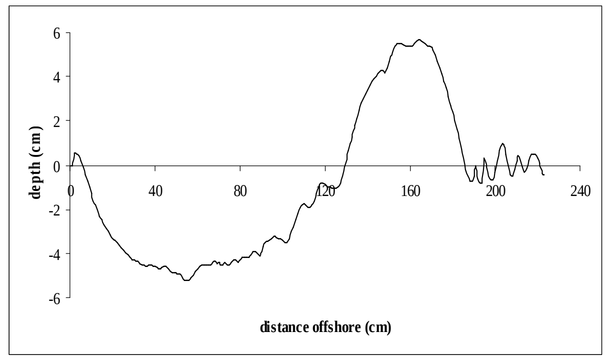
The resultant profile of Exp. W109



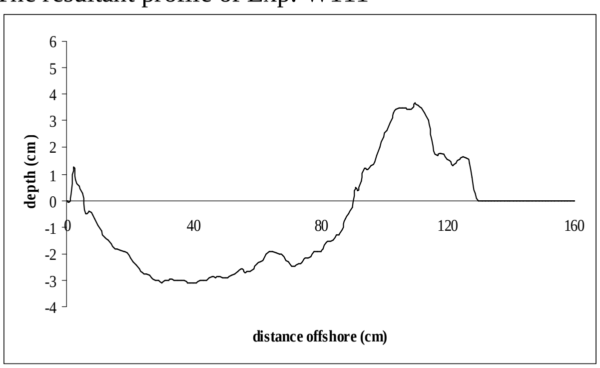
The resultant profile of Exp. W110



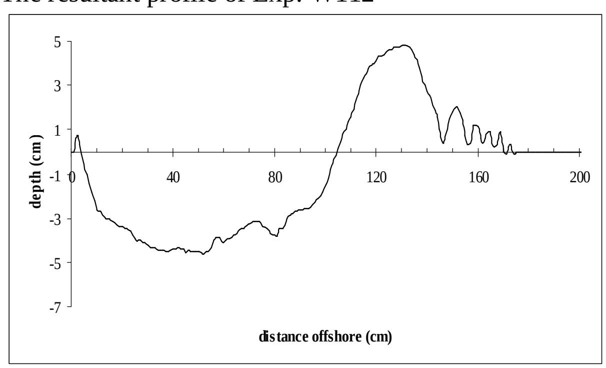
The resultant profile of Exp. W111



The resultant profile of Exp. W112



The resultant profile of Exp. W113



The resultant profile of Exp. W114

CHAPTER 3

ANALYSIS AND THE VERIFICATION OF EXPERIMENTAL DATA

3.1 Introduction

The field of coastal engineering involves providing reliable and economic design solutions to support man's activities in the coastal zone. Coastal engineering must study and attempt to understand such diverse topics like wave mechanics and wave climate prediction, shoreline erosion and protection methods, dredging technology estuarine processes, and environmental impacts of coastal projects. Laboratory investigations play an important role in many of the above areas, because visual observations can provide physical in-sight (Hughes, 1993). From an engineering point of view it is of considerable importance to quantify the various properties related to beach profile change. This regards geometric parameters such as bar volume and trough, as well as more complex quantities such as the net cross-shore sand transport rate. The principle physical mechanism that determines beach profile change must be described to model the profile response. For this response, it is necessary to study the profile evolution under different wave properties, sand characteristics, and profile shape. However, to establish cause and affect relationship between the governing factors and the profile response it must be possible to clearly delineate these relationships. Use of field profile data as a basis for developing a numerical models is extremely difficult due to the complexity and randomness of naturally occurring conditions and coast of data collection. Laboratory facilities provide an environment where such investigation may be carried out efficiently at almost and spatial or temporal scale.

3.2 Experimental analysis

The experimental analyses are carried to search for a relation among the parameters involved in the experiments. Off course, the target aim is to define the bar volume and the erosion volume and distance of center of masses in terms of the wave parameters and sediment characteristics. The dependency among the parameters affecting the event is analyzed to make the relation clear. To investigate the relation between geometric properties of the various morphologic features of the profile and the wave and sand characteristics dimensional similitude has been carried out. The primary parameters used were: wave period T, deep water wave height H, median grain size d_{50} , and fall velocity of the material w. also, various non-dimensional quantities were formed, such as H/d_{50}, H/wT, $V_{bar/}d_{50}^2$, $V_{bar/}H^2$, H/L_o, Ω/d_{50}, Ω/H, $V_{erosion}/H^2$, $V_{erosion}/d_{50}^2$.

The non-dimensionless parameter H/wT is actually called dimensionless fall speed parameter. the dominant parameter affecting the morphological changes on the beach profile is the deep-water wave height and it should appear in most criteria together with a parameter involving a quantity describing the sediment, such as the fall velocity or grain size. In a theoretical sense, the sediment fall velocity is superior to the grain size in development of profile classifications, as it incorporates both grain characteristics and fluid viscosity. The dependency of parameters between each other is given in the following sections.

3.3. Regular wave analysis

Examination of beach profile changes modified from storm wave environment under regular waves is carried out. The primary parameters influencing the event, wave period T, deepwater wave height H, are compared with the morphologic features such as bar volume V_{bar} , and erosion volume $V_{erosion}$, and distance of center of masses Ω. The relation between the bar volume, erosion volume, and average displacement is examined with respect to vegetated and non-vegetated conditions; and also, their relation with incoming wave height is searched. The effect of wave period on morphologic characteristic is also examined. The corresponding figures representing those relations are given coming figures:-

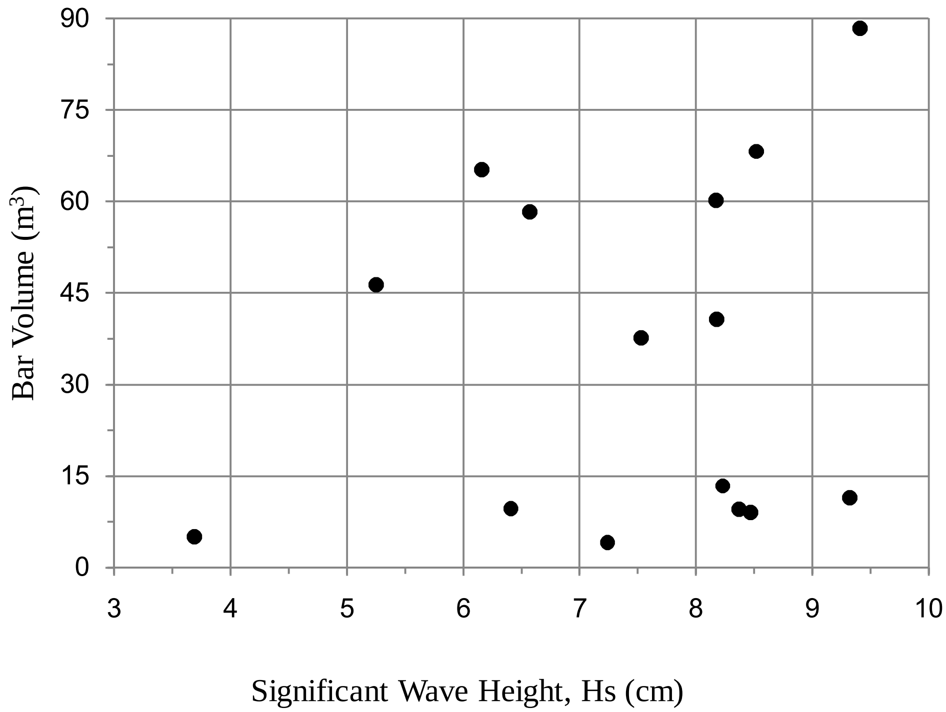


Fig.3.1. Change in bar volume with wave height (vegetation)

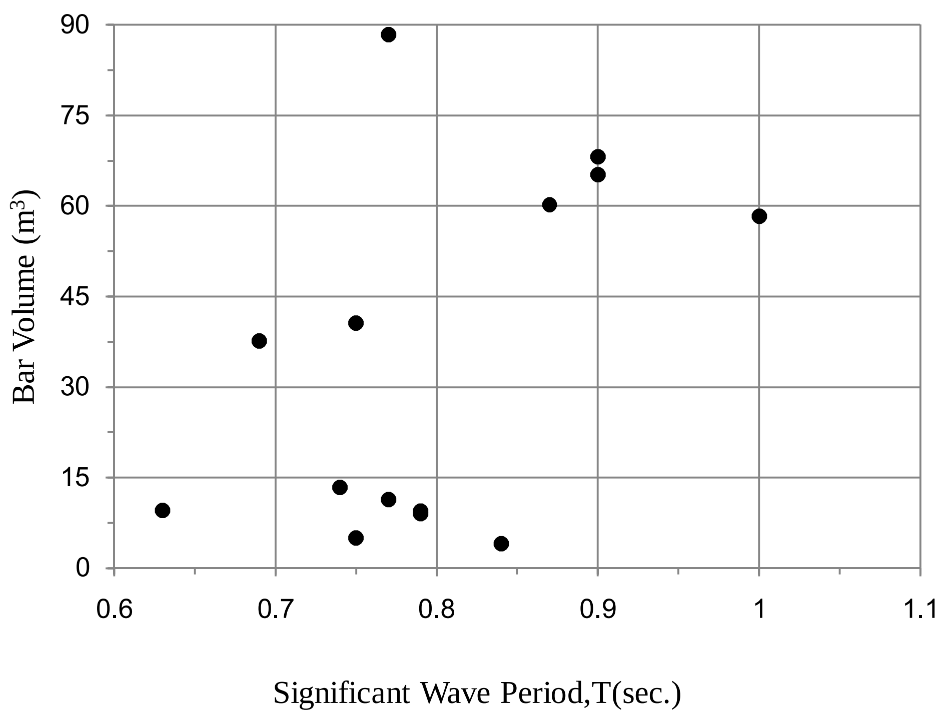


Fig.3.2. Change in bar volume with wave period (vegetation)

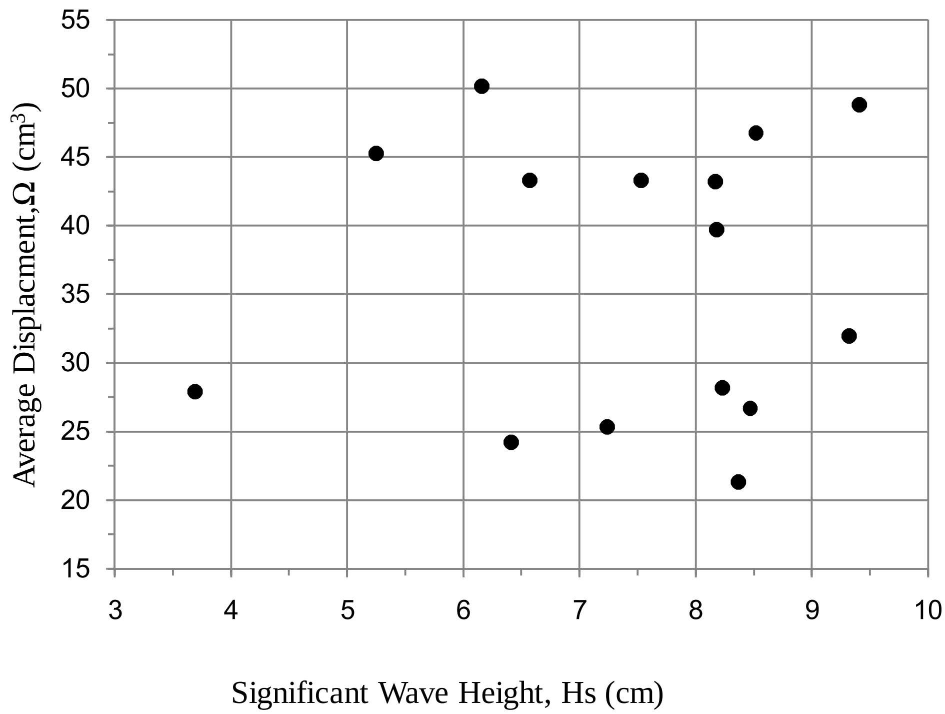


Fig.3.3. Change in Average Displacement, Ω with wave height (vegetation)

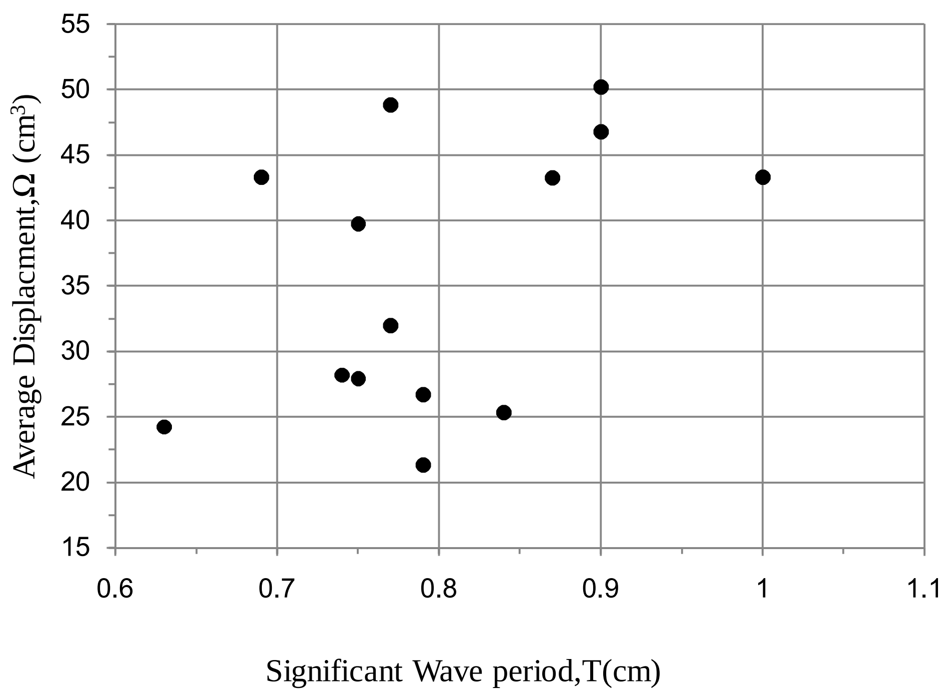


Fig.3.4. Change in Average Displacement, Ω with wave period (vegetation)

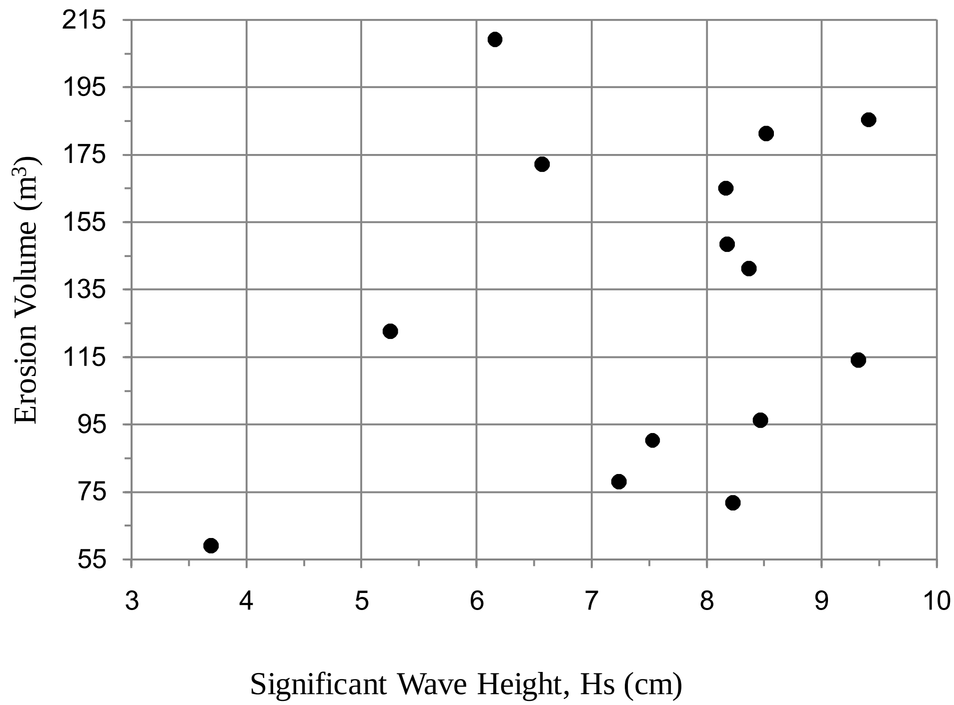


Fig.3.5. Change in erosion volume with wave height (vegetation)

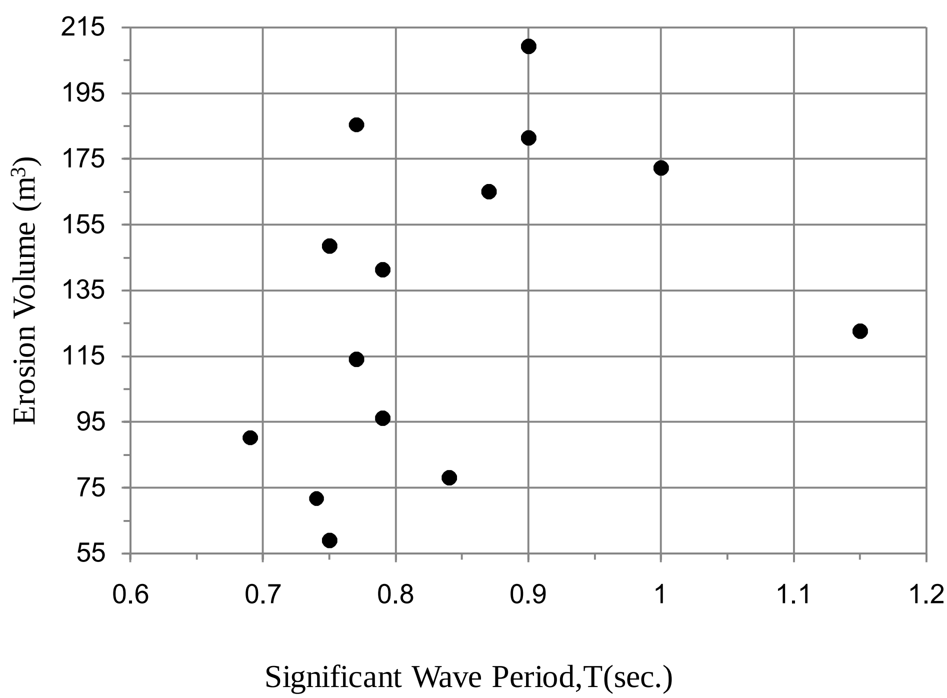


Fig.3.6. Change in erosion volume with wave period (vegetation)

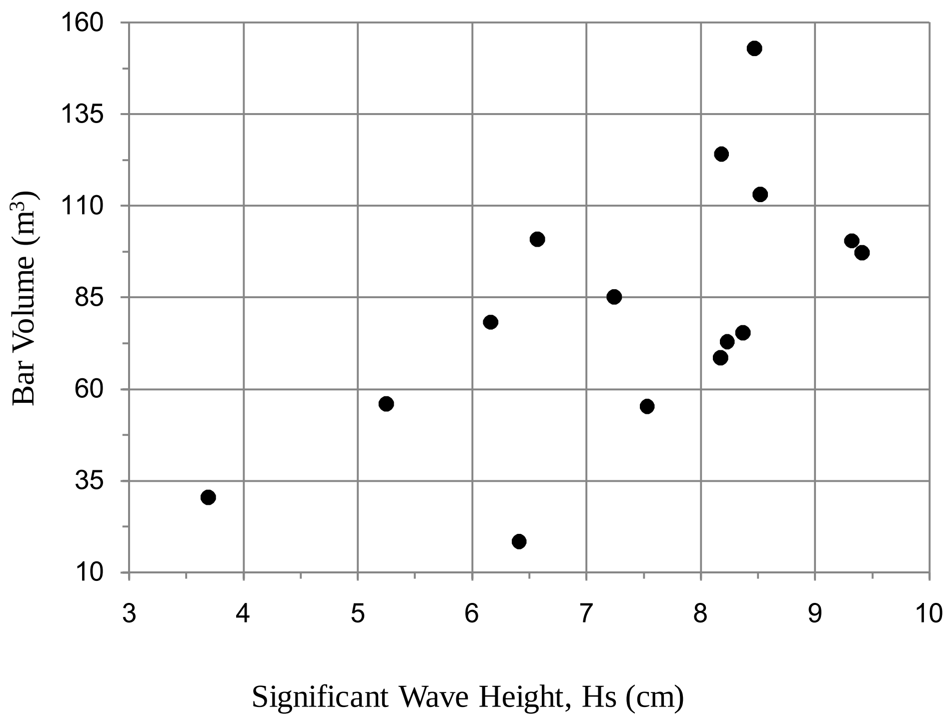


Fig.3.7. Change in bar volume with wave height (non-vegetation)

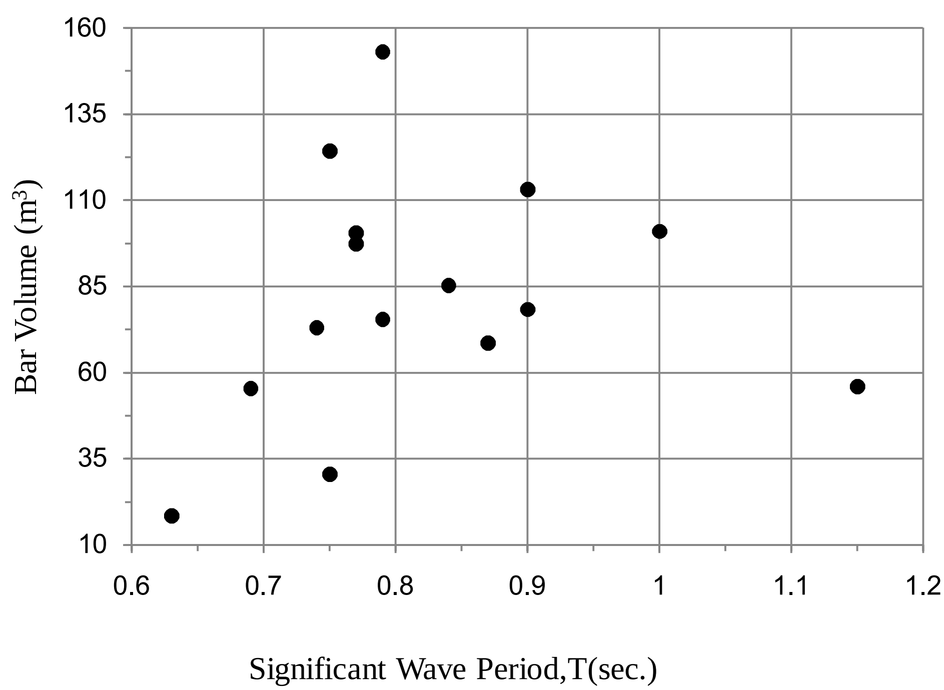


Fig.3.8. Change in bar volume with wave period (non-vegetation)

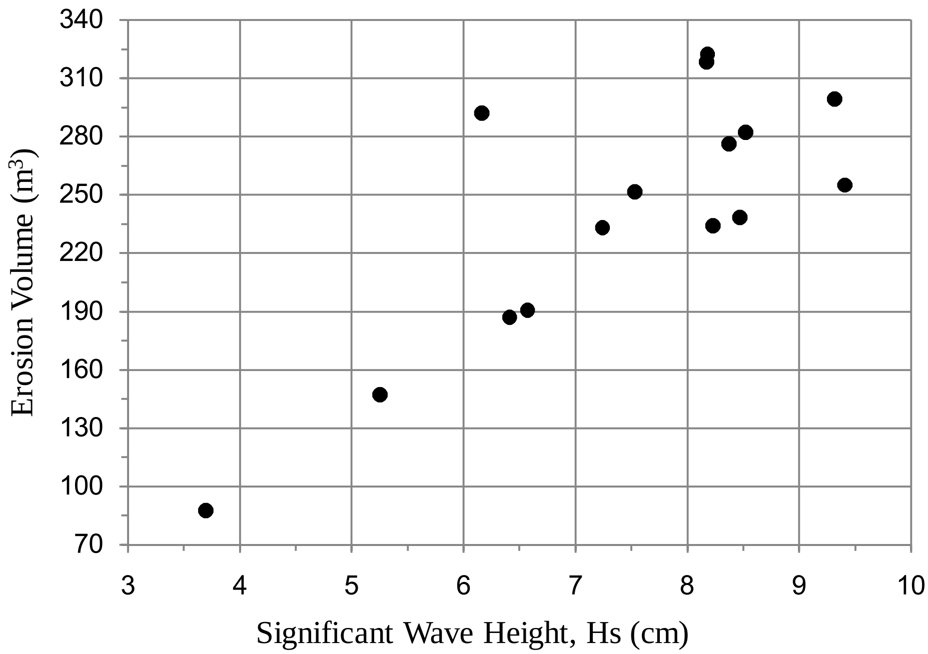


Fig.3.9. Change in erosion volume with wave height (non-vegetation)

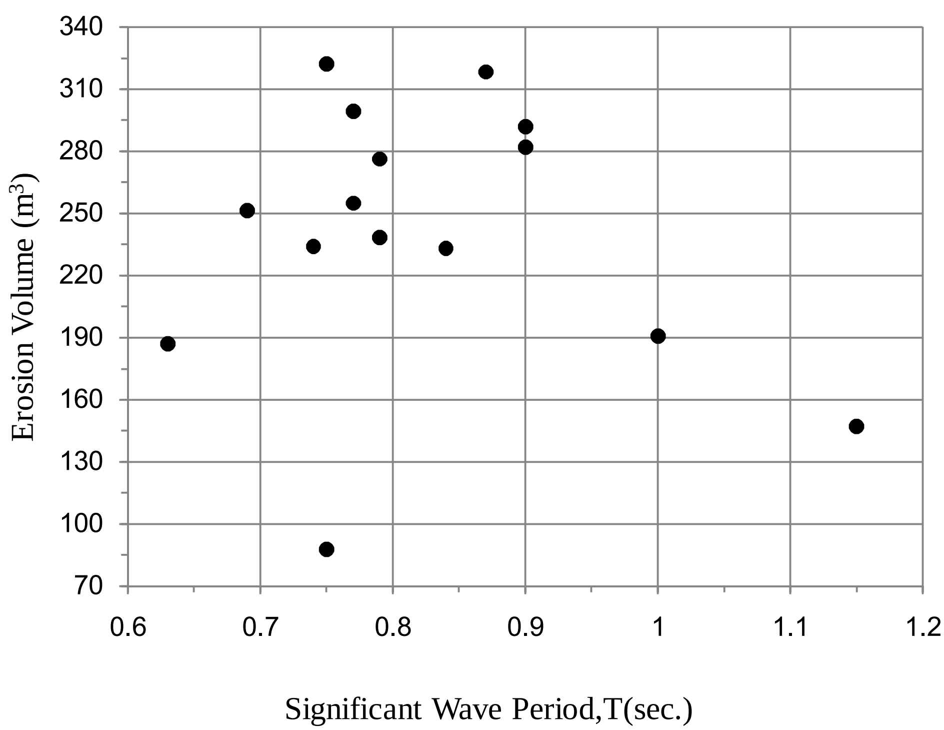


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Fig.3.10. Change in erosion volume with wave period (non-vegetation)

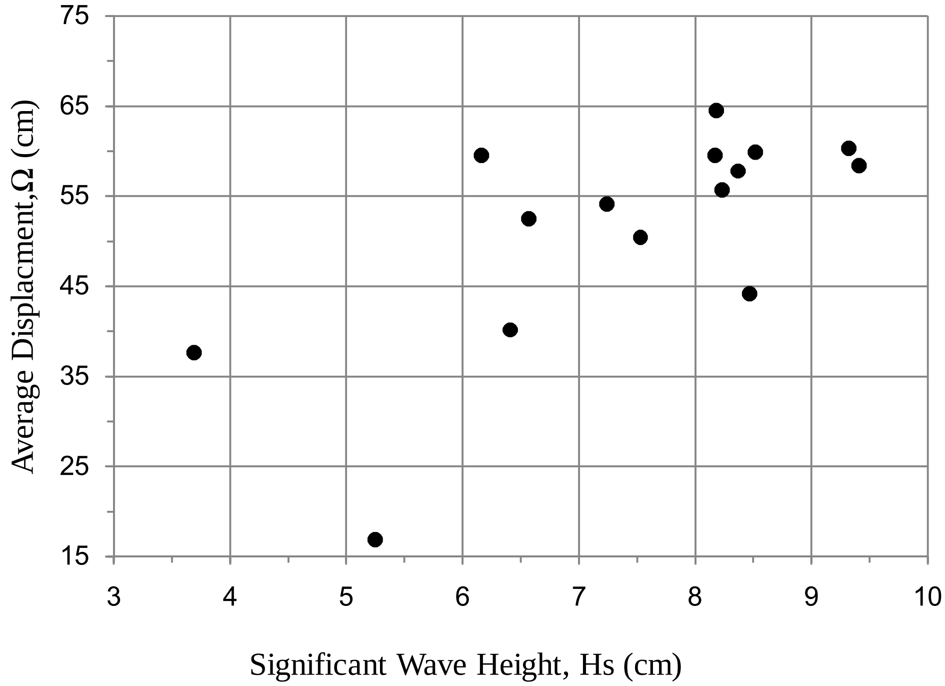

Fig.3.11. Change in Average Displacement, Ω with wave height (non-vegetation)

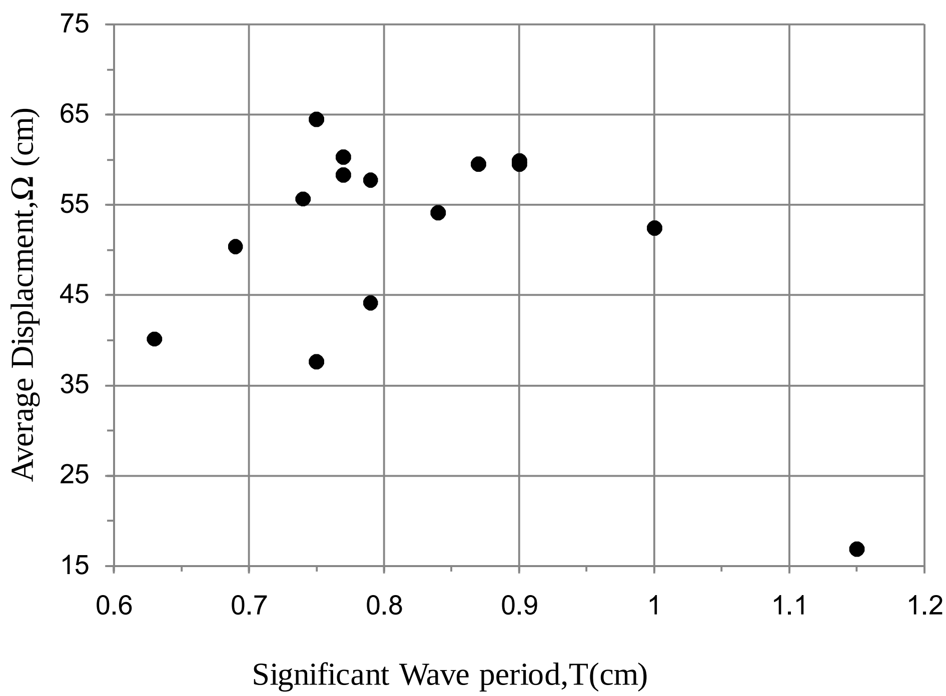

Fig.3.12. Change in Average Displacement, Ω with wave period (non-vegetation)

3.4. Irregular wave analysis

The criteria investigated above were developed for predicting tendencies for bars and erosion volumes, and average displacement to form under idealized laboratory conditions of regular wave flumes. The utility of such criteria has been questioned for applicability to the actual situation. Actually waves have a spread in height and period following an irregular distribution, called random waves. The response of beach profile under the attack of irregular waves is also examined to observe the trends between the related parameters. The primary parameters influencing the event are compared with the morophologic features such as bar volume, V_{bar}, and erosion volume, $V_{erosion,}$ and distance of center of masses **Ω**. The relation between the bar and erosion volume and average displacement is considered together with their relation with incoming wave height. The effect of wave period on morphologic characteristic is also examined. Incoming wave height values and wave period values measured during the experiments. The corresponding figures representing those relations are given coming figures:-

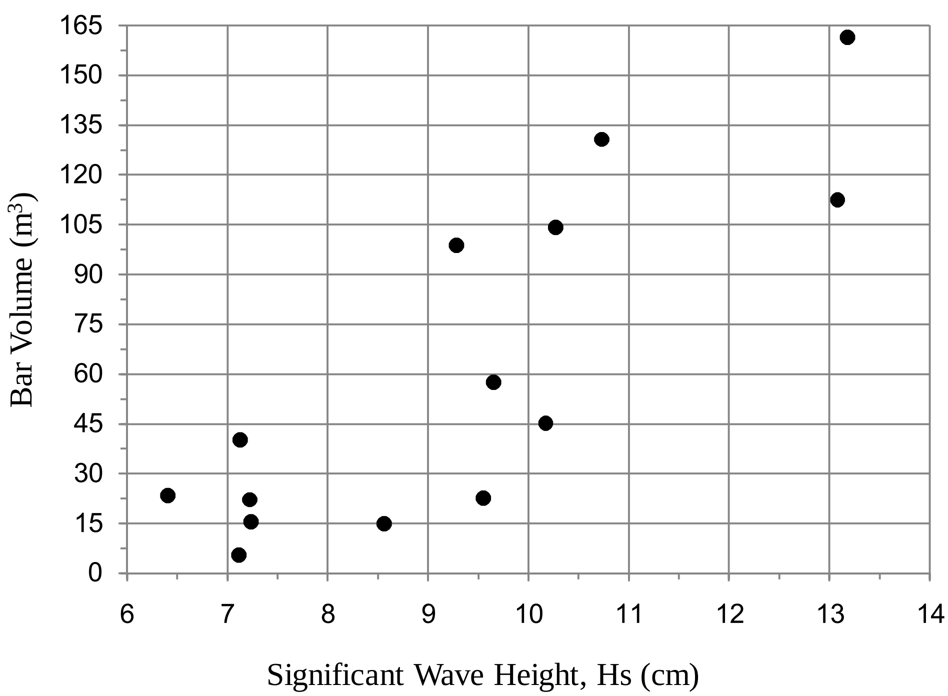

Fig.3.13. Change in bar volume with wave height (vegetation)

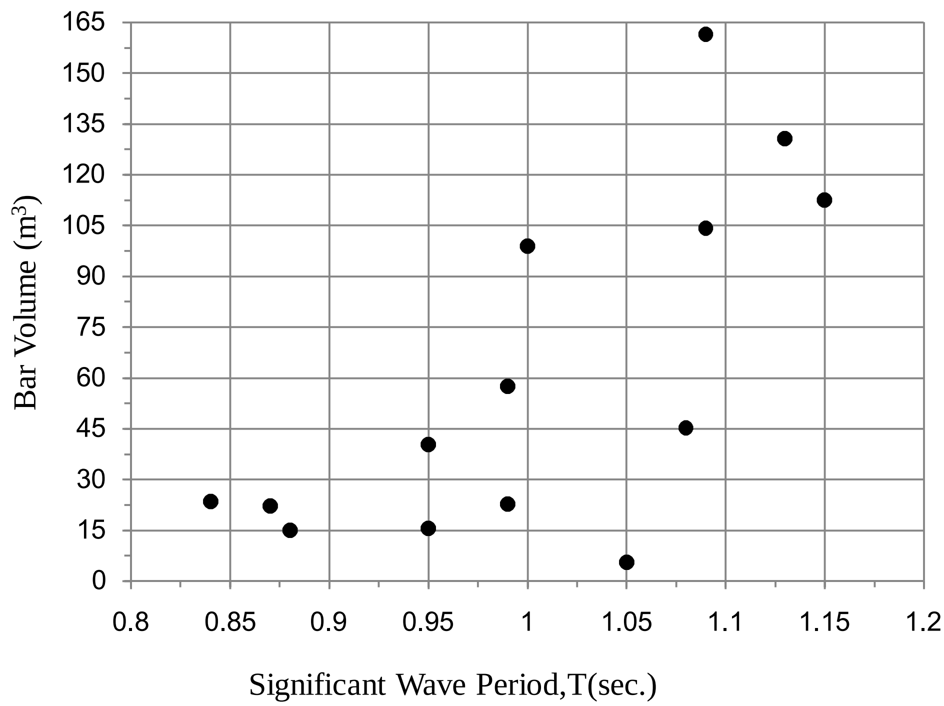

Fig.3.14. Change in bar volume with wave period (vegetation)

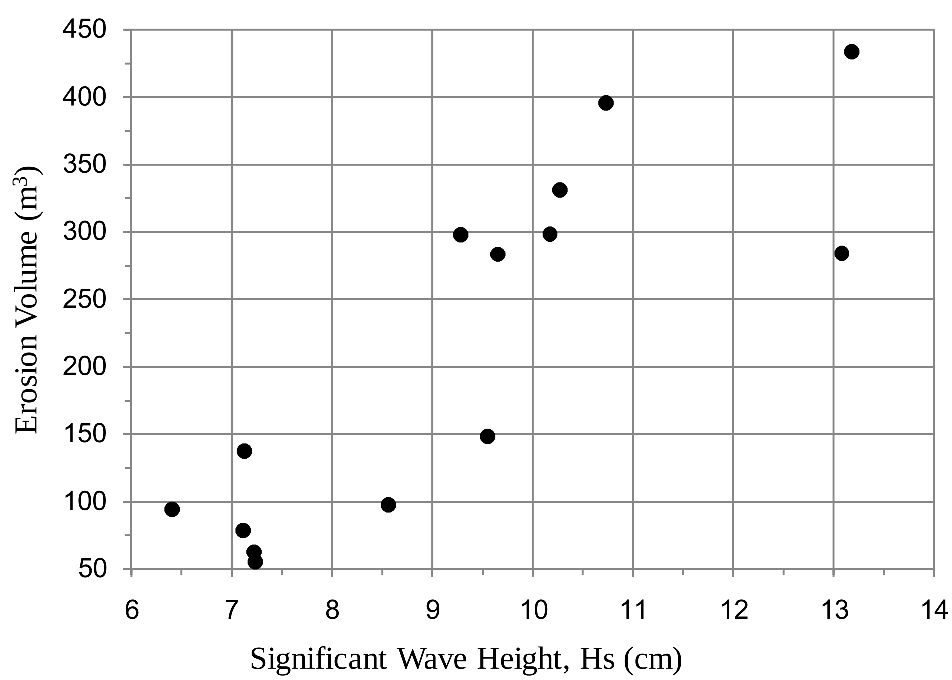

Fig.3.15. Change in erosion volume with wave height (vegetation)

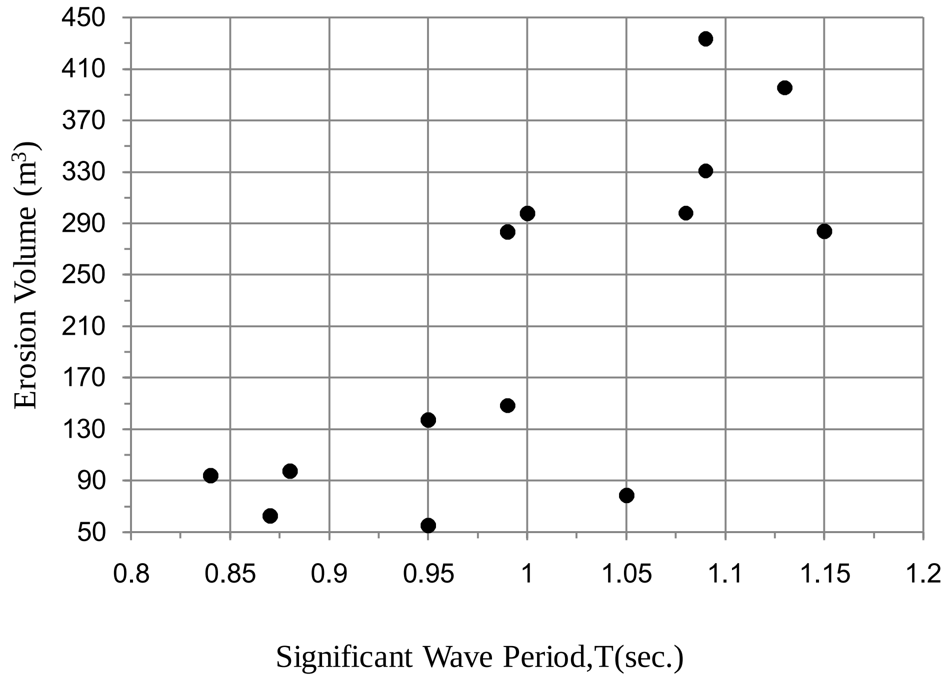

Fig.3.16. Change in erosion volume with wave period (vegetation)

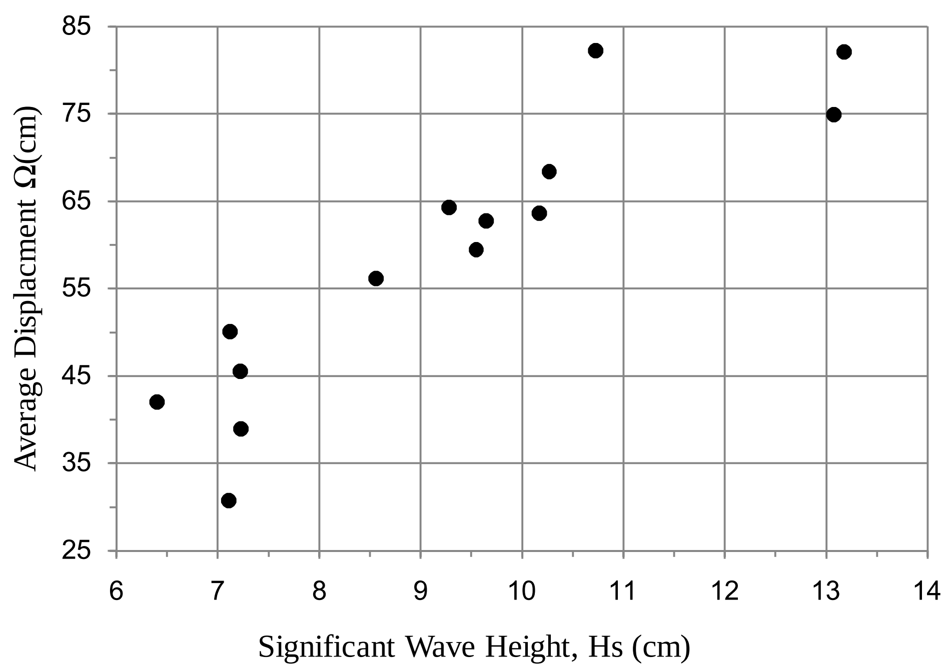

Fig.3.17. Change in Average Displacement, Ω with wave height (vegetation)

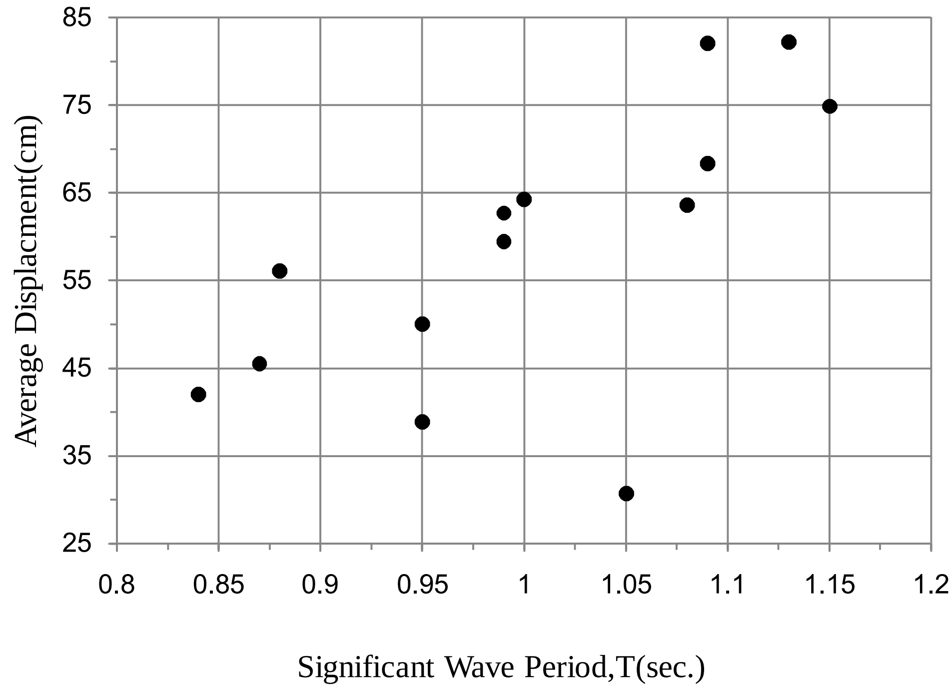

Fig.3.18. Change in Average Displacement, Ω with wave period (vegetation)

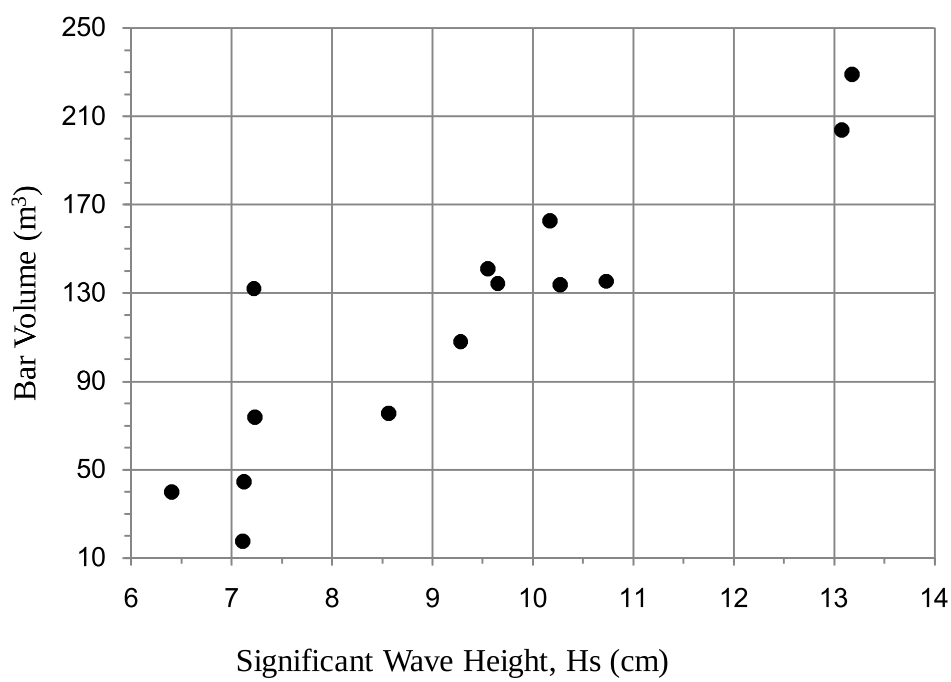

Fig.3.19. Change in bar volume with wave height (non-vegetation)

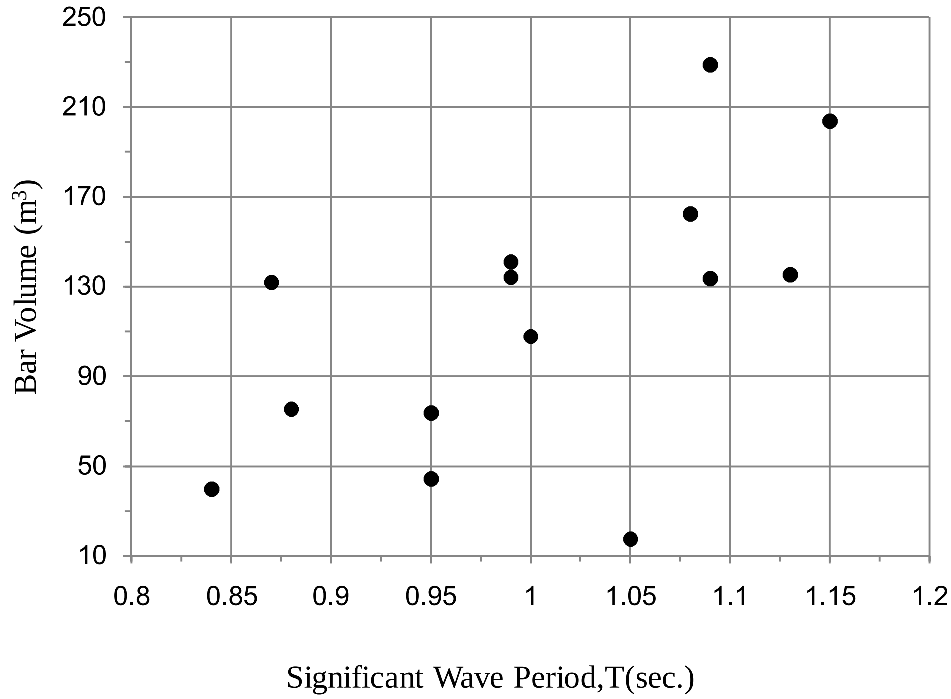

Fig.3.20. Change in bar volume with wave period (non-vegetation)

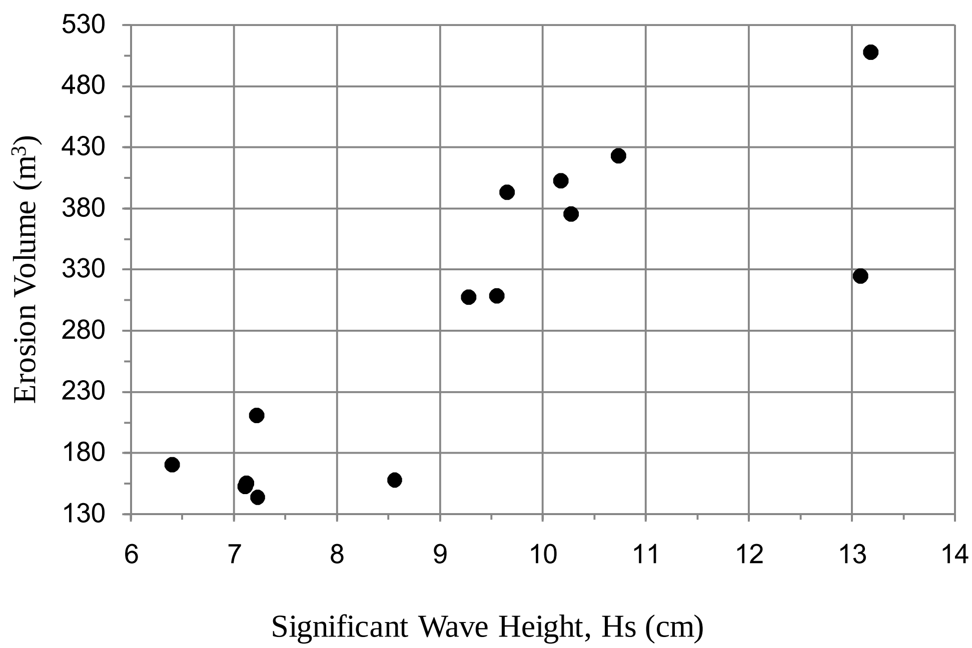

Fig.3.21. Change in erosion volume with wave height (non-vegetation)

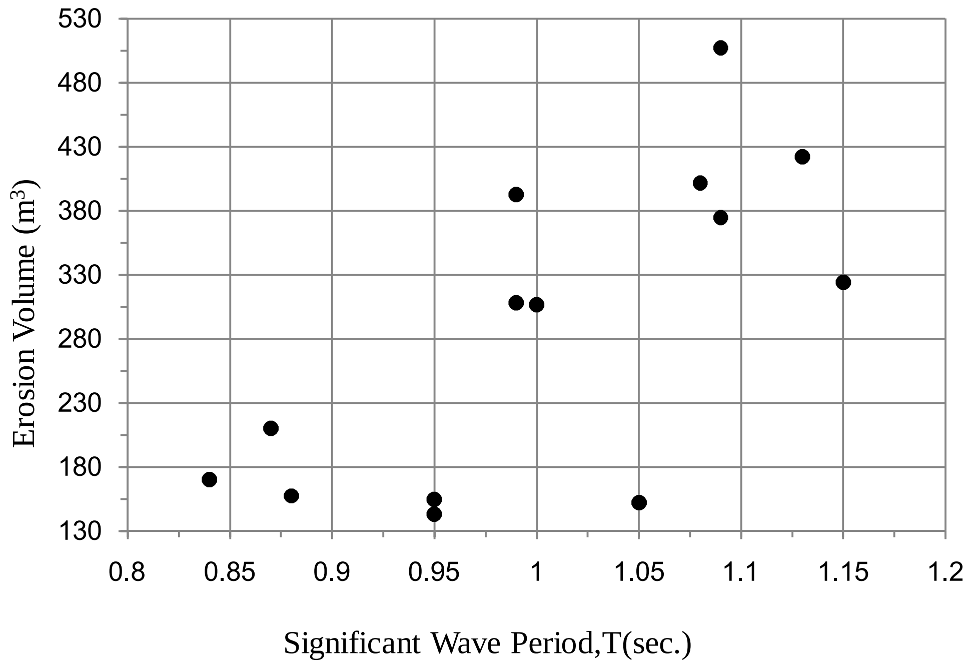

Fig.3.22. change in erosion volume with wave period (non-vegetation)

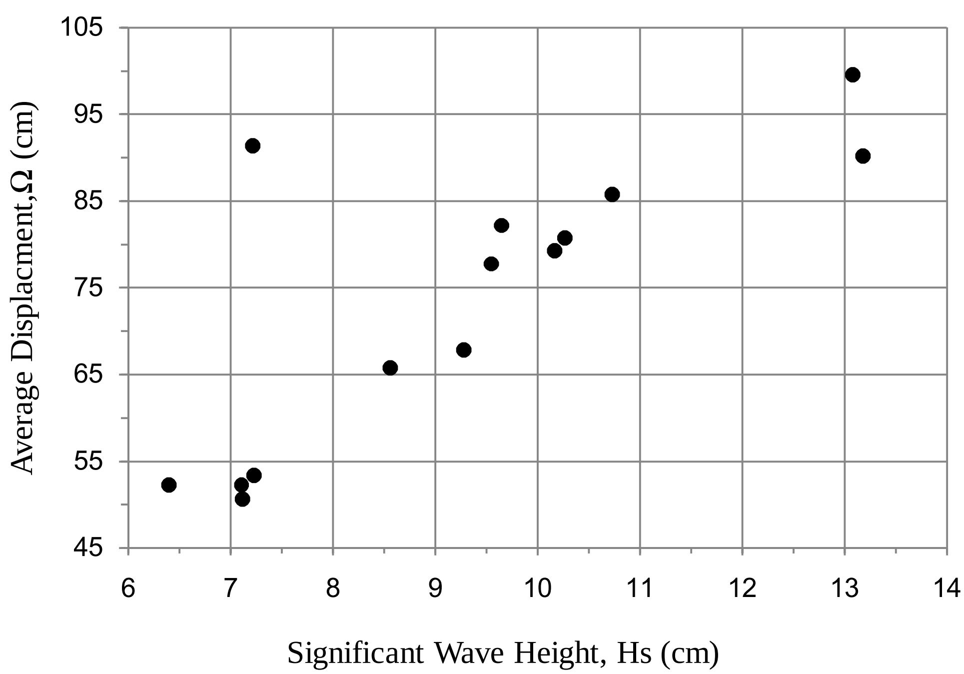

Fig.3.23. change in Average Displacement, Ω with wave height (non-vegetation)

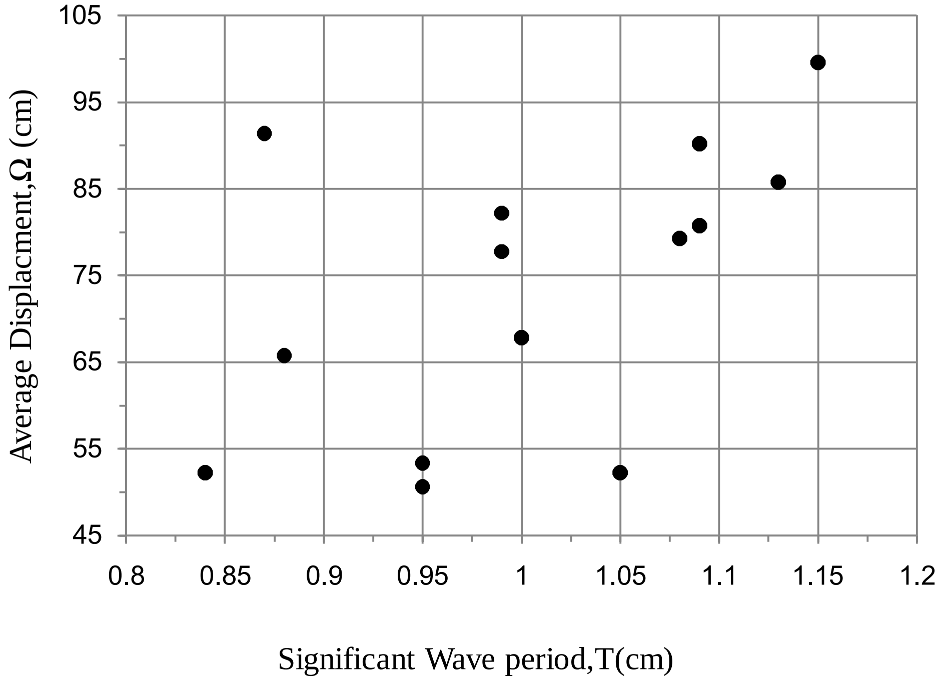

Fig.3.24. change in Average Displacement, Ω with wave period (non-vegetation)

In general the result of comparisons on wave parameters resulted in the following comments:

- The area of erosion and offshore bar decreases if the magnitudes of vegetated area increases.
- The area of erosion and offshore bar increase under same climatic conditions when there is no vegetation.
- Ω (distance between center of masses) increases if there is no vegetation.
- Ω decreases if the magnitudes of vegetated area are increasing.
- Equilibrium profiles consummate by bigger wave heights have larger bar volumes.
- The bigger the grain size is, the greater the fall speed becomes, which in turn signifies a smaller bar volume.
- The greater damage on the beach, the smaller the wave energy dissipation along the vegetated area, which in turn signifies either high wave climates or loose vegetation.

- For some of diameter grains, as the equilibrium bar moves offshore, its volume increases.
- The wave period and the morphologic changes are weakly related with each other.

After the findings of the analyses of experiments, it can be completed that the barred beach and erosion beach profiles generated by storm waves depend on wave height, wave length and number of vegetation; the size of sediment grains forming the beach profile and their fall velocity; the unit weight of water and sediment grains and the slope of beach profile. As a result, a general functional expression representing an event related to the effect of vegetation and non-vegetation on beach profile changrs is:

f (H, T, L, γ_s, γ_w, $A_{erosion}$, A_{bar}, tan ß, ψ, Ω, d_{50}, γ_w)=0

where H, T and L are the wave height, period and length, respectively. w, γs and d_{50} are sediment fall velocity, specific weight and mean diameter, respectively; γw is the specific weight of water; Aerosion and Abar are the area of erosion and bar, respectively; Ω is the horizontal distance between the centers of barred and eroded profiles; ψ is the vegetation parameter and tan ß is the initial slope of the beach profile. As a result ten non-dimensional parameters are investigated as below:

H/d_{50}, dimensionless depth parameter.

H/wT, fall speed parameter.

H/L_o, wave steepness parameter.

Ω/d_{50}, dimensionless beach damage parameter.

Ω/H, dimensionless beach damage parameter.

A_{bar}/H^2, dimensionless bar parameter.

A_{bar}/d_{50}^2, dimensionless bar parameter.

$V_{erosion}/H^2$, dimensionless erosion parameter.

$V_{erosion}/d_{50}^2$, dimensionless erosion parameter.

Ψ, dimensionless vegetation parameter.

3.5. Verification of experimental data

The comparisons of the results of experimental data with previously developed models were carried in order to verify the results of the experiments. The Günaydın and Kabdaşlı (2003) equation; The Silvester and HSU (1997) equation; the Murat et al, (2006); and Özölçer (2008) were used for the comparison and validation purposes. The equations are given in Table 3.1. In order to verity the result of the experiments, the wave data as an independent variable (H_s,ζ,G_{sp},D_p) are used in equation (1) and (H_o,L_o,tanß) are used in equation (2),and (H_o,L_o,tanß,d_{50},m) are used in equation (3), and (H_o,T,tanß,d_{50},m) are used in equation (4).the result are compared with the result of this study.

Tabel 3.1 Comparison equations.

(Günaydın and Kabdaşlı,2003) $Ve = (1/1.5 \text{ X } 10^{-6}) [\, ln\, H_s\, \zeta / G_{sp}\, D_p) -4.1396]$.........Equ. (1)
(Silvester and Hsu, 1997). $V_{bv} /(H_0\, L_0) = 160(H_0 /L_0) \tan ß+ 11.560[(H_0 /L_0) \tan ß]^2$.....Equ.(2)
(Murat,İsmail , Ömer, Servet ,2006) $V_{bv}/d_{50}^2 =0.0627m^{-0.1223}(H_0/L_0)^{-0.8938}(H_0/d_0)^{2.2587}$ ..Equ.(3)
(İsmail özölçer,2006). $Ve =0.033m^{-0.079}\, T^{0.77} H_0^{1.282}\, d_{50}^{-0.435}$..Equ.(4)

A comparison between the experimental results and Equation (1) did not match with each other. The trends of them were even showing different relationships such that the data input from the experiments were ending with negative results. Therefore, Equation (1) was not valid to be considered as a representative equation for the results of these experiments. Silvester and Hsu equation, Equation (2) exhibit trends similar to the data result of this study, as depicted in Figure 3.26.

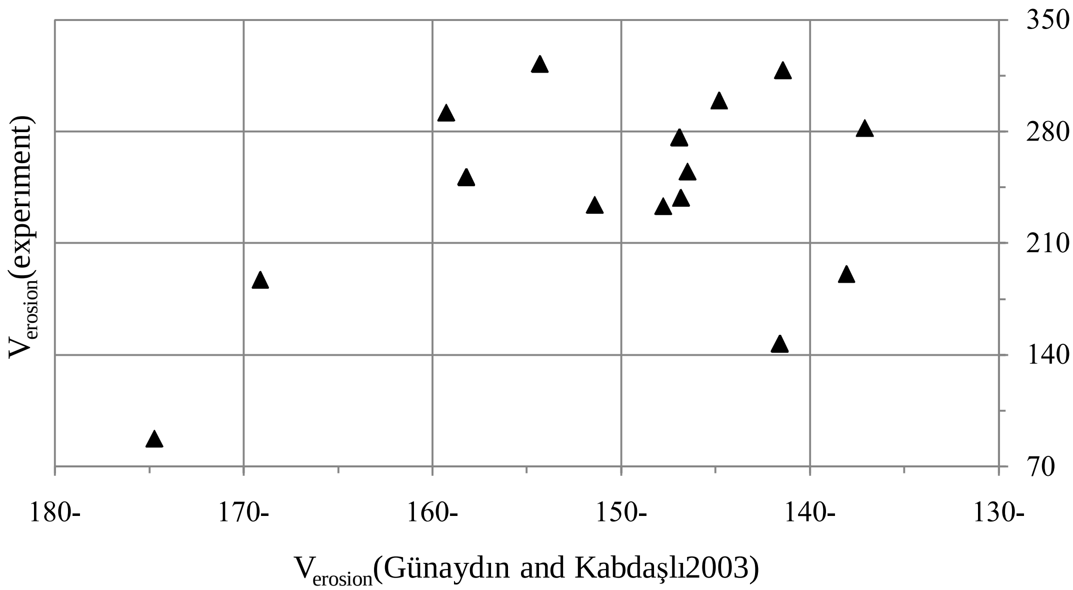

Fig.3.25. Comparison of $V_{erosion}$ in experimental with proposed equation (1)

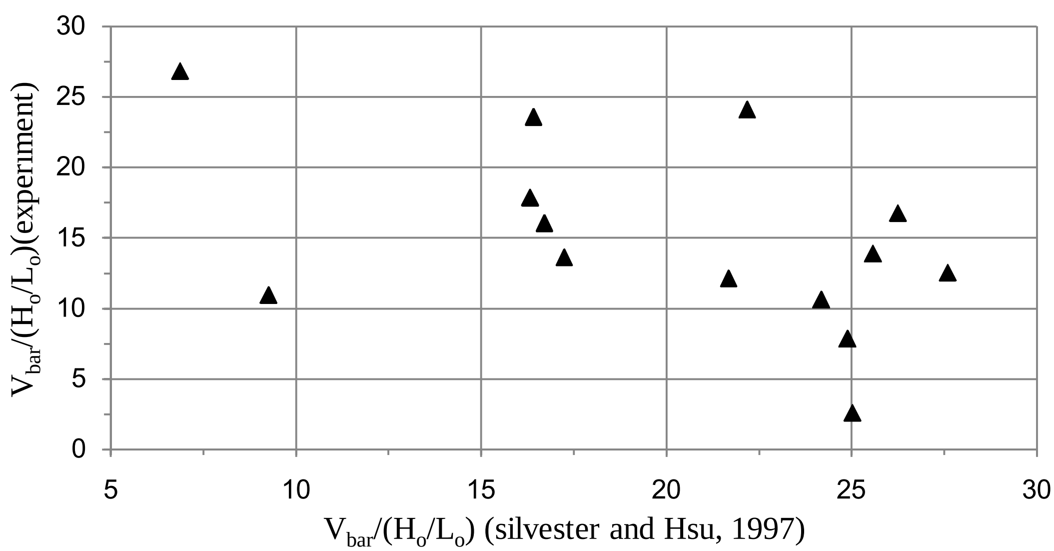

Fig.3.26. Comparison of V_{bar} in experimental with proposed equation (2)

A comparison between the data study and the Murat and İsmail and Ömer and Servet, (2006). Equation (Eq. (3)) in terms of Fig. 3.27. The proposed equation produces the good results, which are very close to experimental data as indicated in Fig3.27. Murat and İsmail and Ömer and Servet's, (2006).equation exhibit trends better to the test results.

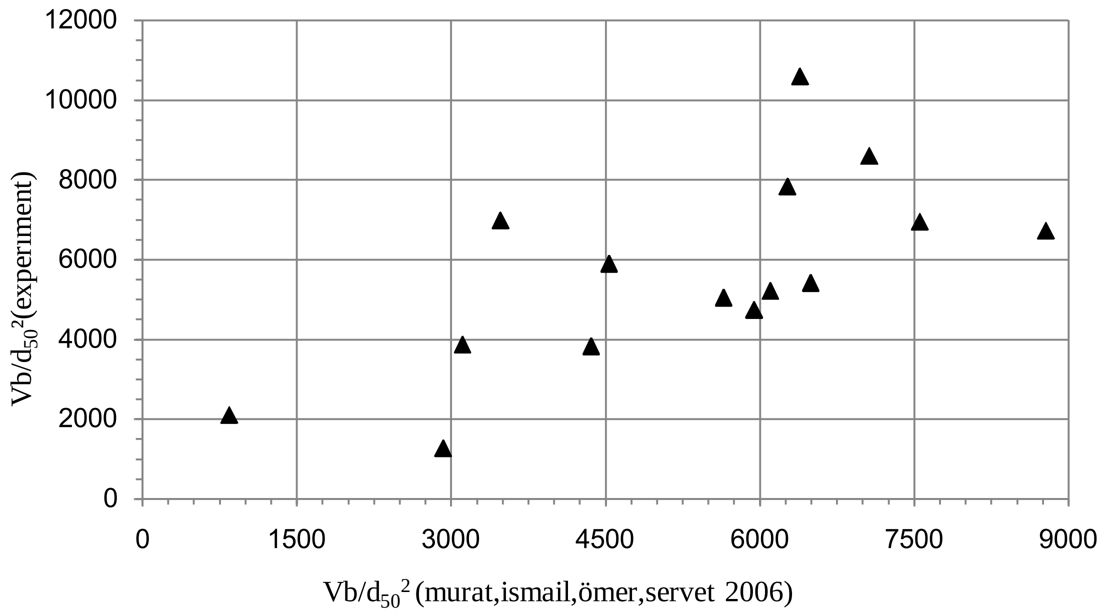

Fig.3.27. Comparison of V_{bar} in experimental with proposed equation (3)

A comparison between the data study and the İsmail özölçer (2006).equation (Eq. (4)) in terms of Fig.3.28. The proposed equation produces the good results, which are very close to experimental data as indicated in Fig3.28. İsmail özölçer's equation exhibit trends better to the test results.

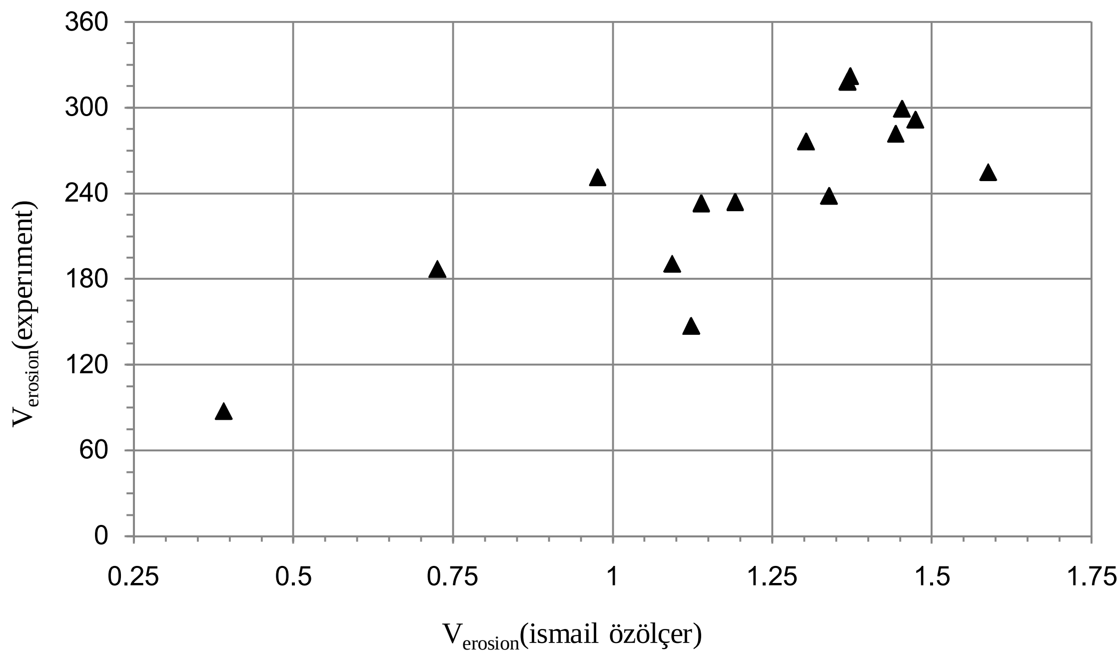

Fig.3.28. Comparison of $V_{erosion}$ in experimental with proposed equation (4)

3.6. Summary

This experimental study investigated coastal erosion and bar geometry under the influence of the regular and irregular waves with protected and non-protected conditions, and after making verifications with other equations to approve the study data, the results were good.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The experiments were conducted in two different wave flumes where the slope of the beach profile, grain size and its fall velocity were constant. In both of the wave flumes the flumes were divided into two equal parts where at one side the beach profile was unprotected while on the other side the profile was protected by emergent vegetation. One flume was used to observe the changes of beach profiles under regular waves whereas the second one was used to test the profiles under irregular waves. Finally, the results of experiments performed during each test are measured and plotted at Tables 4.1 to 4.2.

In each test of each flume, the initial beach profile was subjected to wave attack until equilibrium conditions were attained. The wave records obtain by the wave gage and recorder were analyzed to determine the wave height, H and period T for each test. Each test initiated with sending storm waves to the initially sloped beach profile and finalized when the beach profile accomplished as the dynamic stability conditions attained. The final position of beach profiles were than plotted and labeled successively to illustrate the volume of erosion and volume of bar and the distance between their centers of masses (Ω).

Table 4.1 Experimental result for regular wave analysis with protection (vegetation)

Experiment Name	Wave Height, H_s (cm)	Wave Period, T (sec)	Distance of center of masses, Ω (cm)	Area of Erosion, A_e (cm^2)	Area of Bar, A_b (cm^2)	Vegetation Parameter, Ψ
S1	7,12	1	43,32	172,3	58,29	8,625
S2	9,28	0,75	27,93	59,1	5	8,625
S3	10,27	1,15	45,27	122,7	46,32	8,625
S4	10,73	0,9	50,19	209,26	65,24	8,625
S5	6,4	0,9	46,78	181,4	68,2	20,125
S6	9,65	0,87	43,25	165,12	60,22	20,125
S7	10,17	0,75	39,74	148,56	40,64	20,125
S8	13,18	0,77	48,83	185,43	88,4	20,125
S9	7,22	0,69	43,32	90,34	37,66	41,68
S10	7,23	0,77	31,98	114,1	11,4	41,68
S11	7,11	0,79	21,34	141,35	9,54	41,68
S12	13,08	0,63	24,25	48,7	9,6	41,68
S13	8,56	0,79	26,70	96,33	9,00	63,25
S14	9,55	0,74	28,20	71,85	13,3	63,25
S15	7,24	0,84	25,36	78,12	4,07	63,25

Table 4.2 Experimental result for irregular wave analysis with protection (vegetation)

Experiment Name	Wave Height, H_s (cm)	Wave Period, T (sec)	Distance of center of masses, Ω (cm)	Area of Erosion, A_e (cm^2)	Area of Bar, A_b (cm^2)	Vegetation Parameter, Ψ
S101	7,12	0,95	50,04	137,15	40,25	8,625
S102	9,28	1	64,25	297,89	98,86	8,625
S103	10,27	1,09	68,35	330,87	104,24	8,625
S104	10,73	1,13	82,21	395,56	130,73	8,625
S105	6,4	0,84	41,98	94	23,46	20,125
S106	9,65	0,99	62,69	283,3	57,58	20,125
S107	10,17	1,08	63,57	298,08	45,28	20,125
S108	13,18	1,09	82,06	433,65	161,49	20,125
S109	7,22	0,87	45,48	62,5	22,18	41,68
S110	7,23	0,95	38,89	55,1	15,51	41,68
S111	7,11	1,05	30,69	78,54	5,5	41,68
S112	13,08	1,15	74,87	284	112,53	41,68
S113	8,56	0,88	56,11	97,25	15	63,25
S114	9,55	0,99	59,43	148,4	22,74	63,25

4.2. The effect of vegetation on the evolution of bars

The most common physical environment that is observed during the storm wave attack was also observed during the tests. However, the existence of vegetation was minimizing the wave energy dissipation rate which is directly related with the distance travelled by sediment particles in order to help the evolution of the offshore bar. As a result, it is obvious that the stability of beach profile was attained at shorter time periods than expected. Eventually, the experimental observation and their results show that equilibrium bar is most closely related to deepwater wave height, particle grain size (or fall speed) and the existing vegetation field. Perhaps, the initial beach slope is also related to this natural evolution. The experimental results on regular and irregular waves also state the importance of depth parameter, fall speed parameter and number of vegetated profile in the definition of offshore bar. The relation among the dimensionless offshore bar parameter, dimensionless depth parameter, fall speed parameter and sand diameter and number of vegetated profile for regular and irregular wave analysis are given respectively in the following equations

$$\frac{A_{bar}}{d_{50}} = \frac{H}{d_{50}} \times \frac{1}{\Psi} + (\Psi)^{-0,1} \tag{4.1}$$

$$\frac{A_{bar}}{d_{50}} = \left(\frac{1}{\gamma_s} \times \frac{H}{d_{50}} \times \frac{H}{wT} \times \frac{1}{\Psi} \right)^{0,5} + \Psi^{-5} \tag{4.2}$$

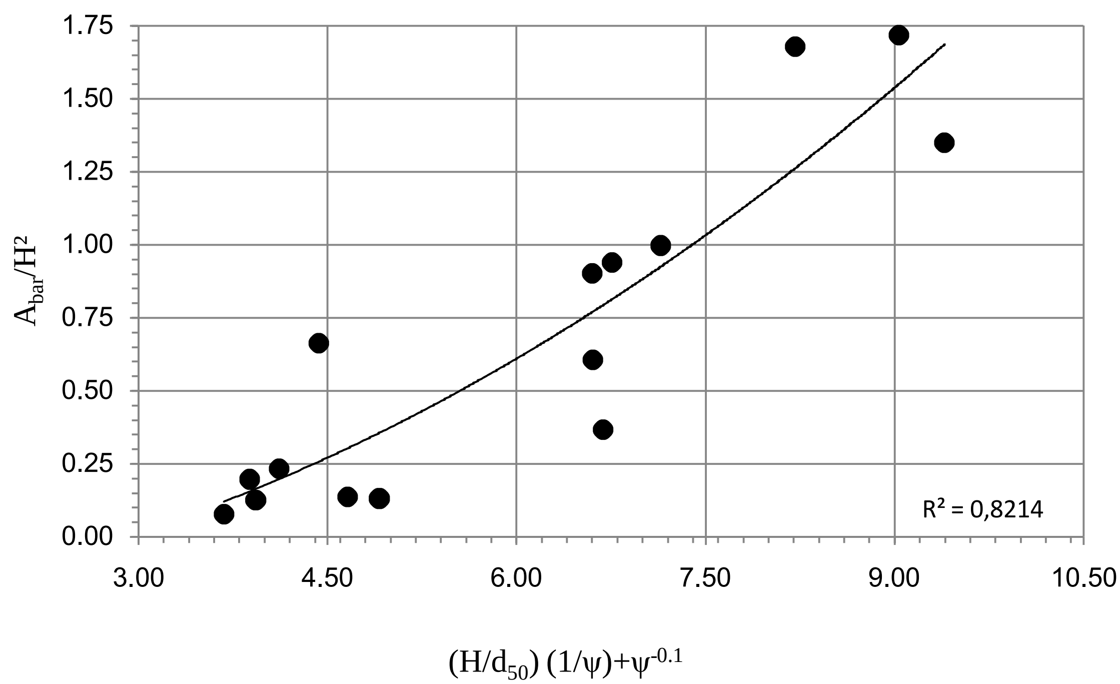

Fig.4.1.Dimensionless trend of offshore bar area under regular wave attack.

Where A_{bar} represents the optimum amount of sand contained within the bar per unit length of beach. Figures 4.1 and 4.2 illustrate the effect of formerly described dimensionless parameters on barred profiles for regular and irregular wave tests, respectively. The resultant curve at Fig.4.1 agrees quite well with the data where the determination coefficient is 82.14%. The relationship between dimensionless parameters under irregular wave climate also predicts outstanding results with R=0.79. It is compulsory to mention that the results of regular wave analyses always follows more linear proportionality between the parameters than the random wave analysis. The reason is that the random waves supply always the same wave energy which is always constant. However, random wave energy, due to its complex structure shows fluctuations, sometimes generating high waves with high energy capacity, sometimes generating small amplitude waves with closely no energy which is dissipating before reaching to the profile.

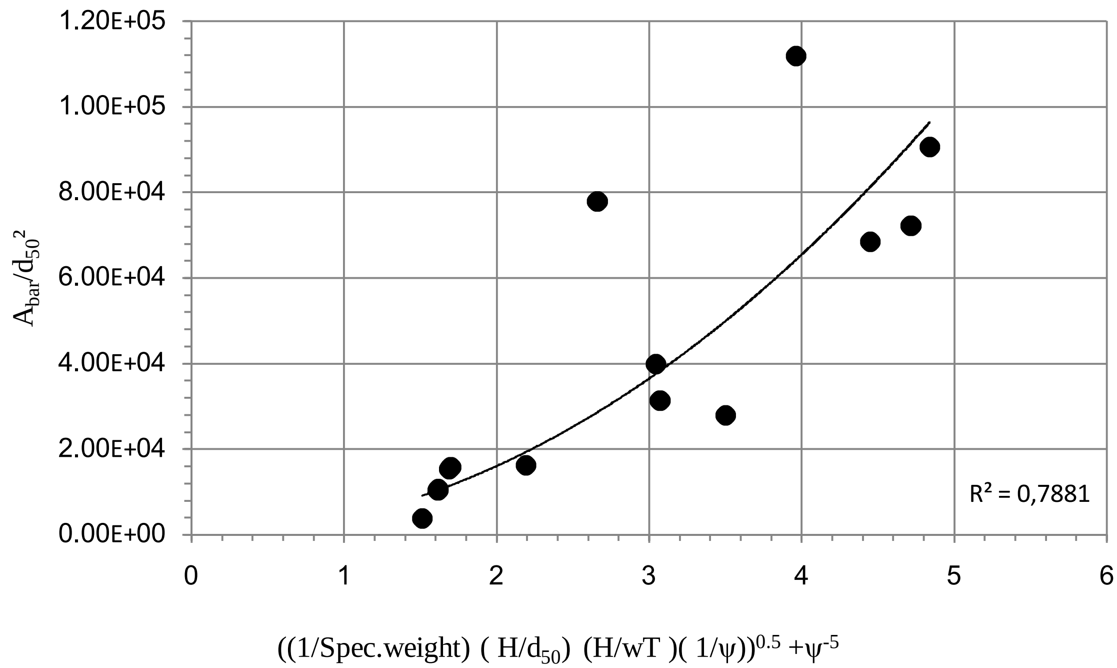

Fig.4.2.Dimensionless trend of offshore bar area under irregular wave attack.

4.3. The effect of vegetation on the evolution of eroded profile

All along the experiments, the sand moved on, off along the beach profile. These movements reshape the profile, forming beach erosion. The sand was travelling with each breaking wave under the force action due to energy dissipation. The increase in energy dissipation progressively increases the dislocation of the sediment grains on the erodible territory, enlarging the eroded area. Corollary to such erodible effect, as the area occupied by vegetal cover over the beach profile is extended, considerable decrease in coastal erosion is observed. The causes and effects of this reduction includes;

- Retardation or abrogation of wave break phenomena
- Reduction on sand dislocation since plant roots anchored the sand
- Absorbtion of substantial wave energy due to friction with protective vegetal stem.

The results of the experiments show that the amount of erosion is directly proportional with the wave height and inversely proportional with the sediment particle diameter and ψ of vegetation. Therefore, predefined dimensionless erosion parameter can be related to number of vegetated profile, depth parameter and fall speed parameter. The erosion parameter is finally defined in terms of the above dimensionless parameters. However, it was observed that as the good trends were attained, the effect of fall speed parameter diminished on the derived equation. Therefore, the final empirical relation that defines the amount of erosion under the protection of emergent vegetation, the regular and irregular wave analysis are given respectively in the following equations (4.3) and (4.4)

$$\frac{A_{erosion}}{H^2} = \left(\frac{H}{wT}\right)^{-0.1} + (\Psi)^{-1} \qquad (4.3)$$

$$\frac{A_{erosion}}{d_{50}} = \left(\frac{H}{d_{50}}\right)^{2} + (\Psi)^{-0.2} \qquad (4.4)$$

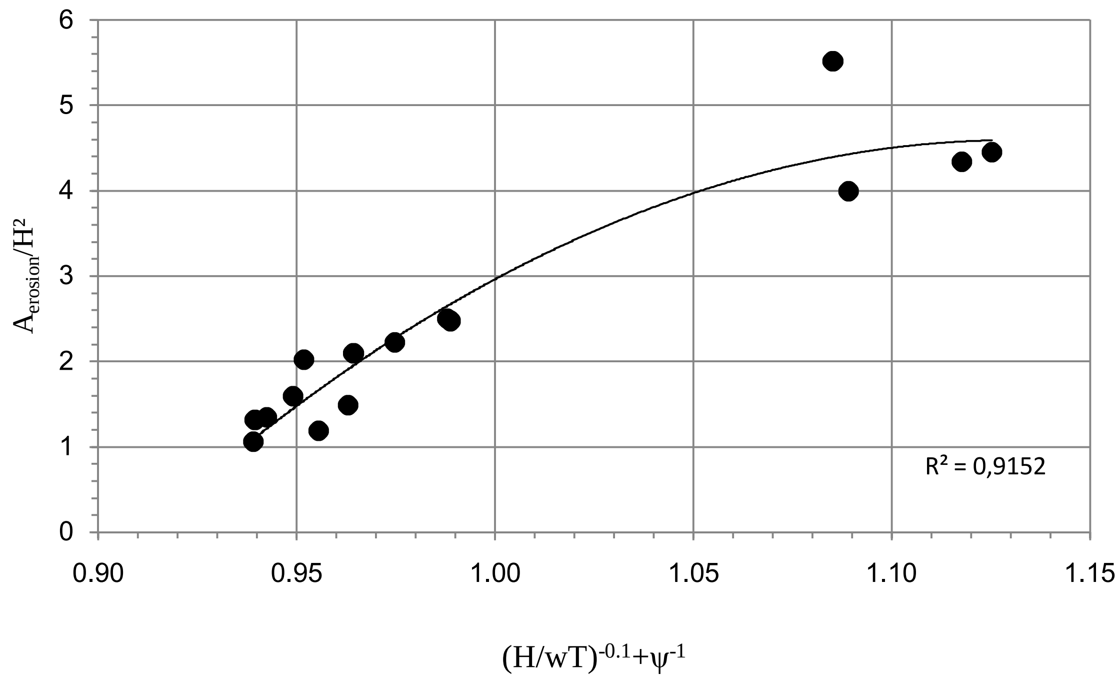

Fig.4.3.Dimensionless trend of offshore erosion area under regular wave attack.

The coefficient of determination, R^2, between the dimensionless parameters is 91.52% (Fig.4.3.). The coefficient of determination, R^2 between the dimensionless parameters is 82% (Fig.4.4.). The depth parameter was effective when the regular waves were under consideration and the fall speed parameter was dominating the beach profile changes under irregular wave analysis.

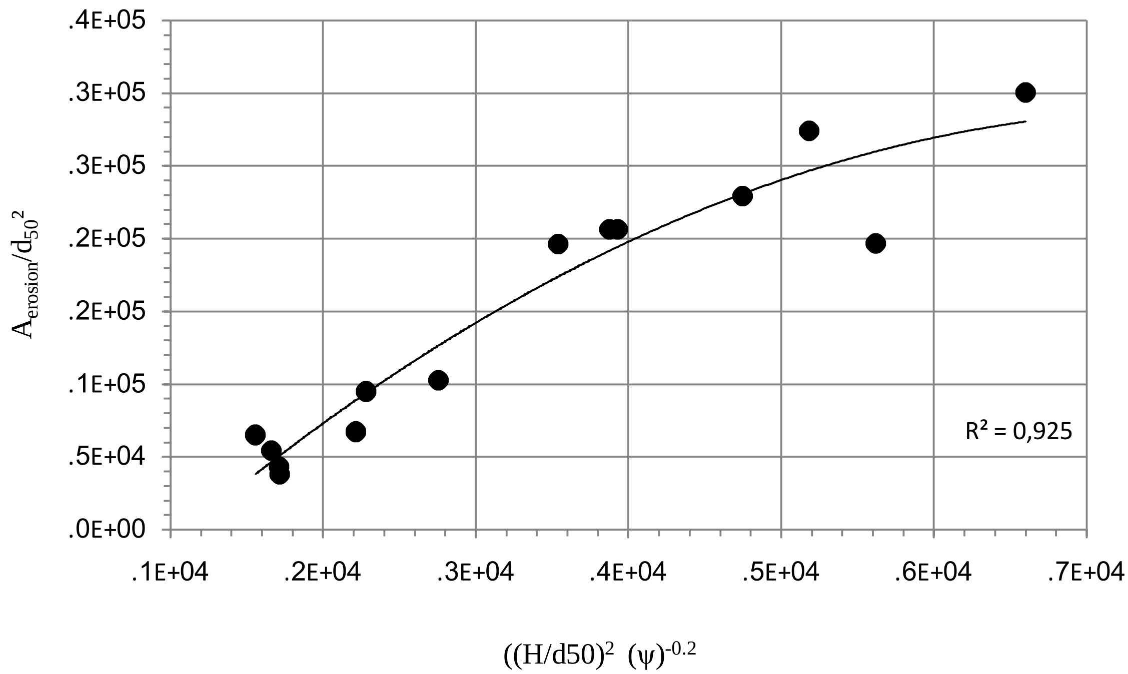

Fig.4.4.Dimensionless trend of offshore erosion area under irregular wave attack.

4.4. The effect of vegetation on average sediment displacement under regular-irregular waves

The amount of sediment dislocation caused by wave breaking depends on energy dissipation per unit volume necessary to move bulk of sediment from one place to another. The center of mass of offshore bar is the best point to define the offshore location of the bar. The uneven occurrence of shoreline disposition under storm waves is inevitable due to the erosion of beach foreshore. Consequently, the original shoreline is not such a precise location to define the distance of offshore bar. Thus, it is necessary to define the bar location by another reference line or point.

Depending on the wave climate and the sediment characteristics of the beach profile, inconsistency is observed on the geometric characteristics of offshore bar and eroded region of the foreshore. Whatever the shape of bar or erosion is, the distance between their center of masses follows a constant relationship, which is useful in defining the average dislocation of sediment particles during a storm (Fig.4.7).

Here, the beach damage parameter, Ω/H is evaluated in terms of number of vegetated profile. The results show that for the regular and irregular wave analysis, the relationship is linear possessing a good trend for coefficient of determination attaining 84% for regular and 88% for irregular wave analysis. The dimensionless relationship between the damage parameter and number of vegetated profile is given in Equations. (4.5) and (4.6) for regular and irregular wave analysis, respectively. The corresponding relations are plotted in Figs. 4.5. and 4.6.

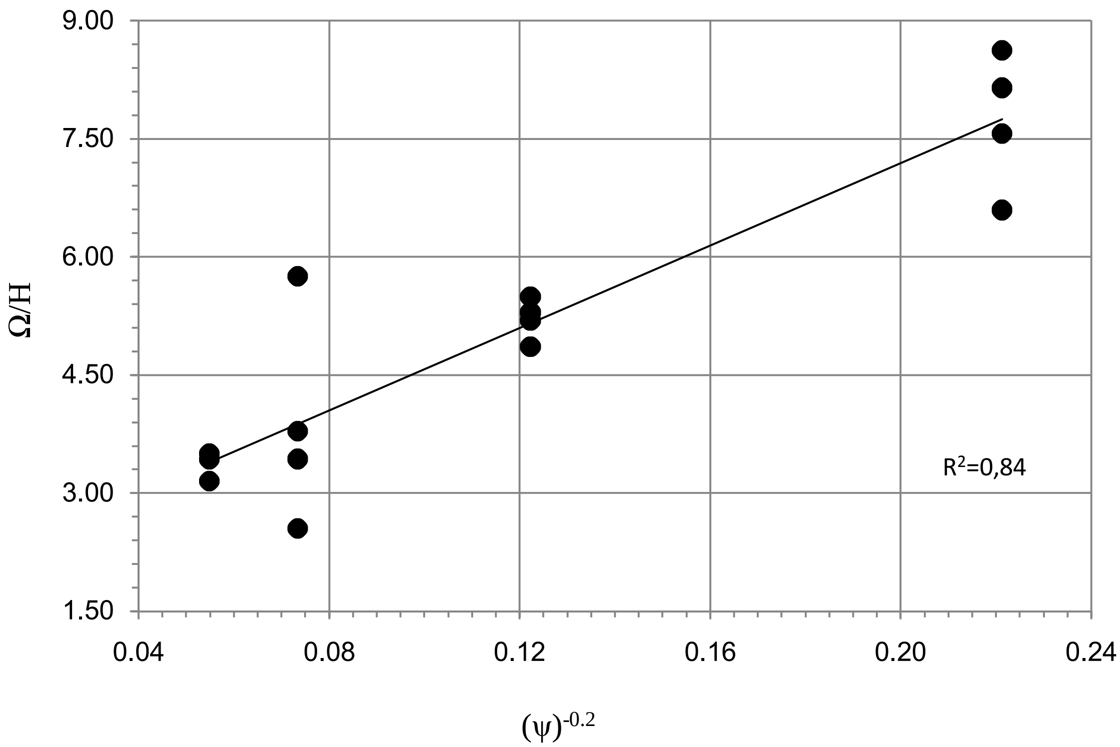

Fig.4.5. The variation of beach damage parameter with dimensionless profile number under regular waves.

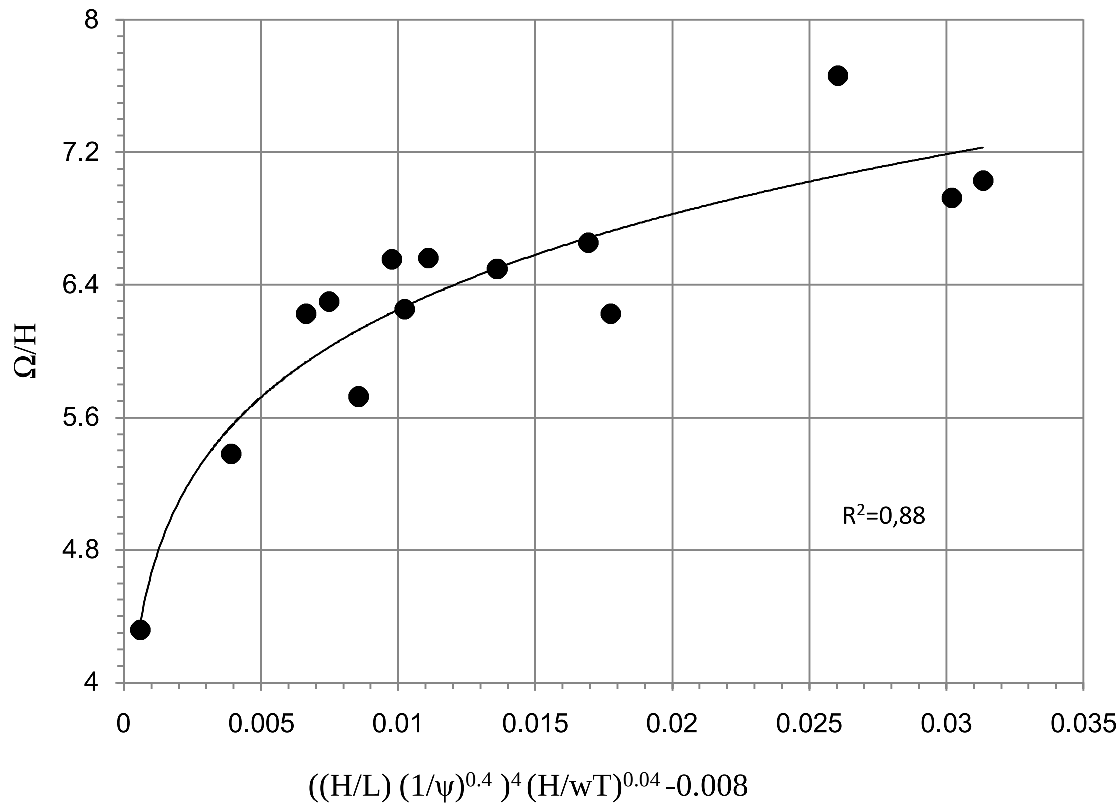

Fig.4.6. The variation of beach damage parameter with dimensionless profile number under irregular waves.

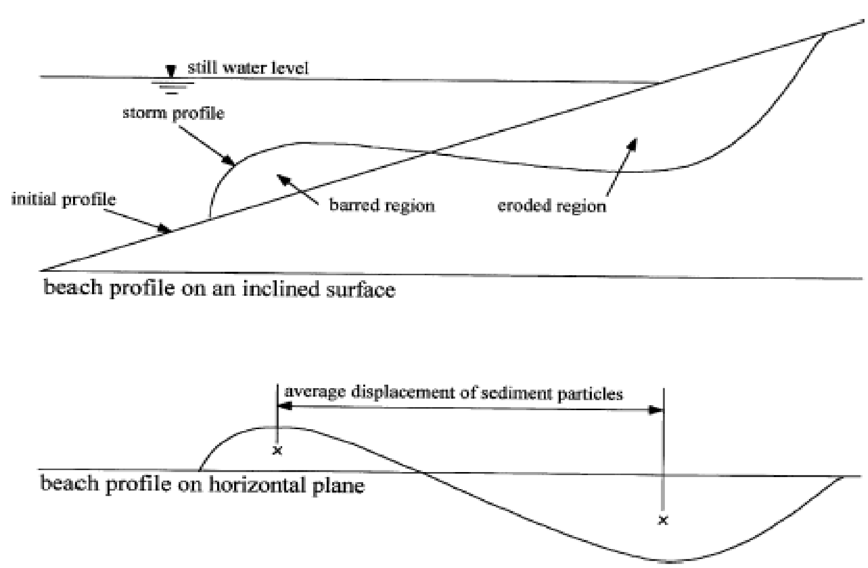

Fig.4.7. definition of sketch of barred profile.

$$\frac{\Omega}{H} = (\Omega)^{-0.2} \tag{4.5}$$

$$\frac{\Omega}{H} = \left(\left(\frac{H}{L} \right) + \left(\frac{1}{\Psi} \right)^{0.4} \right)^{4} \times \left(\frac{H}{wT} \right)^{0.04} - 0.008 \tag{4.6}$$

Table 4.3.Experimental result for regular wave analysis without protection (non-vegetation)

Experiment Name	**Wave Height, H_s (cm)**	**Wave Period, T (sec)**	**Distance of center of masses, Ω (cm)**	**Area of Erosion, A_e (cm^2)**	**Area of Bar, A_b (cm^2)**
W1	6,57	1	52,46	190,75	100,95
W2	3,69	0,75	37,61	87,60	30,50
W3	5,25	1,15	16,87	147,18	55,98
W4	6,16	0,9	59,51	291,90	78,30
W5	8,52	0,9	59,87	282,06	113,20
W6	8,17	0,87	59,52	318,45	68,55
W7	8,18	0,75	64,49	322,33	124,23
W8	9,41	0,77	58,35	254,98	97,28
W9	7,53	0,69	50,39	251,47	55,37
W10	9,32	0,77	60,32	299,36	100,50
W11	8,37	0,79	57,76	276,34	75,37
W12	6,41	0,63	40,15	187,06	18,41
W13	8,47	0,79	44,15	238,31	153,07
W14	8,23	0,74	55,67	234,13	72,95
W15	7,24	0,84	54,13	233,19	85,26

Table 4.4. Experimental result for irregular wave analysis without protection (non-vegetation)

Experiment Name	Wave Height, H_s (cm)	Wave Period, T (sec)	Distance of center of masses, Ω (cm)	Area of Erosion, A_e (cm^2)	Area of Bar, A_b (cm^2)
W101	6,57	1	50,65	154,9	44,37
W102	3,69	0,75	67,82	306,94	107,81
W103	5,25	1,15	80,75	374,95	133,61
W104	6,16	0,9	85,77	422,50	135,23
W105	8,52	0,9	52,29	170,36	39,75
W106	8,17	0,87	82,20	392,80	134,11
W107	8,18	0,75	79,26	402,05	162,50
W108	9,41	0,77	90,23	507,34	228,90
W109	7,53	0,69	91,38	210,55	132,0
W110	9,32	0,77	53,36	143,50	73,80
W111	8,37	0,79	52,28	152,60	17,50
W112	6,41	0,63	99,58	324,32	203,75
W113	8,47	0,79	65.79	157.75	75,525
W114	8,23	0,74	77,77	308,26	140,95

4.5. Storm wave effect on bar evolution without protection

The volume of equilibrium bar is most closely related with deepwater wave length and particle grain size. Perhaps, the initial slope of beach profile is also affecting the natural evolution of the offshore bar. In this study it is kept constant. The experimental results carried for regular and irregular waves state the importance of depth parameter in the definition of offshore bar volume. The relationship among the dimensionless bar volume, dimensionless depth parameter and the dimensionless fall speed parameter for regular and irregular wave analysis is given respectively in the following equations (4.7) and (4.8). The trend between the parameters is simulated in Figs.5.8 and 5.9.

$$\frac{A_{bar}}{H^2} = \left(\left(\frac{H}{L} \right)^{-1.2} + \left(\frac{H}{wT} \right)^3 \right)^{0.1} \quad (4.7)$$

$$\frac{A_{bar}}{d_{50}} = \left(\frac{H}{d_{50}} \times \frac{H}{wT} \times \frac{1}{\gamma_s} \right)^{0.4} \quad (4.8)$$

Where V_{bar} is the optimum volume of sand contained within the offshore bar per unit length of beach formed after the storm. The empirical definition follows a linear relationship possessing good trend between the dimensionless parameters. The coefficient of determination, R^2, between the dimensionless parameters is 63% (Fig.4.8.). The coefficient of determination, R^2 between the dimensionless parameters is 84% (Fig.4.9.).

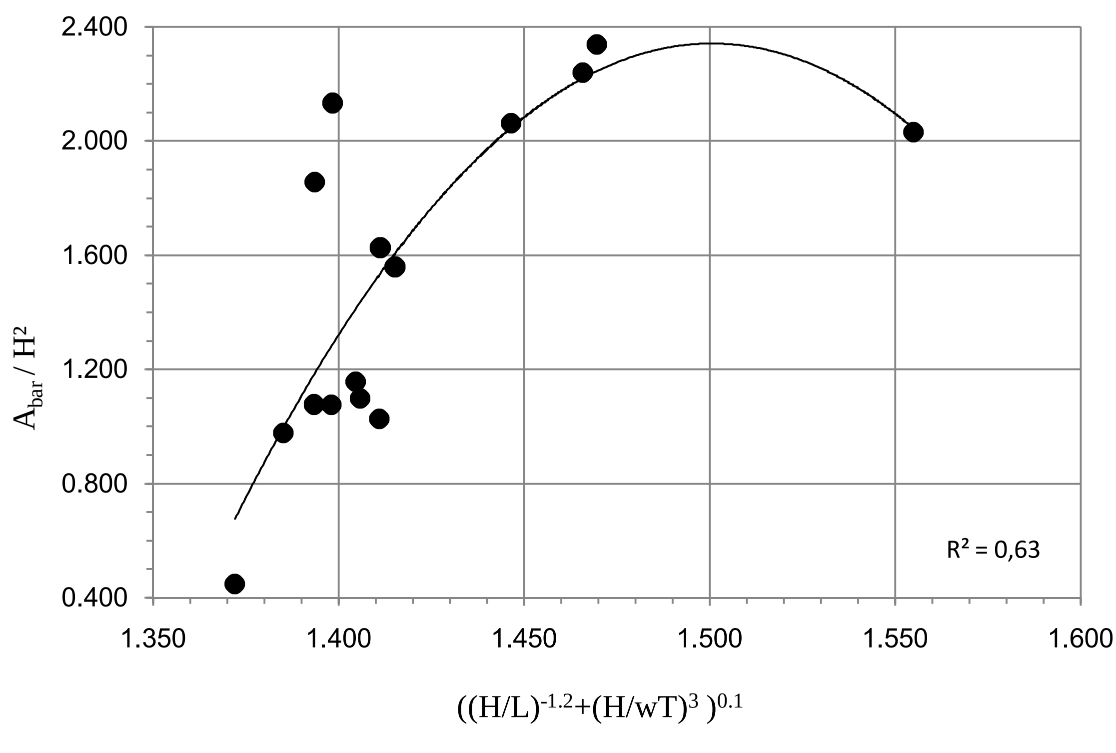

Fig.4.7.Dimensionless trend of offshore bar area under regular wave attack. (non-vegetation)

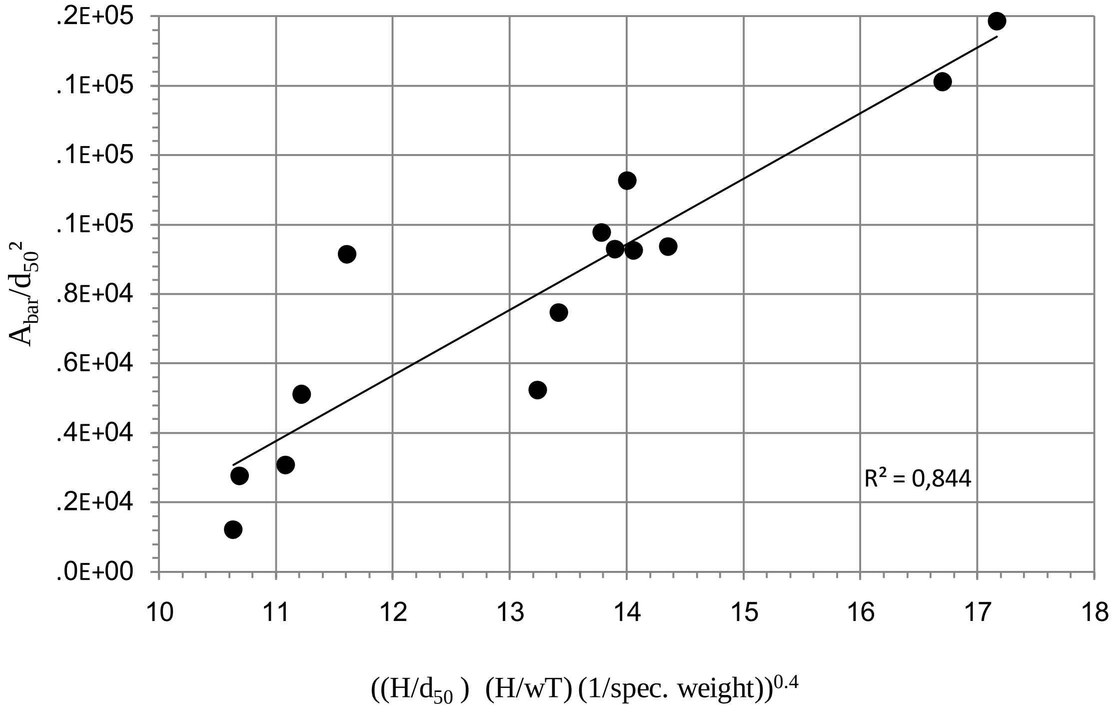

Fig.4.8.Dimensionless trend of offshore bar area under irregular wave attack. (non-vegetation)

4.6. Eroded profile relationships (non-vegetation)

In the absence of vegetal protection, the amount of erosion is increased because the storm waves didn't lose their energy, which is necessarily used to erode the beach profile. The experimental analysis shows that the amount of erosion is directly proportional with the wave height and inversely proportional with the sediment particle diameter. The erosion parameter is finally defined in terms of the dimensionless parameters. However, it was observed that as the good trends were attained, the effect of fall speed parameter diminished on the derived equation. Therefore, the final empirical relation that defines the amount of erosion under non- protection of emergent vegetation, the regular and irregular wave analysis are given respectively in the following equations (4.9) and (4.10),

$$\frac{A_{erosion}}{d_{50}} = 0.2 \times \left(\frac{1}{\gamma_s} \times \frac{H}{d_{50}} \right)^{-1.6} + 1 \quad (4.9)$$

$$\frac{A_{erosion}}{d_{50}} = \left(\left(\frac{H}{d_{50}} \times \frac{H}{wT} \times \frac{1}{\gamma_s} \right) - \left(\frac{H}{d_{50}} \times \frac{H}{L} \right)^2 - \left(\frac{H}{d_{50}} \right) \right)^4 \quad (4.10)$$

The empirical definition follows a linear relationship possessing good trend between the dimensionless parameters. The coefficient of determination, R^2, between the dimensionless parameters is 81.41% (Fig.4.10.). The coefficient of determination, R^2 between the dimensionless parameters is 91.3% (Fig.4.11.).

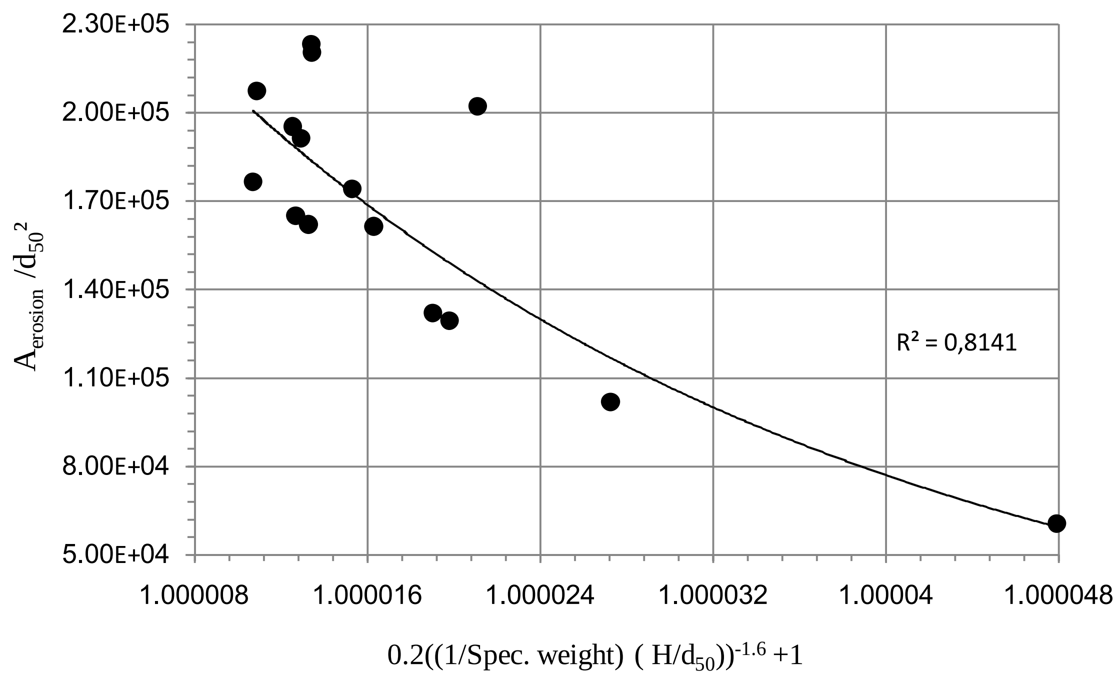

Fig.4.9.Dimensionless trend of offshore erosion area under regular wave attack. (non-vegetation)

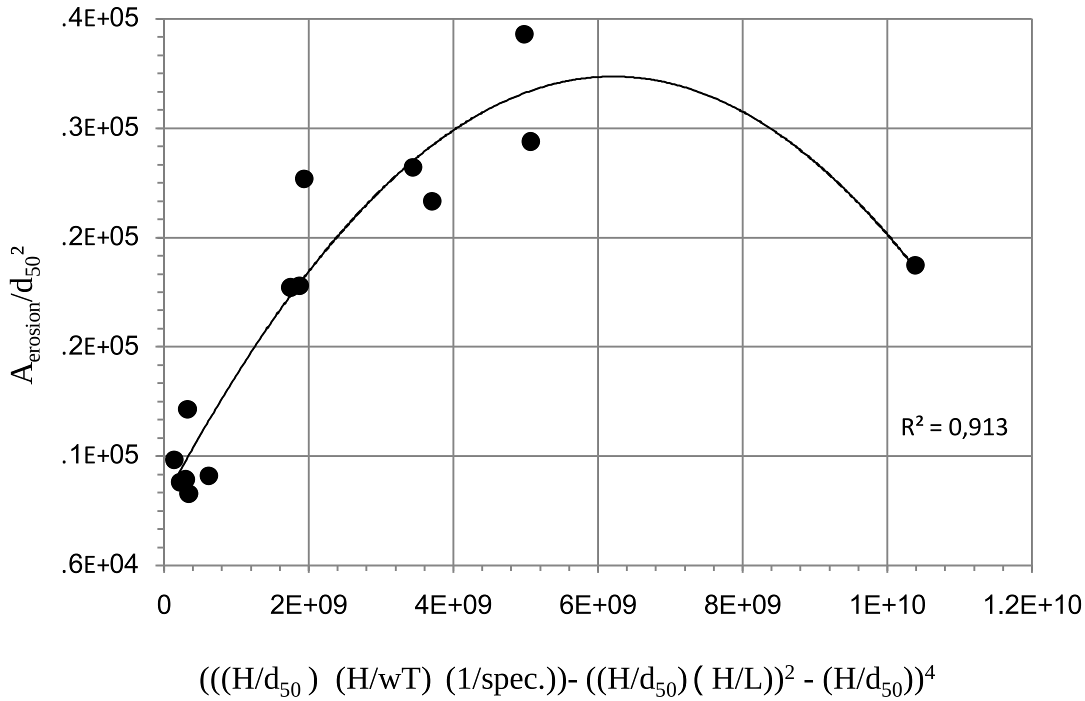

Fig.4.10.Dimensionless trend of offshore erosion area under irregular wave attack. (non-vegetation)

4.7. Average sediment displacement transport Ω under regular-irregular wave without protection. (non-vegetation)

During the experiments the results show that for the regular and irregular wave analysis, the relationship is linear possessing a good trend for coefficient of determination attaining 84,57% for regular and 70,62% for irregular wave analysis. The dimensionless relationship between the damage parameter and profile number is given in Equations (4.11) and (4.12) for regular and irregular wave analysis, respectively. The corresponding relations are plotted in Figs. 4.12., and 4.13.

$$\frac{\Omega}{d_{50}} = \left(0.02 \times \frac{H}{d_{50}} \times \left(\frac{H}{wT}\right)^{-0.9}\right)^{3} + \left(\frac{1}{\gamma_s} \times 5 \times \frac{H}{d_{50}}\right)^{0.4} \qquad (4.11)$$

$$\frac{\Omega}{d_{50}} = \left(\left(\frac{H}{wT}\right)^{0.3} - \left(\frac{H}{L}\right)\right)^{-5} \qquad (4.12)$$

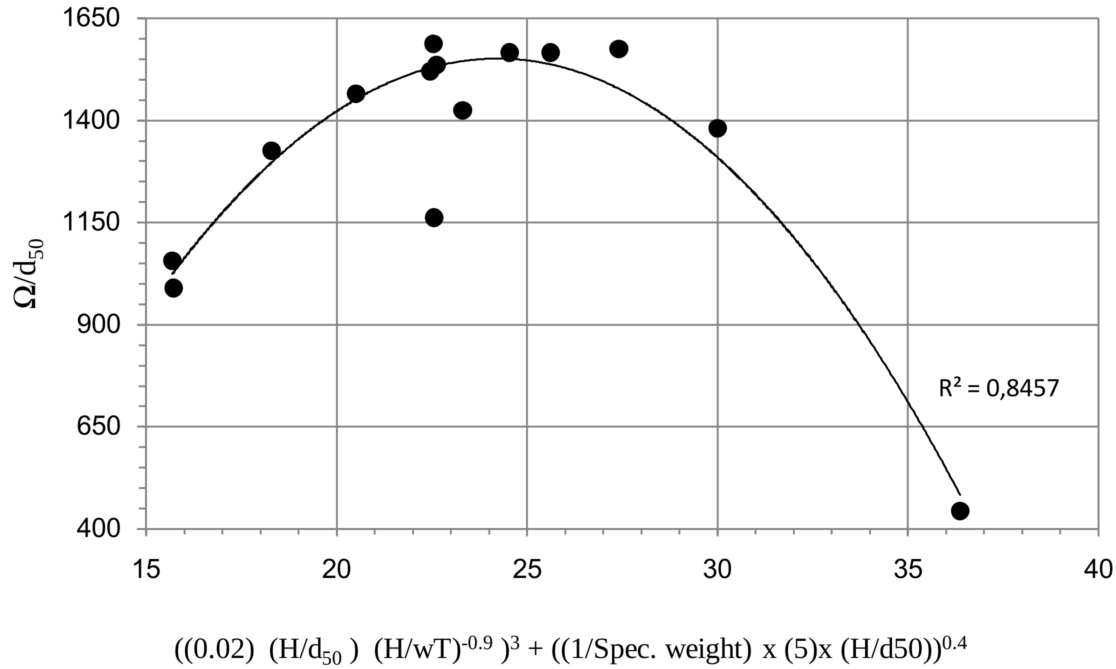

Fig.4.11. The variation of beach damage parameter with dimensionless profile number under regular waves.

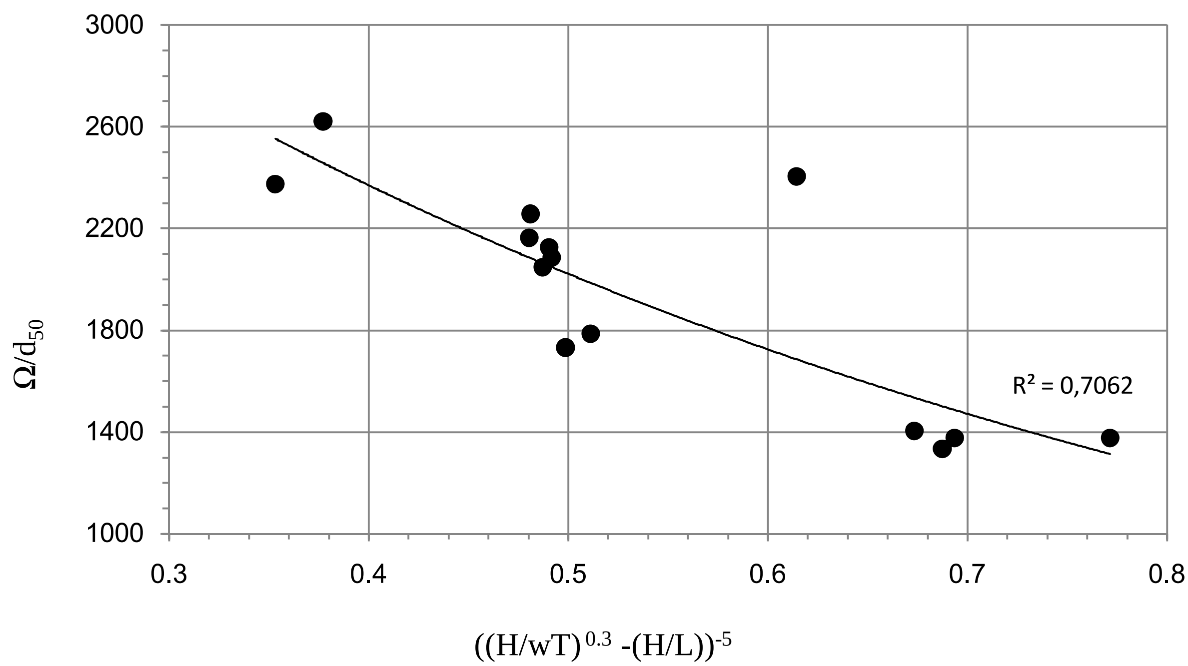

Fig.4.12. The variation of beach damage parameter with dimensionless profile number under irregular waves.

4.8. Relation of experimental data and empirical equations

Independent of applied wave climate (regular or irregular), it can be concluded that even a small vegetation intensity results in beach protection, independent of the incoming wave heights. However, non-protected beach profiles usually sustain damage affected by the action of wave storm. Following figures, Figs. 4.13, 4.14, 4.15, 4.16and 4.17 shows the result of the study carried in this study. The aim is to figure the results of this study with the following figures, under normal wave conditions.Varing wave heights starting from 1 meter and extending up to 4 meters are used at different wave periods in order to generalize the relationship between intensity of vegetation and erosion area, bar area and average sediment dislocation

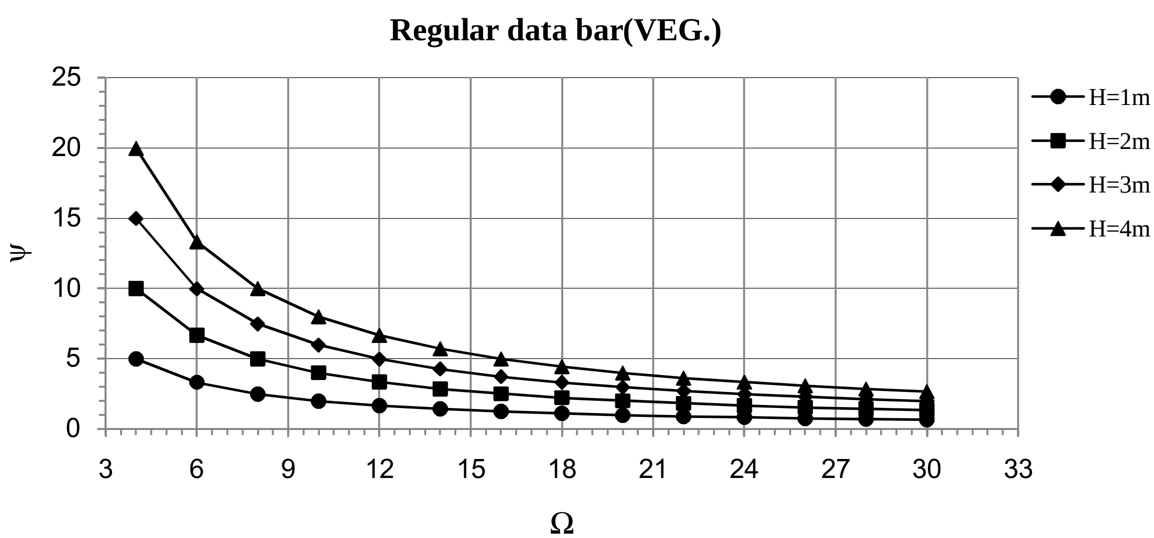

Fig. 4.13. Variation of average sediment transport with vegetation parameter under regular waves.

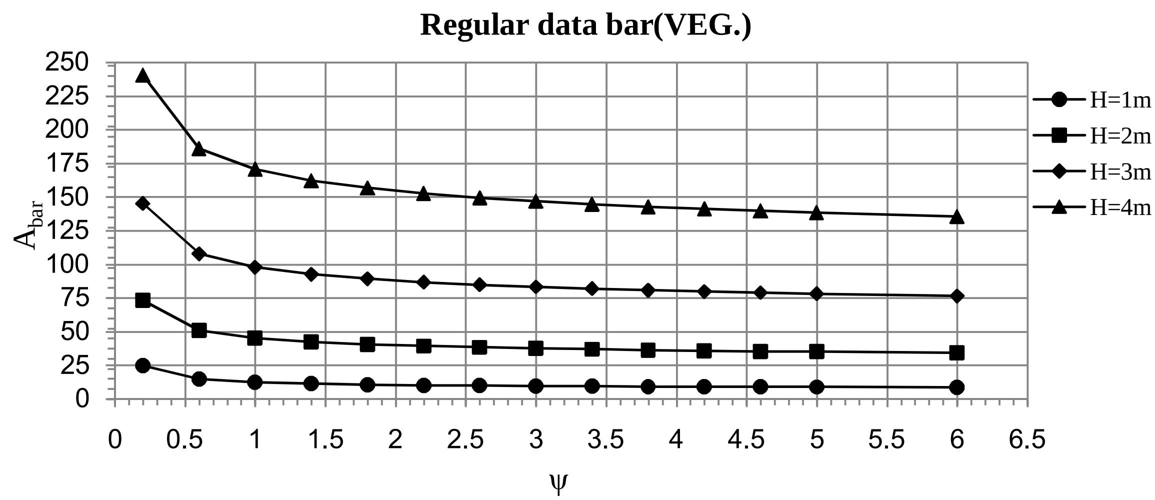

Fig. 4.14. Variation of area of bar with vegetation parameter under regular waves.

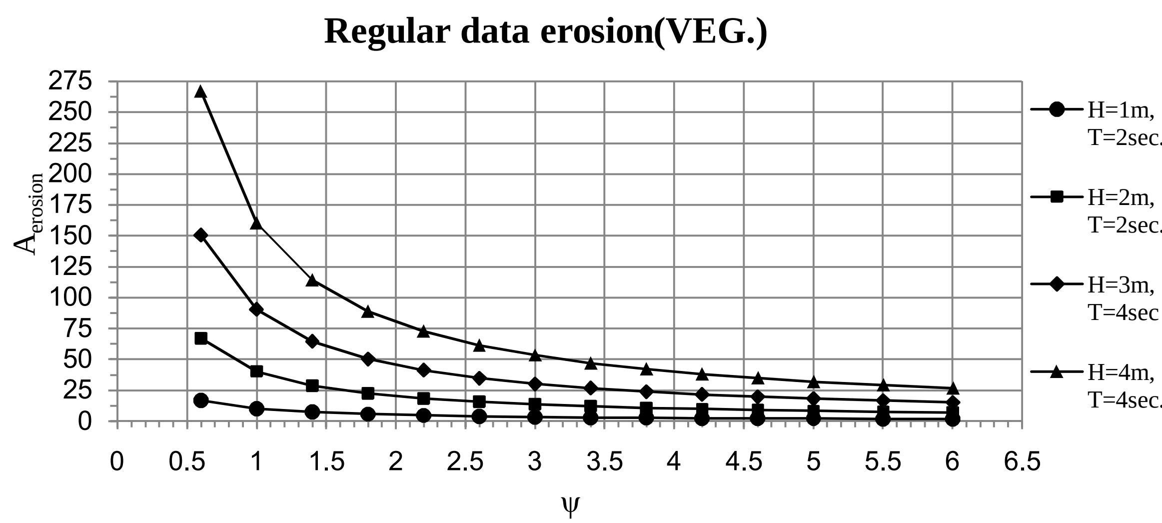

Fig. 4.15. Variation of area of erosion with vegetation parameter under regular waves

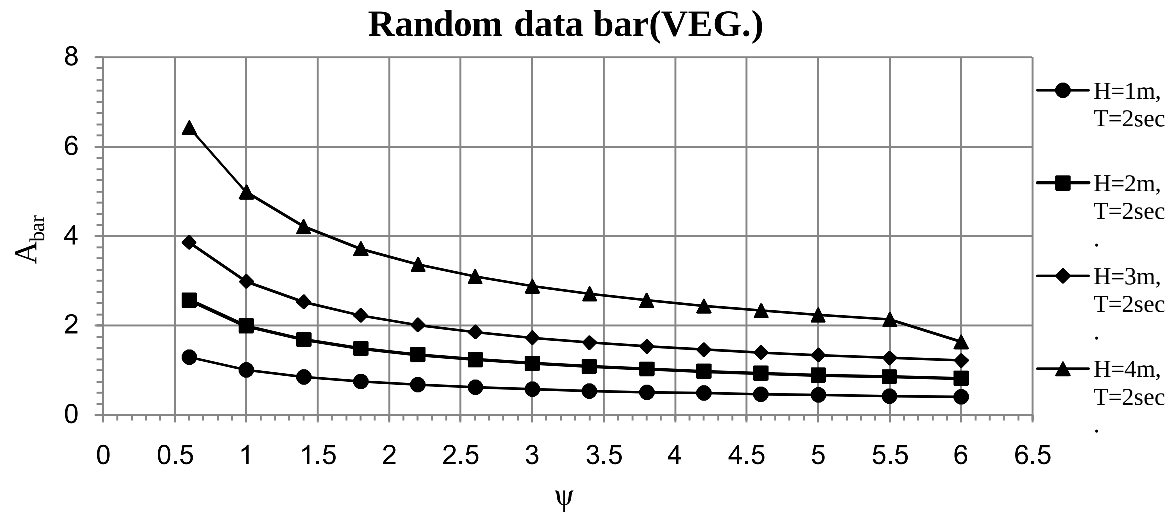

Fig. 4.16. Variation of area of bar with vegetation parameter under irregular waves

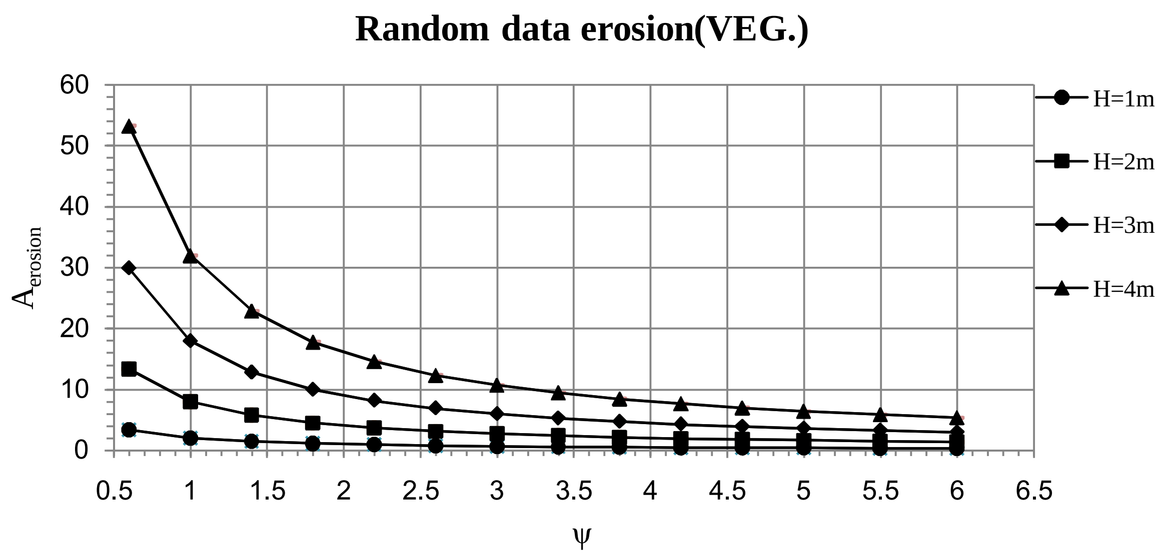

Fig. 4.17. Variation of area of erosion with vegetation parameter under irregular waves

CHAPTER 5

6. Conclusion

This experimental study investigated coastal erosion and coastal bar and average displacement of sediment particles geometry under the influence of the regular-irregular waves, with-without vegetal protection. Natural beach sand was used in this study, where the mean sediment diameter was 0.33mm and the specific gravity of the sand was 2.55. The initial beach slope kept constant 1:5.

The experimental studies demonstrate the expected changes on morphologic features of beach profiles. The result of other studies are compared with the result of this study and show that the experiments produced good result. It is observed that, when the wave height increases, the bar area and erosion area increases.

The experimental results are analyzed and the most important governing parameters on coastal changes under the protection and non-protection of emergent vegetation were defined. These parameters were written as a dimensionless group, and, based upon the experimental data, empirical equations were developed for regular and irregular waves.

The change of beach profile was analyzed, considering the volume of erosion, volume of bar and the distance between their center of masses. In volume of bar, the relationship between the parameters were more accurate on regular wave analysis in vegetal case, where polynomial equation in regular and power equation for irregular were described the relationship. Therefore, in volume of erosion, the relationships between the parameters were more accurate on irregular wave analysis in vegetal case, in which polynomial equation described the relationship. However, in non-vegetal case, while defining bar and erosion volume, relationship between the parameters were more accurate under irregular waves, where polynomial and power and linear equations respectively described the relationship. In average sediment displacement the relationship between the parameters were more accurate on irregular wave analysis in vegetal and non-vegetal cases, where polynomial, linear, power and exponential equations described the relationship.

The result of this study has shown that, still, there are some studies that should be carried in order to better understand the physical behavior of beach profile. These studies can be carried on wave energy dissipation while wave breaks and dissipates within the vegetation or can be concentrated on elapsed time for evolution of equilibrium beach profile conditions for non-vegetated and vegetated conditions.

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