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DEPARTMENT OF THE ARMY — CORPS OF ENGINEERS

BEACH EROSION BOARD
OFFICE OF THE CHIEF OF ENGINEERS

BEACH PROFILE AS AFFECTED BY VERTICAL WALLS

TECHNICAL MEMORANDUM NO. 134

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BEACH EROSION BOARD
CORPS OF ENGINEERS

JUNE 1963

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FOREWORD

An important aspect in consideration and design of shore improvement measures is the resulting effect on the beach of placing smooth-face walls in the zone reached by wave action. In many cases such walls may produce severe scour and loss of the beach both behind the wall as well as in front of the wall.

This memorandum presents the results of a laboratory model study to investigate the equilibrium beach profile resulting when vertical walls of various top elevations above or below the elevation of the undisturbed water surface (relative to incident wave height) were located in the beach zone and subjected to wave action. As might be expected walls of highest relative top height, by allowing less energy to pass over the wall, resulted in greatest scour in front of the wall, while lower walls resulted in increased scour dimensions behind the wall. Effects of wave steepness and grain size of beach material were also investigated. It is believed that the results of this investigation could prove useful in considering practical problems involving vertical-face walls, although care must be exercised in interpretation for prototype use as appreciable scale effect may be involved.

This report was prepared at the Hydraulic Engineering Laboratory, Institute of Engineering Research, University of California in pursuance of contract DA-49-055-CIV ENG-63-4 with the Beach Erosion Board, which provides in part for the study of transport of coastal sediments. The author of this report, Abdel-Latif Kadib, was a graduate student at that institution during this investigation.

This report is published under authority of Public Law 166, 79th Congress, approved July 31, 1945.

TABLE OF CONTENTS

LIST OF FIGURES

SYMBOLS

D_o - Mean diameter of the bed material.

H_o - Deep water wave height.

L_o - Deep water wave length.

R - Vertical height of the limit of the uprush above still-water level.

S - Horizontal distance of the limit of the uprush measured from the wall.

T - Wave period.

d - Depth below still-water level.

h - Height of the wall top with respect to the still-water level, being considered positive upwards.

δ - Vertical height measured from the still-water level to the lowest point of the scour pool behind the wall, being considered positive if below the still-water level.

ξ - Width of the scour pool behind the wall.

Z - Vertical height in front of the wall measured from the still-water level.

ρ_s - Density of the bed material

BEACH PROFILE AS AFFECTED BY VERTICAL WALLS

by

Abdel-Latif Kadib
University of California

CHAPTER I

INTRODUCTION

General

Beach erosion has been a problem as long as there have been oceans and shores for the ocean to wash against. Natural erosion is caused basically by two natural actions of water, (1) incoming waves and (2) littoral currents.

Individuals took it upon themselves to construct protective works of one kind or another. The types and the examples were as varied as the individuals constructing them. In addition, a type which might be entirely effective in one locality may be totally inadequate under another set of apparently similar conditions. Some of the bank protection works subjected to wave attack consist of vertical sheet piling walls in combination with revetments, concrete slabs, and heavy concrete blocks(1)*; Figures 1 and 2 show some examples of such protection works. Even with the use of these expensive works, failure was always anticipated due to the erosion of sand from behind these structures.

Description of the problem

This investigation is concerned with the equilibrium profiles of protected beaches. It includes an experimental investigation of a sandy beach protected by a vertical seawall. One of the many aspects of the whole problem is the influence of geometric variables like the change of the vertical wall top elevation above and below the still-water level, the mean diameter of the bed materials, and different scale ratios of the wave on the same material.

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*Numbers pertain to references on Page 39

The equilibrium profiles of protected beaches may be found experimentally. In order to be able to make use of such experiments we must know: (1) the character of the incident wave; (2) the action of these waves on the protected beach; (3) the effect of the vertical wall top elevation on the variables forming the equilibrium profiles; and (4) the similarity between model and prototype conditions.

On a vertical wall there are two types of waves possible: (1) a breaking wave, which is most severe; and (2) a clapotis, or reflected wave, which is not so severe[4]. In nature a vertical wall may be acted upon by waves that before breaking may have had the character and qualities of solitary waves[17]. Immediately before and after breaking the waves always have an irregular form which cannot be expressed by a simple equation, and even if the waves before and after the reflection should have the character of the solitary waves, this probably will soon be lost[18]. It is difficult to formulate any theoretical rules about the effect of a vertical wall on a beach profile. The problem may be illuminated by an experimental study of beach behavior and the final equilibrium profile.

The equilibrium profile

The variables describing the equilibrium profile are shown in Figure 4. In this sketch, Z is the vertical height in front of the wall measured from the still-water level to the equilibrium profile; S is the horizontal distance of the limit of the uprush measured from the wall; R is the vertical height of the limit of uprush above the still-water level; δ is the vertical height measured from the still-water level to the lowest point of the scour pool behind the wall, being considered positive if below the still-water level; ξ is the horizontal distance measured from the top of wall to the equilibrium profile (this distance gives the width of the scour pool behind the wall); h is the height of the wall top with respect to the still-water level, being considered positive upwards; D_o is the mean diameter of the sand used.

The variables required to describe the character of the incident waves are the deep-water wave height, H_o, and the wave period, T.

General analysis of the problem

The parameters controlling the profile of a sandy beach without a seawall have been shown by former studies[15] to be: the properties of the deep-water wave given by the deep-water length, L_o, wave height, H_o and the properties of bed materials of a sandy beach expressed by the representative grain size D_o (average diameter) and density (ρ_s). In the present study we add the variables h, Z, R, S, δ and ξ. A consideration of the various terms shows that the following dimensionless groupings can be used to represent the relationships between the variables: h/H_o, R/H_o, Z/H_o, δ/H_o, ξ/H_o, and H_o/L_o.

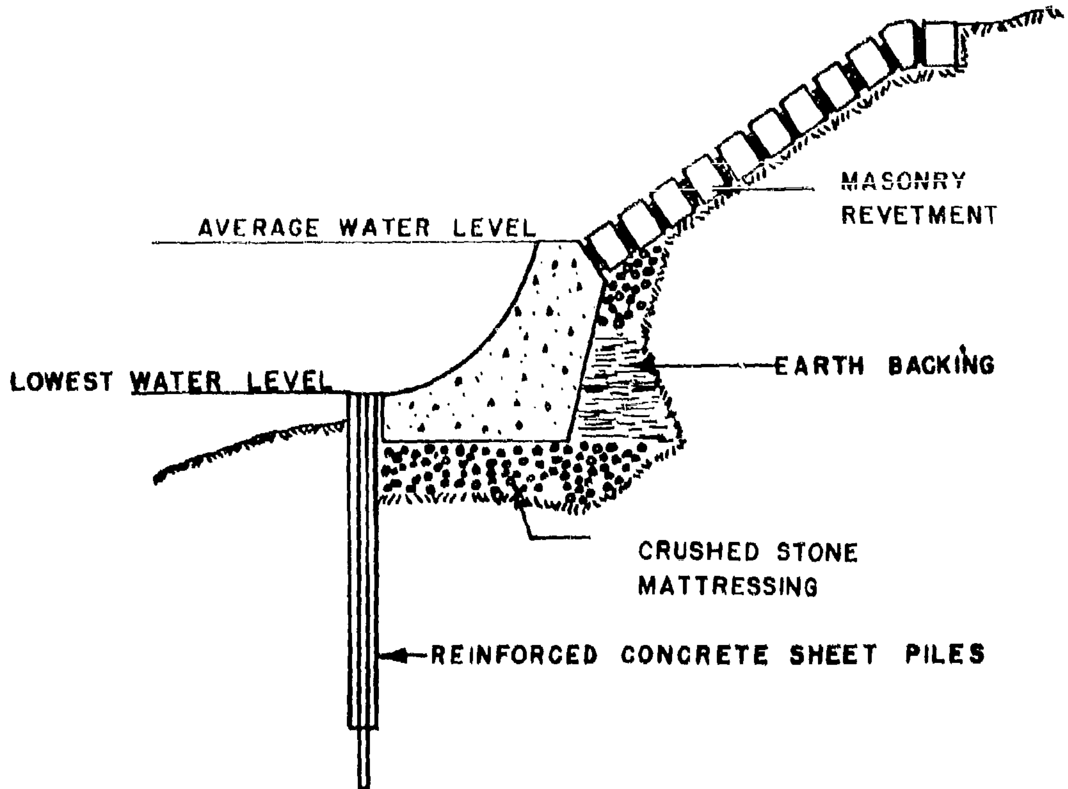


FIGURE 1 — EXAMPLE OF PROTECTION WORKS

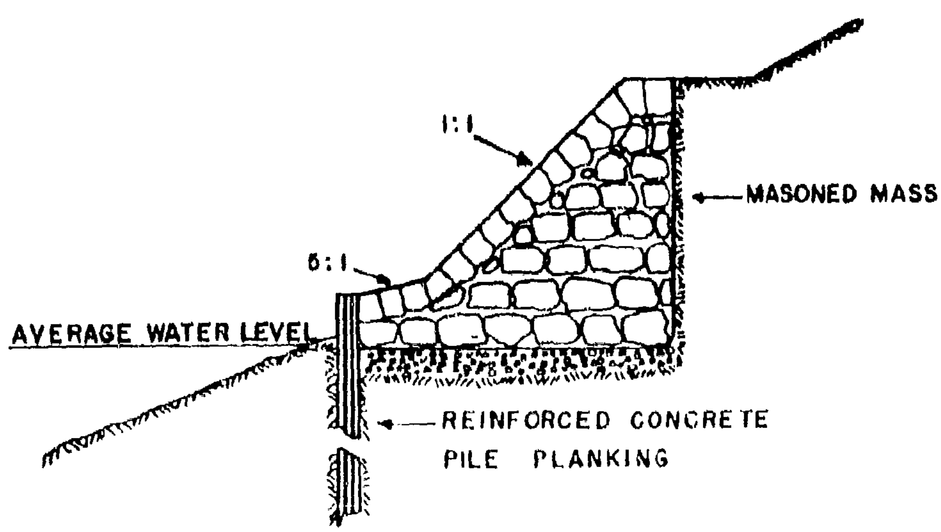


FIGURE 2 — EXAMPLE OF PROTECTION WORKS

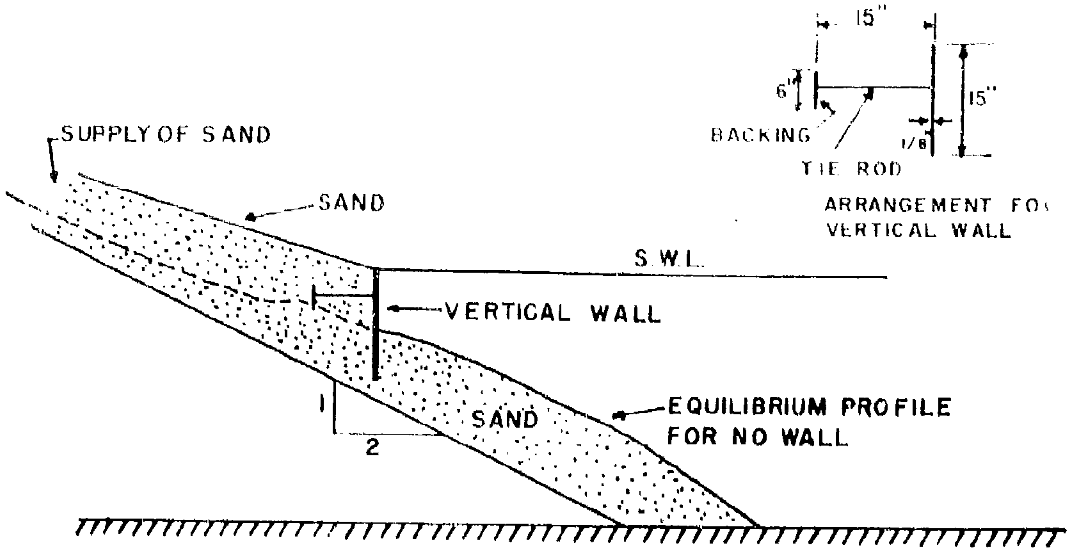


FIGURE 3 - SKETCH OF THE PROFILE BEFORE TEST

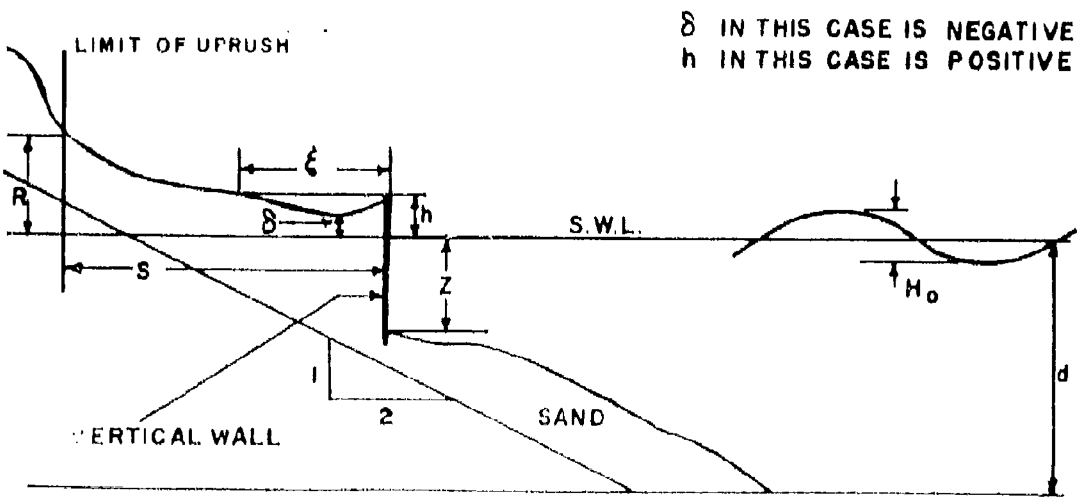


FIGURE 4 - SKETCH OF THE EQUILIBRIUM PROFILE

Previous work

The Beach Erosion Board conducted many studies for beach profiles and sand movement by waves. Laboratory studies of beach profiles[30] indicated that the shape of the equilibrium profile is primarily a function of the wave characteristics and the relative coarseness of the bed material. Scott[31] studied the effect of wave steepness on the movement of sand along the bottom. His experimental results showed that for waves with steepness ratios above 0.03, storm profiles were produced, whereas for waves with steepness ratios less than 0.02 summer profiles prevailed. Bruun[32] studied the development of beach profiles for different wave conditions in the Mission Bay area and in the Danish North Sea coast. He also investigated the seasonal variations and the average annual recession of the coastline in both areas. Watts[33] found from his experimental studies that varying the wave period 10 or 30 percent from a mean period with the actual period changes being made every 10 minutes or every hour, final foreshore and offshore slopes were produced that were similar to those formed by a constant period wave attack. Ippen and Eagleson[34] investigated the mechanics of the processes by which beach sediments are sorted selectively when acted upon by shoaling waves. They present a theoretical analysis which yields a general functional equation for net particle velocities. The introduction of tidal action was studied by Watts and Deardruff[35]. They gave the effect of tidal action on the foreshore and offshore slopes of beaches.

An excellent survey of beach stability has been given by Minikin (2, 3, 4, 5, 6) wherein a comprehensive report about the coastal forces and the forms of protection was presented. The International Congress of Navigation[7] has had a committee studying the general problem of vertical breakwaters, and as a part of this subject the study of the action of water particles in front of a vertical breakwater was made by Sainflou of the (Ponts et Chaussees) of France. This investigation was expanded by Benezit and Renaud[9] to include the velocities of the particles at the sea bottom in front of the breakwater, but the action of the water at the immediate toe of the wall was not considered.

Meyer[10] made a model study of wave action on beaches, and Waters[11] studied the equilibrium slope of beaches under various wave conditions. Bagnold[12] made some model experiments for beach formation by waves. Johnson[13] suggested that beach profiles could be studied non-dimensionally. Three different models were used[14] to study beach profiles due to wave action. It was concluded that: "The similarity of profiles obtained from comparable setups and the close agreement between the stable slopes resulting from these tests with a given material are both indicative of the fact that a small-scale study of wave action on various materials could be used in studying full-scale wave action on <u>identical materials</u>. It is believed that the results obtained from such tests would give reliable indications of the stable slopes to be expected for beaches or dam faces subject to full-scale wave action."

Additional studies have been made recently in Japan[15] using two different mean diameter sands to study the equilibrium profiles of sandy beaches. The only work known to the writer concerning the equilibrium profiles of sandy beaches protected by vertical wall is the work done by Dorland[16], studying the equilibrium slopes in front of seawalls due to wave action. He studied the building of beaches in front of the seawall under the action of fairly steep waves.

CHAPTER II

GENERAL THEORETICAL CONSIDERATIONS

General wave theory

The waves investigated were deep water waves--periodic disturbances under the control of gravity and inertia. In deep water, waves are characterized primarily by two factors; height, H_o, which is the difference in elevation between the trough and the crest of the wave, and the period, T, which is the time between the passage of two consecutive crests past a fixed point. Other characteristics like the wave length, L, may be derived from the expression relating it to the period, T; $L_o = 5.12\ T^2$. The wave steepness is defined as the ratio between wave height and length, H_o/L_o.

Most waves are generated at sea in what is called deep water, where the bottom has no effect on the normal wave properties. When the waves approach a structure located in shallower water, the bottom affects the waves and changes their characteristics. The term "deep water" is customary to consider water deeper than one-half the wave length; $\frac{d}{L} > \frac{1}{2}$.

Energy dissipation

In general, the energy of a wave striking a seawall or shore line is transformed or dissipated by[19]:

1. Reflection

2. An increase in the potential energy--that is, wave uprush

3. Heat

   a. Generated by the turbulence of the breaking of the wave.

   b. Generated by the roughness of the structure.

   c. Generated by the mixing in the voids of a permeable structure.

1. Reflection

When an oncoming wave strikes a structure or even a natural coast, it can be partially or wholly reflected[19]. The problem of waves partially reflecting from a boundary is difficult, especially when the amount of energy either dissipated or transformed at any boundary is unknown[20].

Some tests concerning "the damping action of submerged breakwaters" are mentioned in (24). The experiments are important for the construction of submarine breakwaters.

2. Wave uprush

When a wave rushes up a beach or structure, some of the kinetic energy of the wave is transformed into potential energy as it runs up the beach. Several investigators have studied wave uprush experimentally, using dimensionless parameters[19, 21, 22, 23].

3. Roughness

The addition of roughness to a surface increases the turbulence and this dissipates energy. Many structures have been built incorporating a surface roughness in an attempt to reduce the wave uprush. Some have been successful and some have not[19].

The effect of a vertical wall on the beach profile

If, along some stable beach, an impermeable bulkhead or wall is inserted, it will cause a partial standing wave to form, increasing the water motion at the bottom and putting the sand into suspension[28]. The result is a scour at the wall; the beach in front of the wall is flattened and the material is drawn some distance down the beach[17, 25].

Minikin[4] gave three different effects which may be possible: (1) the effect of the clapotis in front of a vertical wall; (2) the effect of the collision of the backrush with the oncoming wave; and (3) the effect of reflection.

Choice of beach materials

Theoretically, similarity requires that the mean diameter of the granular materials of the bed be reduced in the model in the same ratio as the ratio of the lengths, and that the ratios of the specific weights of the movable material be the same as the ratio of the densities of the liquids. In practice, however, the size required may be violated because it is sometimes impossible to obtain a non-colloidal beach material of proper size for the model. Some experiments[14] in models have shown that violation in similarity considerations in this respect does not prevent good results. However, in beach problems the known formulas of dynamic similarity are difficult to apply because of the fact that there is no continuous flow at the beach[29].

CHAPTER III

LABORATORY SETUP

General arrangement

The laboratory tests were made in the Hydraulic Laboratory, University of California, Berkeley. The protected beach model was located in an existing wave channel. The general arrangement of the experimental equipment is shown in Figure 5. Fresh water was used for this investigation.

The wave channel

The wave channel used for this investigation is of uniform cross section, 106 feet long, one foot wide and 3 feet deep. A flap-type wave generator is located about 7 feet from one end. Behind the flap and against the end of the wave channel is a $2\frac{1}{2}$-foot long vertical wave absorber made of aluminum metal borings held in place by a wire screen mesh. The channel is equipped with a series of glass panels for visual observations. One synchronized motor-driven crank, attached to the top and hinged to the bottom of the wave-generating flap, controls the amplitude of its translating and rotating oscillation.

A $\frac{1}{2}$-horsepower A.C. motor drives the wave generator. A Varidrive unit attached to the motor offers a convenient method of changing the gear ratio between the motor and the wave generator. The wave generator is capable of generating waves up to 0.7 foot high and with period from 0.5 to 2 seconds.

The model beach

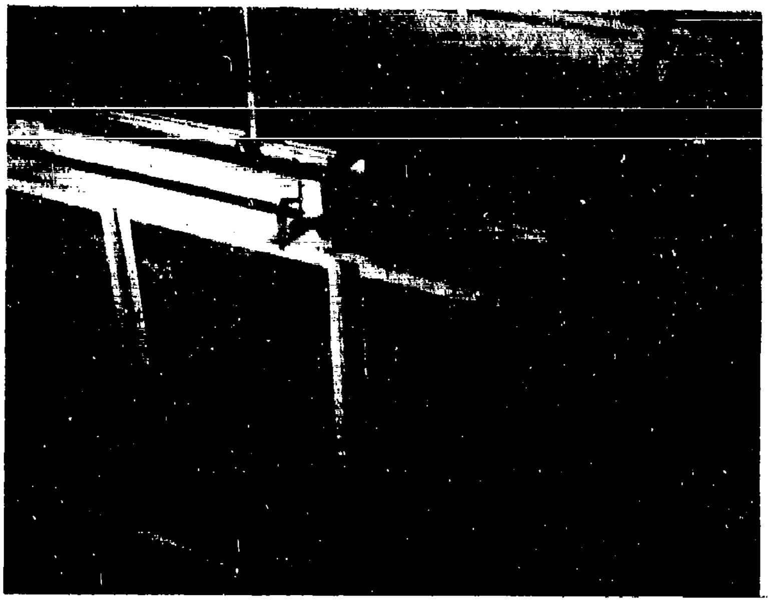
The model beach was located at about 75 feet from the wave generator. Sand was placed to form a beach with a slope 2 horizontal to 1 vertical. Because it is desirable that seawalls should not be built where the wave breaks, and the winter profile be determined to select the position of the wall[17], similar conditions were made in the model and the position of the vertical wall was chosen as shown in Figure 6. The wall consisted of a vertical aluminum sheet 1/8 inch thick, 15 inches high, and 12 inches wide. The wall was reinforced by two longitudinal $\frac{1}{4}$-inch steel rods attached to a supporting plate 12 inches high by 12 inches long. Figure 3 shows this general arrangement.

Profile measurements

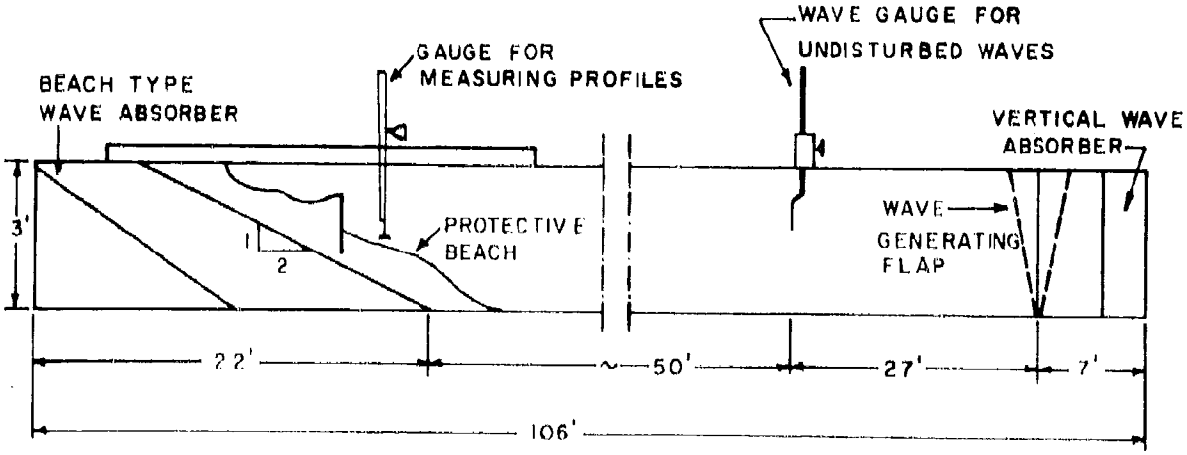
Equilibrium profiles were measured at the center of the beach using a point gage specially arranged so that it could move longitudinally and laterally. A point gage was also used for measuring the depth of the water in the channel. Each gage was equipped with a vernier reading to 0.001 foot.

Wave measurements

Wave heights were measured by standard parallel-wire conducting-type wave gages[26]. The output was amplified by using a Brush Universal amplifier, and recorded on a Brush recorder.



(a)



(b)

FIGURE 5 — GENERAL ARRANGEMENT OF THE EXPERIMENTAL EQUIPMENT

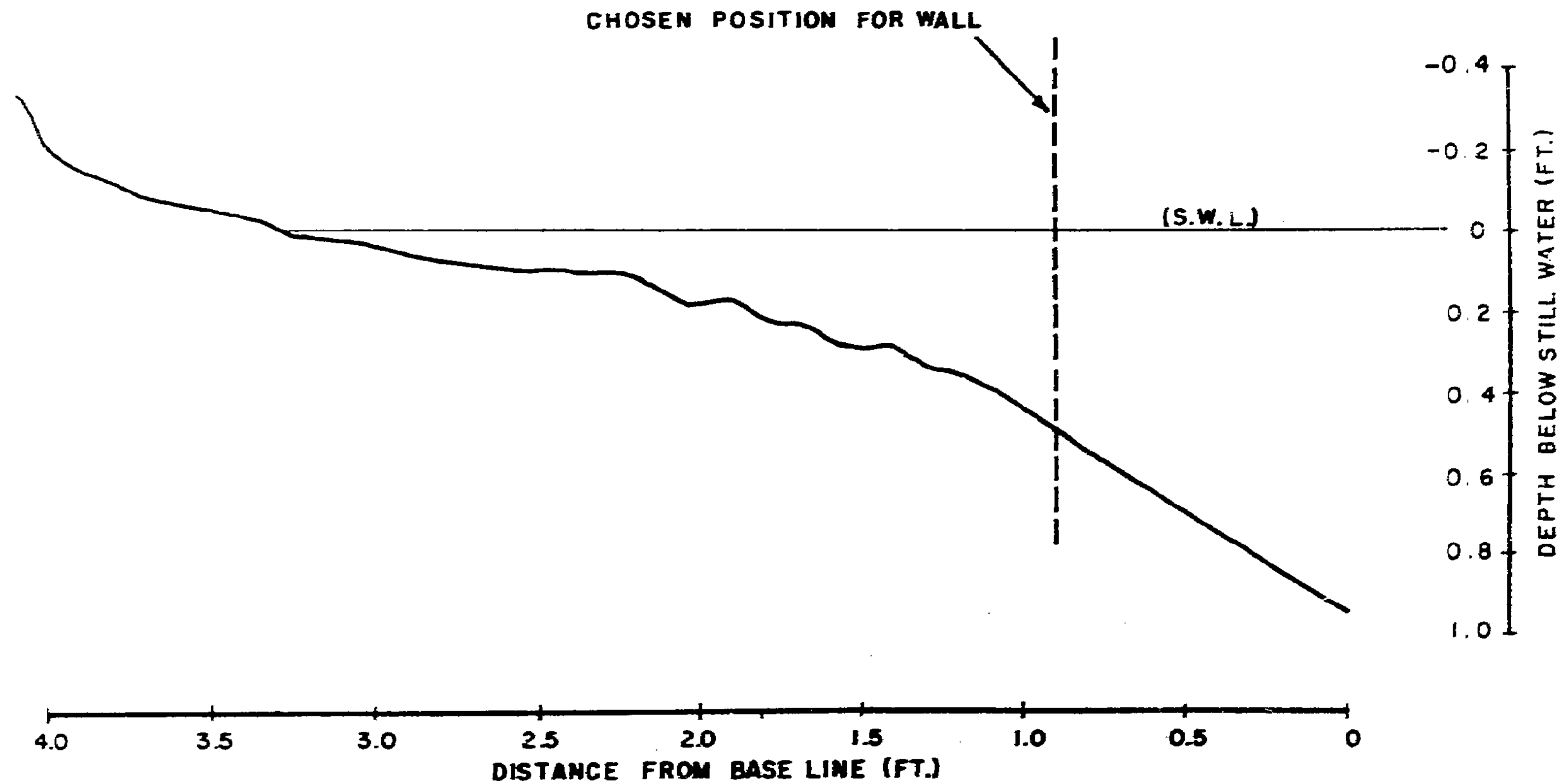


FIGURE 6 - PROFILE FOR RUN NO. 1(A)—NO WALL

CHAPTER IV

EXPERIMENTAL PROCEDURE

Scope of the tests

The experimental program consisted of four series of tests, designed as series A, B, C, and D. The purposes of these tests were as follows: (A) to study the effect of vertical wall top elevation on the equilibrium profile, and to investigate the different variables describing the profile; (B) to study the effect on the profiles of gravel blanket placed behind the wall; (C) to study the effect of using coarser material for the bed; (D) to provide some information, for a limited number of different wave scale ratios, on the relationship between the variables governing the equilibrium profile. Primary importance was placed on obtaining and measuring the equilibrium profiles. Comparison of the different profiles obtained gave information on the variables governing the shape of the profile. Visual observations for the beach were made for all the tests.

The variables affecting the equilibrium profiles were determined for six different elevations of the top of the vertical wall, for two different sands* as bed materials: sand (1) having a mean diameter of 0.325 mm; (2) with mean diameter 1.35 mm (only four different elevations for the vertical wall top elevation were used for this latter sand size). Both sands have a specific gravity of about 2.65.

The principal model characteristics are enumerated in Table 1. For a more detailed analysis, see appendix where all tables appear.

All runs were made with relatively steep waves, as it was felt that such waves, being typical of storm conditions, should be considered as imposing the largest effect on the wall[16]. The steepness of the incident waves, H_o/L_o, was varied from 0.054 to 0.104 in the tests.

Test procedure

The tests involved measurements of the equilibrium profiles, measurements of the undisturbed wave height, and determination of the wave period.

1. Enough sand was placed behind the wall, and the profile was molded to the equilibrium profile for no wall as shown in Figure 3.

2. The wave gage was calibrated and the water in the wave channel was allowed to become quiet before each run. The wave generator was

* See Figs. 32 and 33 for sand size distribution characteristics,(in Appendix).

then turned on. Records were taken of wave heights corresponding to the first twenty or twenty-five waves. The first few waves in the wave train were neglected. These few waves were followed by several fairly uniform waves, occurring before the waves reflected from the beach could influence the record. The wave height used in the analysis of the data was determined as the average height of the uniform wave that followed the first few waves.

3. Primary importance was placed in obtaining the equilibrium profiles. Every 2 or 3 hours a mark was traced on the glass to study the progress of the experiment; enough sand was added, if needed, at the back of the wall to give the equilibrium profile behind the wall. When no significant change was obtained for a period of 1 or 2 hours, the experiment was stopped and the profile was measured.

4. Equilibrium profile measurements: after the equilibrium condition had been reached, the wave generator was shut down; the equilibrium profile was measured by using a point gage and considering the still-water level as a datum. Profiles were taken at the center section of the channel (1 foot wide). These measurements may be slightly different from those along the edges because of the effect of the side walls[15, 16]. An arbitrary vertical baseline was selected at a distance of 0.90 foot from the vertical wall for measuring the longitudinal distances along the profile. Measurements were taken every 0.10 foot. The limit of the uprush was determined before stopping the wave generator by marking the maximum limit of uprush reached by the last fifteen to twenty-five waves.

5. After each run was completed the sand was remixed to eliminate any effect of sorting from the previous run. The sand was remolded again and the vertical wall top elevation was changed to the required elevation for the next run. Six different conditions for the vertical wall relative height were used for sand 1 (D_0 = 0.325 mm), h/H_0 = -0.50, -0.25, 0, +0.5, and 1.0.

6. The wave generator was adjusted to give the required period and height of the waves.

7. The same procedure was used for sand 2 (D_0 = 1.35 mm), using four different elevations of the top of the vertical wall, i.e., h/H_0 = -0.5, 0, +0.5, and 1.0.

Time required for each run

The time required for each run varied from 10 to 21 hours, depending upon the quantity of sand placed behind the wall, the amount to be moved, the distance it moved in front of the wall, and the depth of movement; the deeper the water the slower the movement of the sand.

CHAPTER V

GENERAL OBSERVATIONS

The equilibrium profile

The equilibrium profiles obtained after the runs, with variable waves, wall top elevation, and two different sands, proved to be rather similar. The features of this equilibrium profile (Figures 14 to 31) are as follows:

1. A scour pool just behind the wall. This scour pool was characterized by two dimensions, (δ), which is the vertical height, measured from the still-water level to the lowest point in the scour pool, being considered positive downwards (Figure 4), and (ξ), the length of the pool measured from the top of the wall. These two dimensions were chosen as the dependent variables describing the shape and extent of the scour behind the wall.

2. Above the scour pool a flat slope exists to the limit of wave attack. This limit was described in this work by (R), which is the vertical height of the limit of the uprush measured from the still-water level, and (S) the horizontal distance from the wall to the limit of the uprush.

3. A somewhat flatter slope than the original beach slope extended about a half wave length in front of the wall. The depth (Z) immediately in front of the wall was assumed to describe the equilibrium in this region.

Effect of the wall top elevation

Two extreme locations for the top elevation of the seawall were investigated: (1) a top elevation of half wave height below the still-water level; (2) a top elevation one wave height above the still-water level.

1. Seawall top elevation at a half wave height below the still-water level. This case may be called a submerged wall. Figure 7 shows the general flow condition observed.

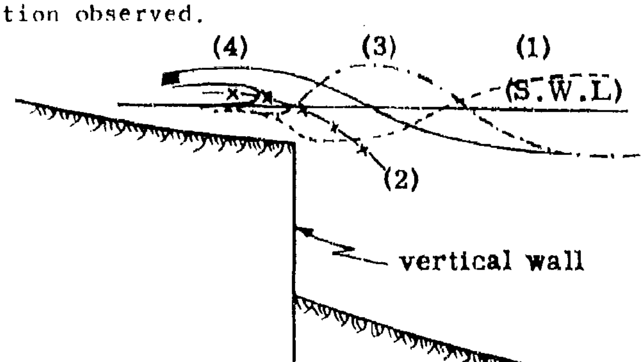


Figure 7.

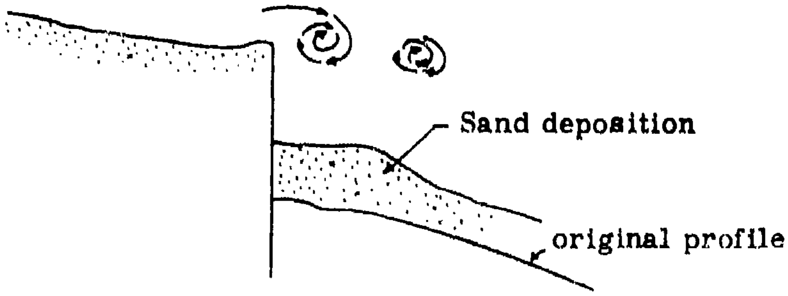
Sketch of the Flow Conditions Observed for $h/H_0 = -0.50$

When the wave approached the wall and the water elevation in trough line (1) reached the elevation of the wall, the top of the wall caused the wave to steepen, because the wave reached a shallow section. Water flowing back from the area behind the wall and shown by line (2) increased that effect, causing the wave crest shown as line (3) to become steeper and finally break with an uprush of water as shown in (4). Due to this mechanism a continuous back and forth motion of the water took place at the top of the wall. A similar explanation of this phenomena has been given by Minikin[27] for submerged dikes constructed to create beaches in localities where severe erosion was occurring.

By putting some lightweight materials behind the wall and observing the water particle motion in front of the wall, a vortex motion was observed as shown in Figure 8, forming a low pressure zone at its center. However during the transient condition some of the sand was observed to deposit in front of the wall. Sand carried in suspension due to the vortex action was deposited on the slope in front of the wall at a distance of about one-half wave length. After no further deposition was observed, the profile in front of the wall was traced on the glass wall of the channel. When sand was added, it was removed very soon by the vortex action described above, and the profile coincided with the equilibrium shape previously traced. In this case, the vortex action was observed to predominate through a region of about a half wave length in front of the wall.

Figure 8

Sketch of the Vortex Motion $h/H_0 = -0.50$



This flow pattern was observed clearly in runs (1-E-a) and (9-e). The profiles are shown in Figures 14 and 15 for some other conditions of the vertical wall top elevation. It can be seen that these two runs gave more deposition in front of the wall (least equilibrium depth Z) than the other conditions of the top wall elevation. It is expected that due to the interaction of the oncoming wave with the back flow, part of the wave energy will be dissipated. The rest of the energy will cause the uprush flow carrying sand both in suspension and along the bottom. The motion of the uprush gradually reduced, due to gravity, friction, and percolation, until action completely ceased. Then water fell back again due to gravity. When the oncoming wave had a trough immediately in front of the wall, the back flow passed over the top of the wall similar to the flow over a weir. At this phase of the process, scour was observed to occur behind the wall and the sand was carried in suspension to the front side. When the oncoming wave had a crest immediately in front of the wall the wave was observed to break behind the wall and more scour was observed in the same region mentioned above.

Both of the above processes are believed to contribute to the formation of the scour pool behind the wall.

2. Seawall top elevation at one wave height above still-water level. In this case considerable reflection of the wave energy was expected due to the presence of the wall. For a depth of water of about three wave heights (Table 2) an increase in the wave height in the immediate vicinity of the wall was observed due to reflection. This increase in the wave height was observed to be irregular in character. Flow of water over the wall occurred only when the crest of the reformed wave in front of the wall was higher than the top elevation of the vertical wall. As the amount of flowing water was small, only minor scour occurred behind the wall (Figures 14 and 15). This was also due to the fact that the back flow was restricted in the area behind the wall.

The orbital water motion in front of the wall was substantially increased due to the wave reflection. This phenomenon caused more scour in front of the wall than the previous case.

The two conditions of the vertical wall top elevation explained above were the extreme cases. For the other conditions of the top of the wall, the combined effect of the two phenomena mentioned was observed.

CHAPTER VI

EXPERIMENTAL RESULTS AND DISCUSSION

To demonstrate the relative importance of the variables h/H_o, R/H_o, S/H_o, Z/H_o, δ/H_o, ξ/H_o and H_o/L_o, the data obtained have been plotted in Figures 9 to 13, inclusive. The equilibrium profiles obtained are shown in Figures 14 to 31, inclusive.

Effect of seawall relative height h/H_o

For this study sand 1 was used. The data are shown in Table 2 and plotted in Figure 9. The effect on the different variables are discussed individually, as follows:

1. Effect on relative runup R/H_o.

Figure 9-a shows the general effect of the vertical wall relative height, h/H_o, on the relative runup, R/H_o. It is apparent from this figure that increasing the vertical wall relative height h/H_o will increase the relative runup value for the same wave steepness. This is to be expected, since the amount of wave energy which will be reflected will increase with increasing relative wall height h/H_o. So we may say that the amount of the energy which has to be dissipated by uprush will decrease with increasing wall relative height h/H_o and give larger values for relative runup, R/H_o. Figure 9-a shows that the relation between the relative wall height and the relative runup for wave steepness H_o/L_o = 0.079 is a fairly straight line within the limit of the experiments. This relationship was also obtained for a wave steepness of 0.096, H_o = 0.22 foot shown in Figure 10-a.

2. Effect on the relative limit of uprush S/H_o.

Figure 9-b shows the effect of the vertical wall relative height h/H_o on the relative distance of the limit of the uprush S/H_o for the equilibrium profile for H/L = 0.079. It was found that increasing the vertical wall relative height will decrease S/H_o value, which is to be expected also for the same reason explained above.

3. Effect on the equilibrium relative depth in front of the wall Z/H_o.

The results are shown in Figure 9-d. Within the limit of the experiments, a minimum value of Z/H_o = 2.00 was obtained for h/H_o = -0.5. Z/H_o increases with h/H_o, until a value of Z/H_o = 3.00 was obtained at h/H_o = 1.00. The reason for this increase of Z/H_o with increase of

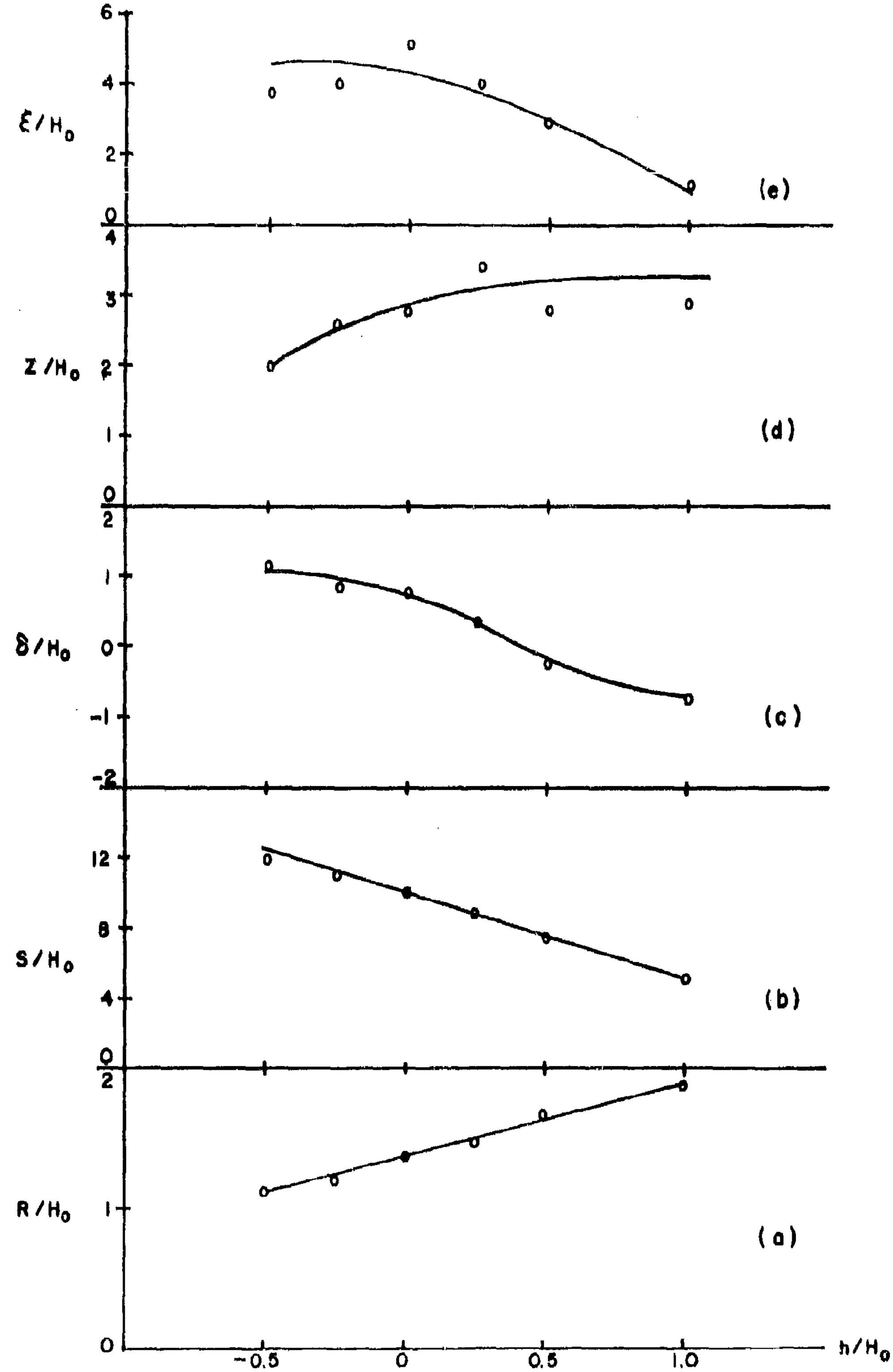


FIGURE 9 - EFFECT OF RELATIVE WALL HEIGHT ON BOTTOM PROFILE
SAND (I), $H_0 = 0.18'$, $H_0/L_0 = 0.079$

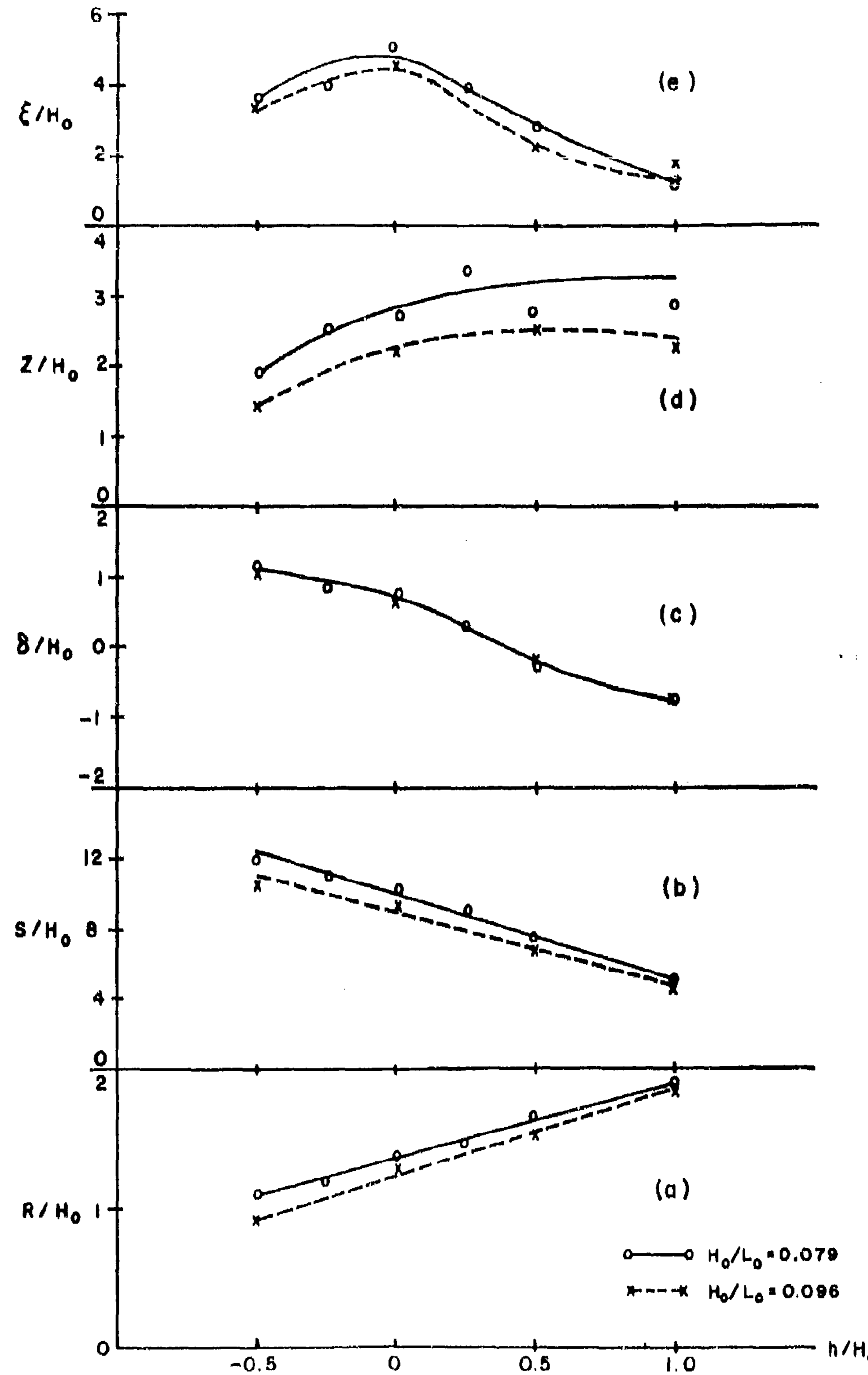


FIGURE 10 - EFFECT OF WAVE STEEPNESS

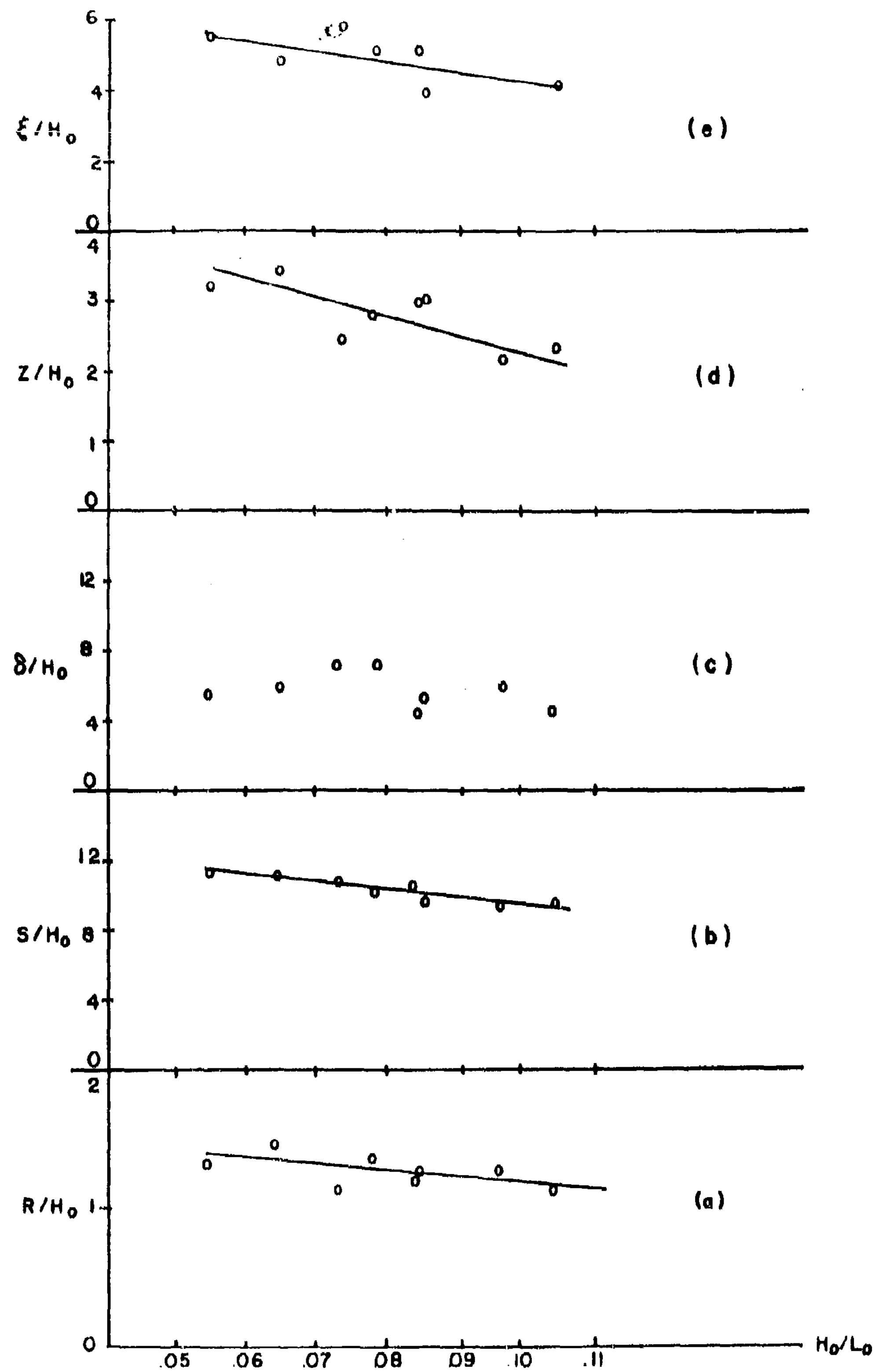


FIGURE 11 - EFFECT OF WAVE STEEPNESS (h=0)

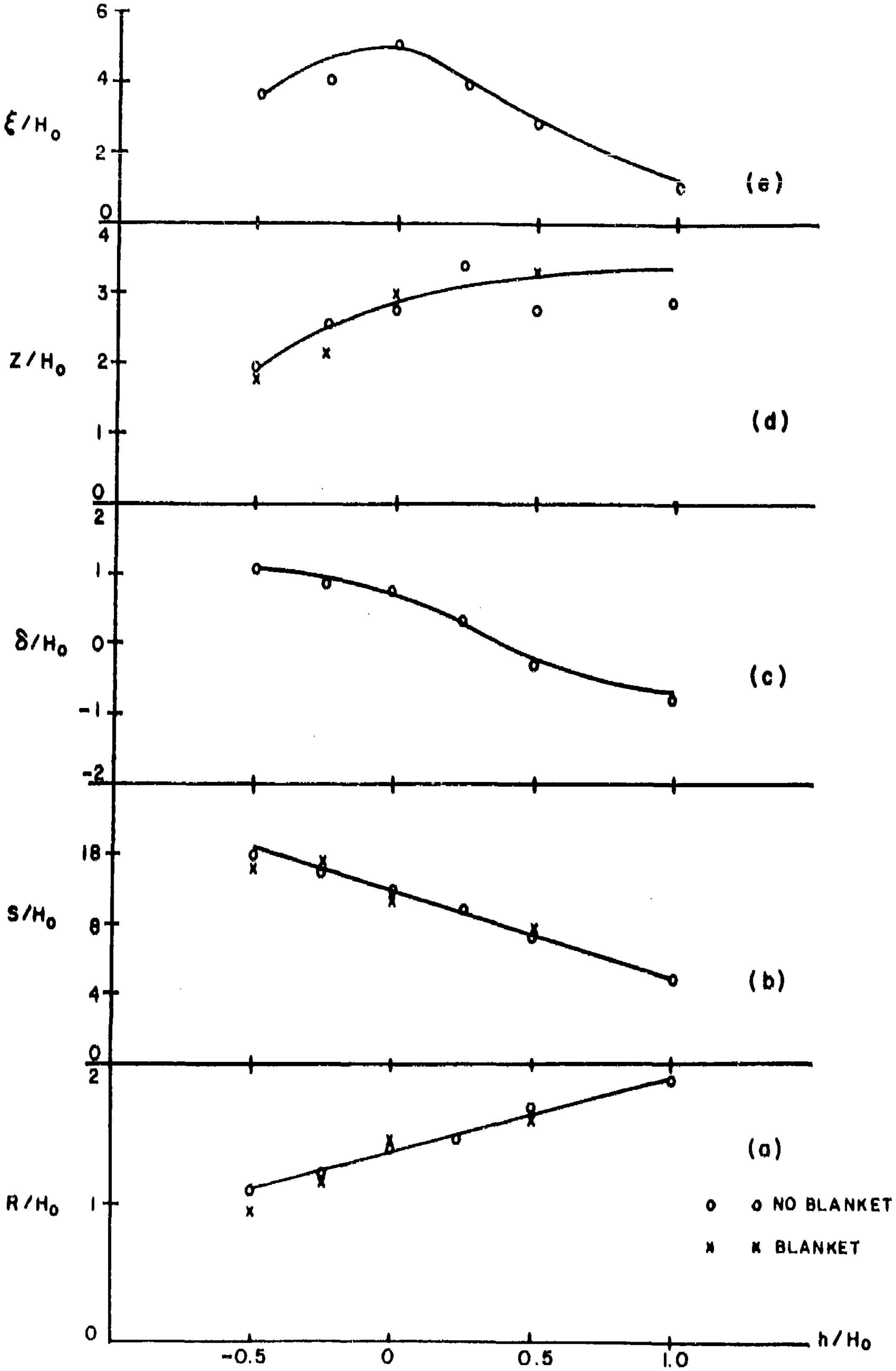


FIGURE 12 - EFFECT OF GRAVEL BLANKET - SAND (I)

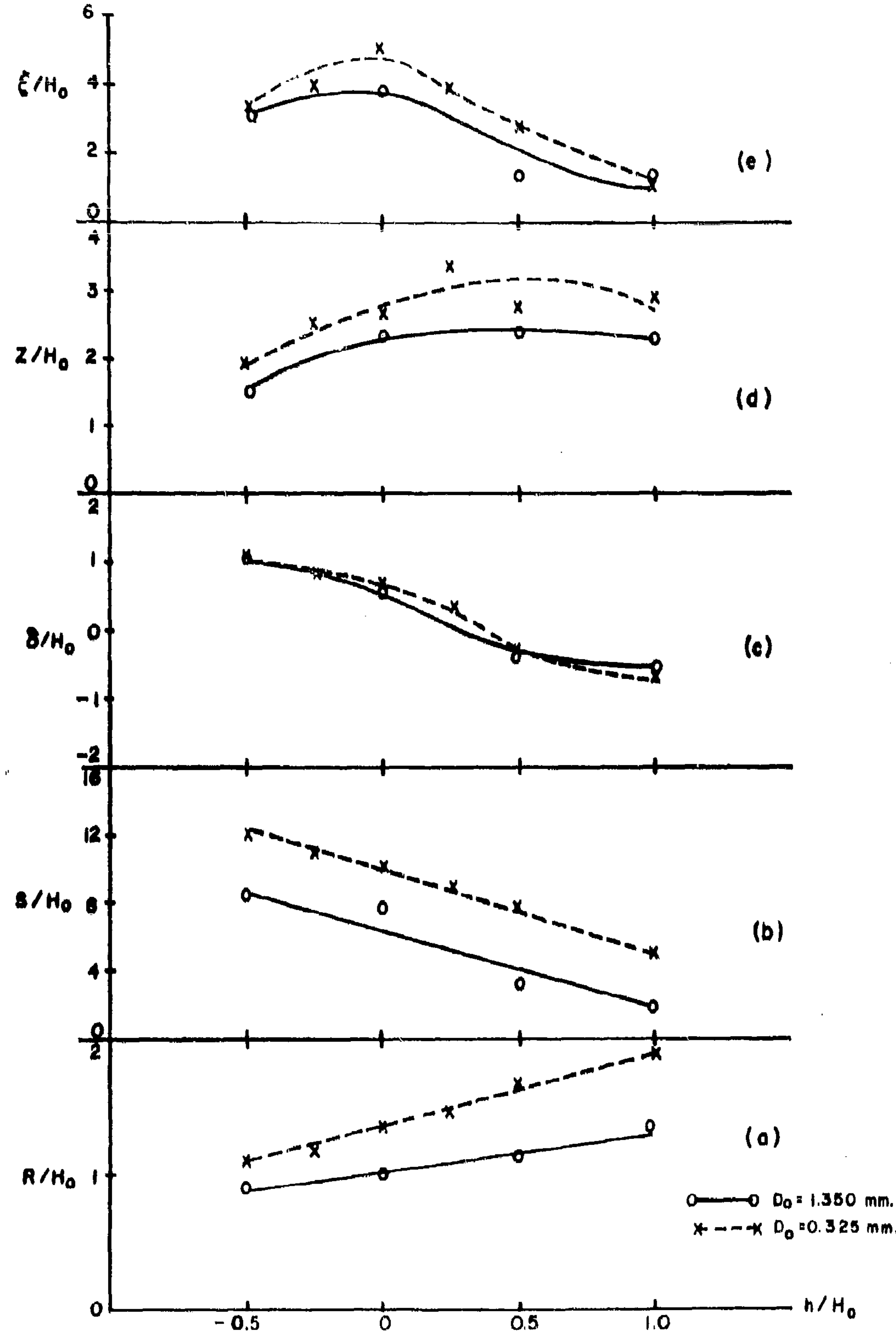


FIGURE 13 - EFFECT OF GRAIN SIZE OF THE BED $H_0/L_0 = 0.079$

h/H_o may be explained by the discussion given on pages 15 through 17, which can be summarized as follows: For an h/H_o value = -0.5 the vortex effect predominates at the surface in front of the wall, the result being a deposition of sand in front of the wall. For values of h/H_o greater than -0.5 the orbital motion in front of the wall started to be effective in giving the deepest scour in front of the wall at h/H_o = 1.00.

4. Effect on the scour pool behind the wall.

The formation of this scour pool was due to the continuous back and forth motion of the water at the wall, as mentioned above. Figures 9-c and 9-e show the relation between the relative dimensions of the scour pool (δ/H_o, ξ/H_o) and the vertical wall relative height h/H_o. From these figures it can be seen that (1) increasing the vertical wall relative height h/H_o will decrease the depth of the scour pool (δ); (2) the relative width of the scour pool ξ/H_o decreases with the increase of h/H_o in the range of h/H_o = 0 to 1.00. In the range of h/H_o = -0.50 to 0.00 the effect of h/H_o value on ξ/H_o does not seem to be significant.

Effect of wave steepness (Sand 1, D_o = 0.325 mm)

For this set of experiments different waves of known characteristics were generated, while the vertical wall top elevation was kept at the still-water level; that is h/H_o = 0. Data from this series of runs are summarized in Table 4. Figure 11 is a plot of these results, and the profiles are shown in Figure 20. Run 9, with wave steepness H_o/L_o = 0.096, was repeated for four different values of wall relative height, h/H_o, for the purpose of comparison with Run 1 (H_o/L_o = 0.079).

The plot of this series of runs shows some scatter of the points. This was expected, because it was difficult to control the amount of sand supplied behind the wall, and in order to change the wave steepness both the wave height and length were changed, which also contributed to the scatter of the points.

The results can be summarized as follows:

1. Increasing the wave steepness will slightly decrease the relative depth in front of the wall, Z/H_o, the relative distance of the limit of the uprush, S/H_o, and the relative width of the scour pool, ξ/H_o (Figures 11-b, d, and e). This may be explained by the fact that the wave near the critical steepness for breaking can be easily "tripped" and made to break by any outside disturbance[24]. This effect of steepness seems to be relatively small for a wall having a relative height ratio of zero or more (Figure 10).

2. The effect of wave steepness, H_0/L_0 on the relative runup value is very small (Figure 11-a) and on the relative depth of the scour pool behind the wall, δ/H_0, does not show a trend for this value of wave relative height, $h/H_0 = 0$. The scatter of the point seen in Figure 11-c does not support a conclusion.

Effect of a gravel blanket behind the wall

A layer of gravel ($1\frac{1}{4}$ inches diameter) 1 foot long normal to the beach and 0.2 foot thick was placed in the scour pool behind the wall. The top of the layer was at the same level as the top of the wall. Sand 1 and the wave used for Run 1 were used for four different heights of the wall. The summary of this series of tests is shown in Table 3. Figure 12 shows the scatter of the data obtained compared with that of the same test condition without using the gravel. These data indicate that the gravel layer behind the wall does not have a significant effect on the main variables forming the profile within the experiment's accuracy. The use of large-scale models may give a better idea about the effect of a gravel layer, since small-scale models may have some scale effect of unknown origin.

Effect of the grain size of the bed

Coarse sand (D_0 = 1.35 mm) was used. Four different conditions of the wall were considered. The equilibrium profiles were measured under the same wave action as Run 1 (H_0 = 0.18 foot and H_0/L_0 = 0.079). The main results are summarized in Table 6 and the profiles obtained are shown in Figures 26 to 29 and compared with those of sand 1 (D_0 = 0.325) for the same conditions of wave characteristics and wall height. From the general consideration of the relations obtained in Figure 13, the effect of the grain size is clear. Less scour occurred compared with sand 1. Table 10 shows a comparison between the effect of sands 1 and 2 on the scour. The order of magnitude of the effect may be summarized as follows:

When the mean diameter of the bed material is increased approximately four times (from 0.325 mm to 1.35 mm) and the wave conditions and the vertical wall relative height are kept the same: (1) the equilibrium depth, Z, in front of the wall will decrease about 15 percent; (2) the maximum distance of the limit of the uprush, S, will decrease about [illegible] percent; (3) the relative runup, R/H_0, for the equilibrium profile will decrease about 25 percent; and (4) the dimensions of the scour pool will be reduced about 20 percent.

Similarity conditions

The purpose of the series of experiments represented by series D (Table 2) was to investigate the feasibility of some known model testing procedures for establishing the choice of the bed materials to be used in the model.

Within the limits of our test facilities three geometrically similar models of different sizes were used. These models had ratios of 1, 1.5, and 2.0. Coarse sand (D = 1.35 mm) was used as a bed material for the three models. The runs used are as indicated in Table 9. The results are represented in the same table and the profiles obtained are shown in Figures 30 and 31.

From Table 9 and Figures 30 and 31 one can conclude that so far as the limit of the uprush and the equilibrium slope of the profile behind the wall are concerned, the results seem to be in good agreement with the previously mentioned practice(14). It is obvious from the results obtained in Table 9 that the results of the three models used gave a reasonable similarity for the values of R, S, and ξ . On the other hand the scour depth, δ , behind the wall and the equilibrium depth, Z, in front did not give similar results for the different models used under the same condition of the top elevation of the sea-wall. As mentioned above, the mechanism of sediment motion around the wall was affected by the backflow of the water over the wall. Therefore, both the gravitational and the internal friction are important. Thus Reynolds Number may become important in the case of the model. This condition makes it very difficult to choose the similarity criterion for the choice of the bed material to be used in the model for the study of the equilibrium region in front of the wall. On the other hand, the similarity of the profiles behind the wall obtained from comparable set-ups and the close agreement between the values of R, S, and ξ resulting from these tests using the same sand as bed material are indicative of the fact that a small-scale study of the equilibrium profiles and the extent of the limit of uprush in this region could be used in studying full-scale wave action on identical materials.

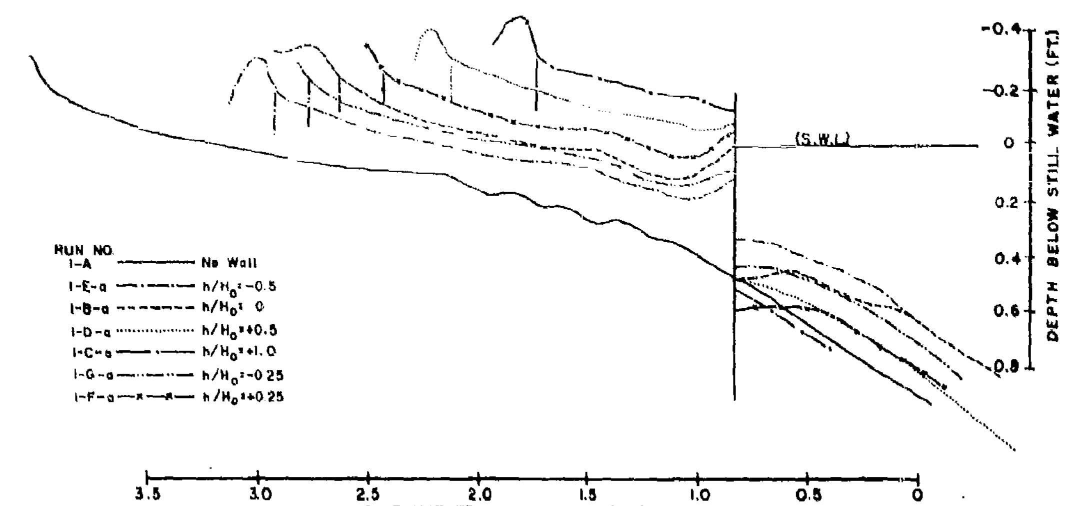


FIGURE 14 - PROFILES FOR RUN NO. (1) — EFFECT OF WALL TOP ELEVATION
$H_0/L_0 = 0.079$; $H_0 = 0.18$ FT.; SAND (1)

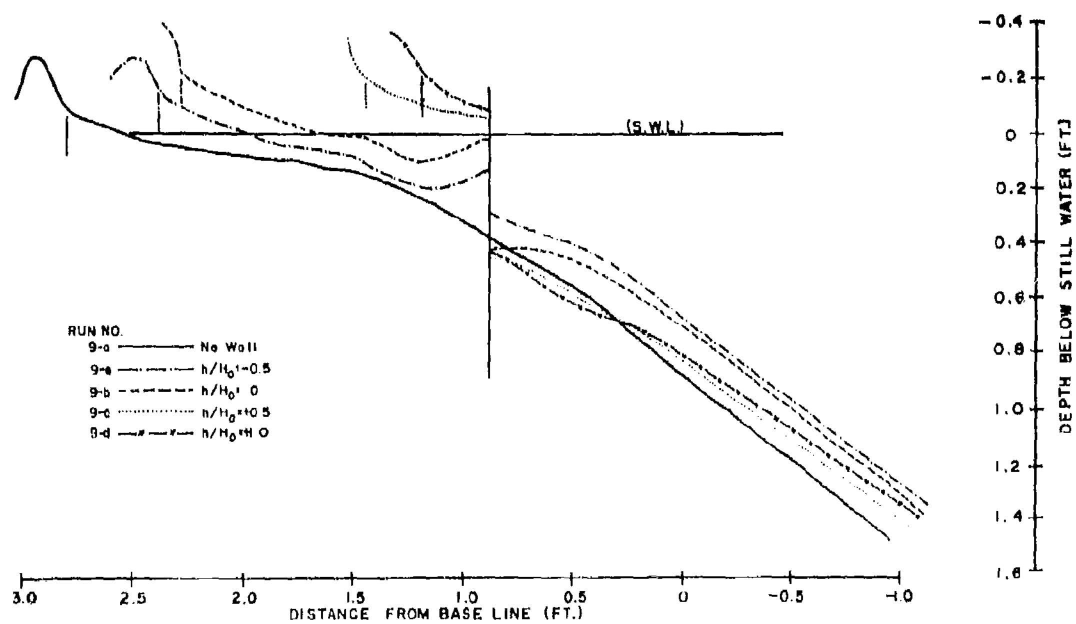


FIGURE 15 - PROFILES FOR RUN NO. (9) — EFFECT OF VERTICAL WALL ELEVATION
$H_0/L_0 = 0.079$; SAND (2)

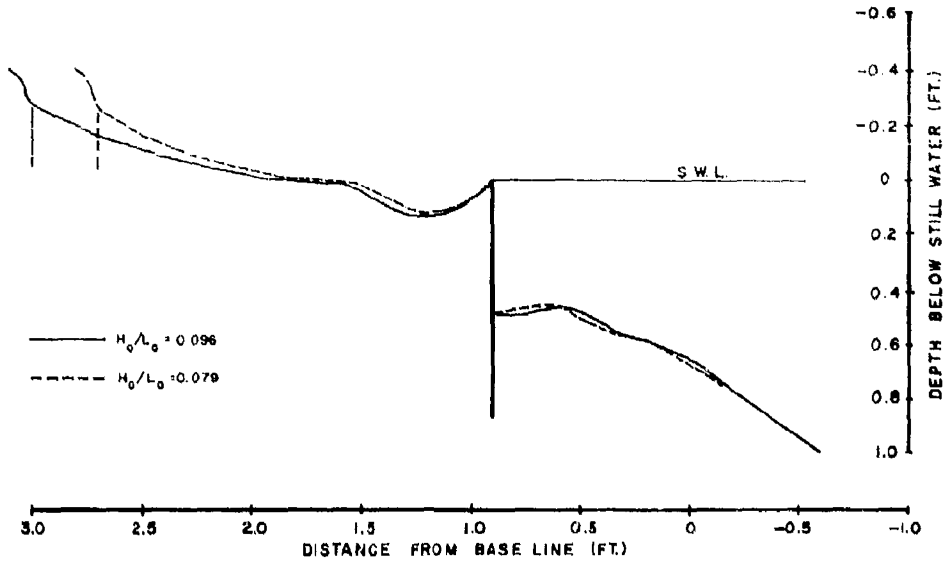


FIGURE 16 - EFFECT OF WAVE STEEPNESS
SAND (I), h=0

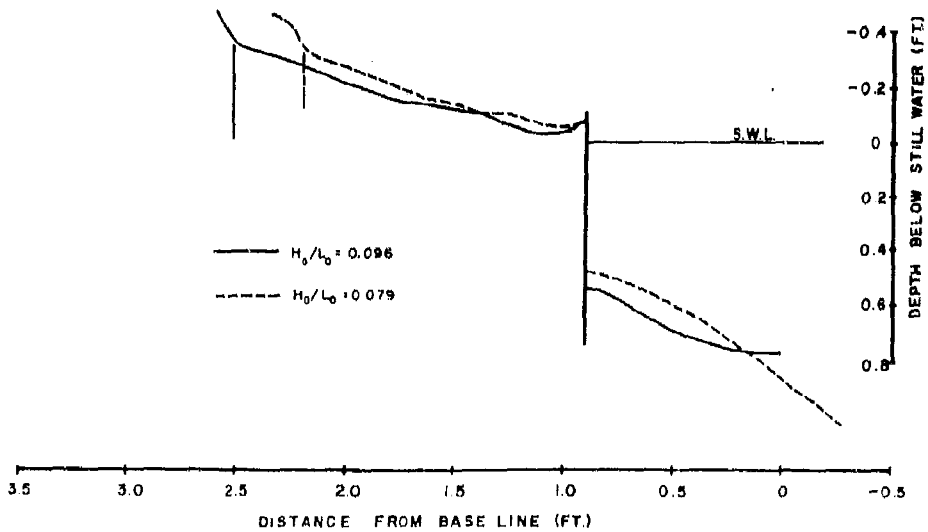


FIGURE 17 - EFFECT OF WAVE STEEPNESS SAND (I), h = $0.5H_0$

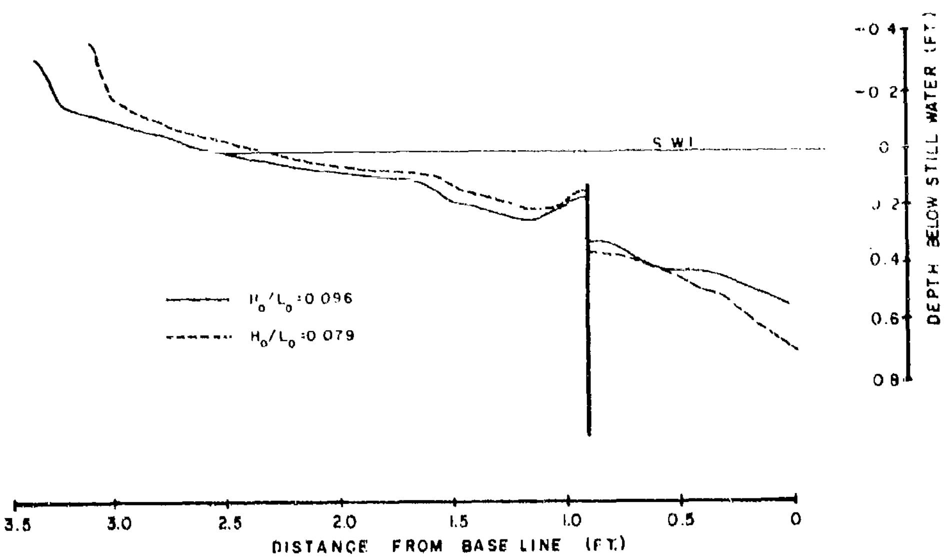


FIGURE 18 - EFFECT OF WAVE STEEPNESS SAND (I), $h = -0.5 H_0$

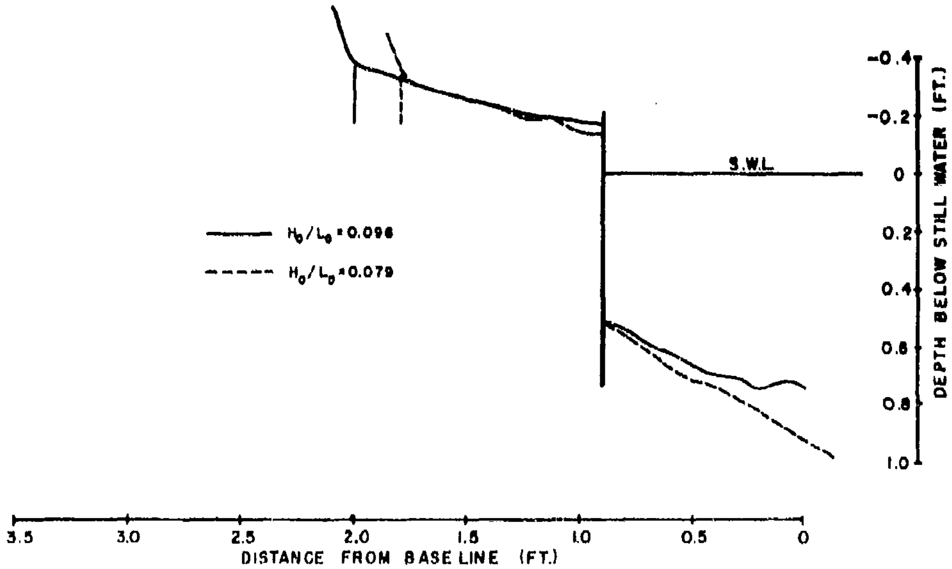


FIGURE 19 - EFFECT OF WAVE STEEPNESS SAND (I), $h = 1.0 H_0$

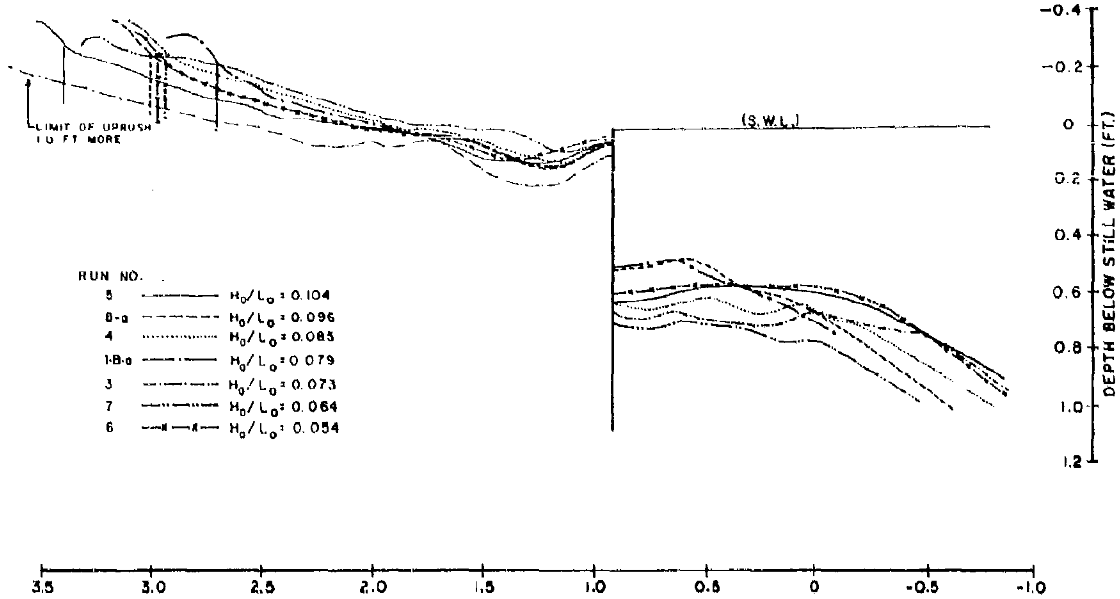


FIGURE 20 - EQUILIBRIUM PROFILES - SAND I
EFFECT OF DIFFERENT H_0/L_0; H = 0

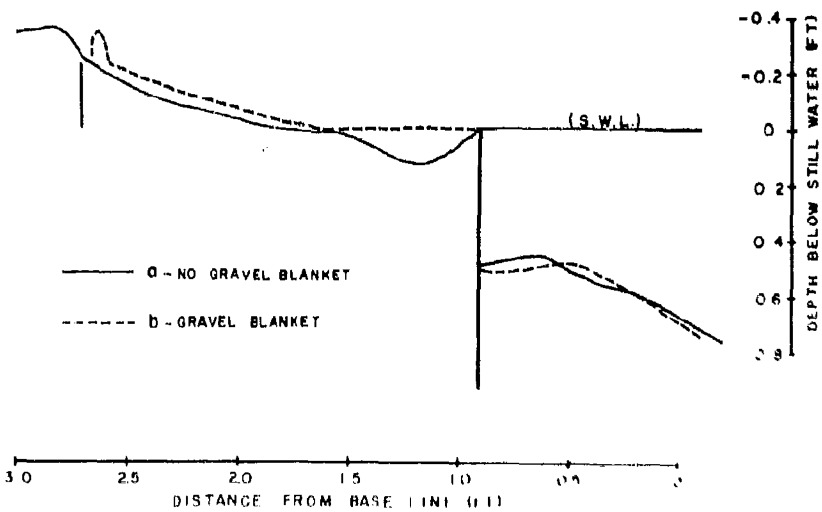


FIGURE 21 - PROFILES FOR RUN NO 1-B (a,b)
h = 0, H_0/L_0 = 0.079
EFFECT OF GRAVEL BLANKET

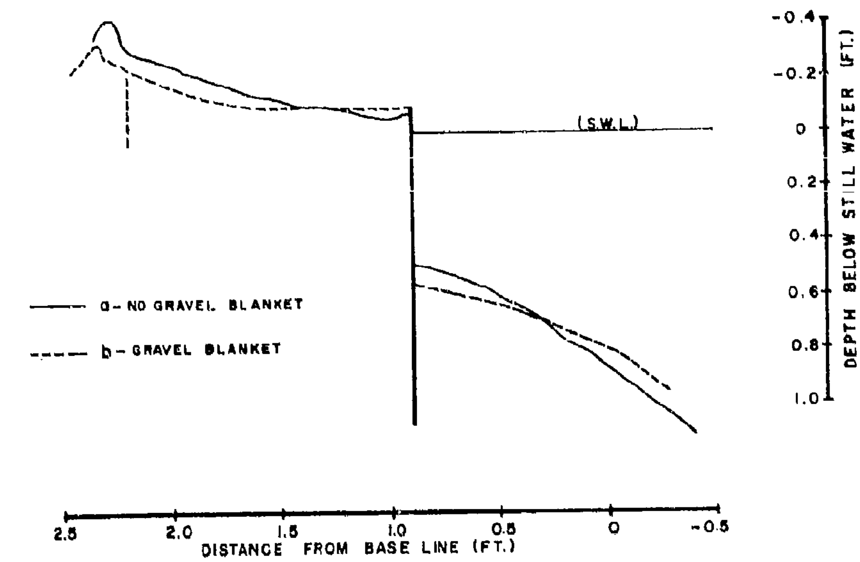


FIGURE 22 - PROFILES FOR RUN NO. I D, (a, b) $h = H_0/2$
EFFECT OF GRAVEL BLANKET

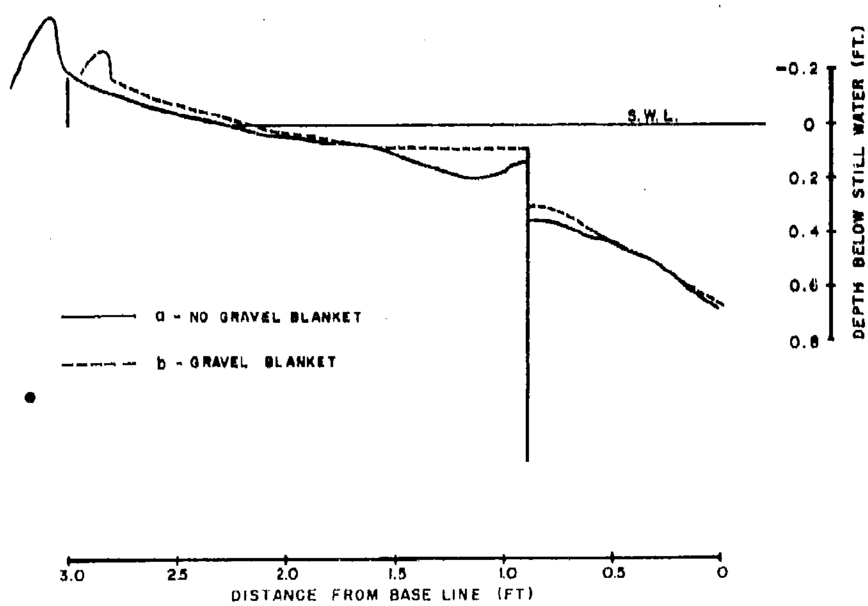


FIGURE 23 - PROFILES FOR RUN NO. I E (a, b) $h = H_0/2$
EFFECT OF GRAVEL BLANKET

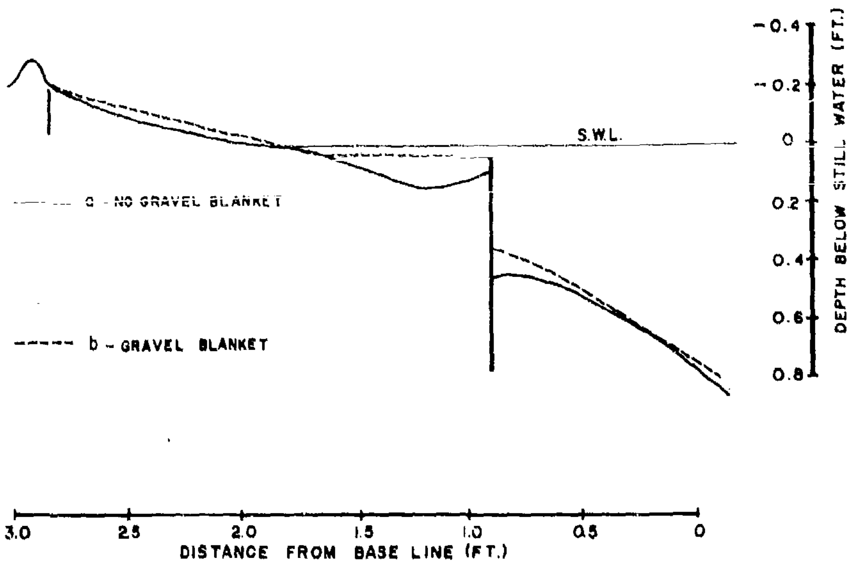


FIGURE 24 - PROFILES FOR RUN NO. I-G (a, b) $h = -0.25 H_0$
EFFECT OF GRAVEL BLANKET

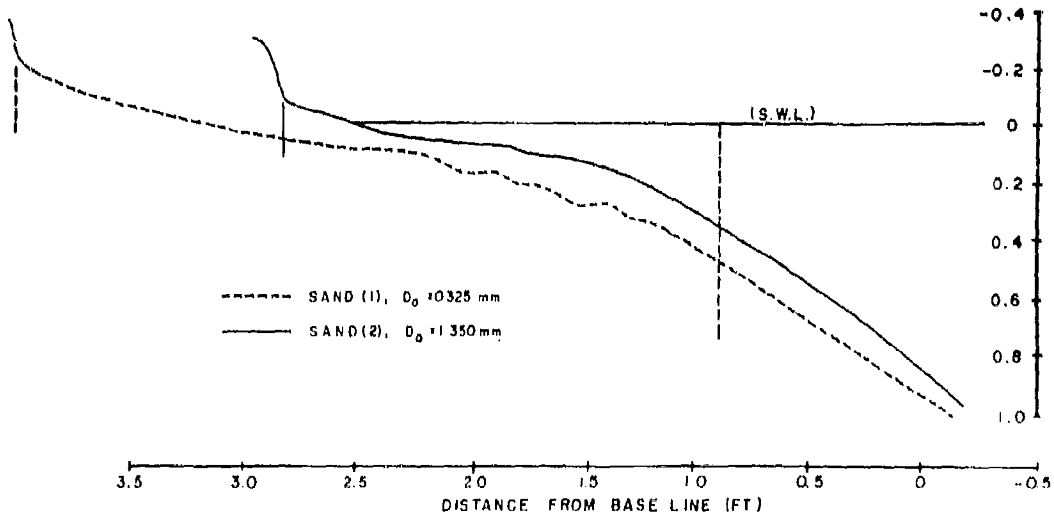


FIGURE 25 - EQUILIBRIUM PROFILES FOR NO WALL $H_0 = 0.18'$; $L_0 = 2.28'$
EFFECT OF GRAIN SIZE OF THE BED $H_0/L_0 = 0.079$

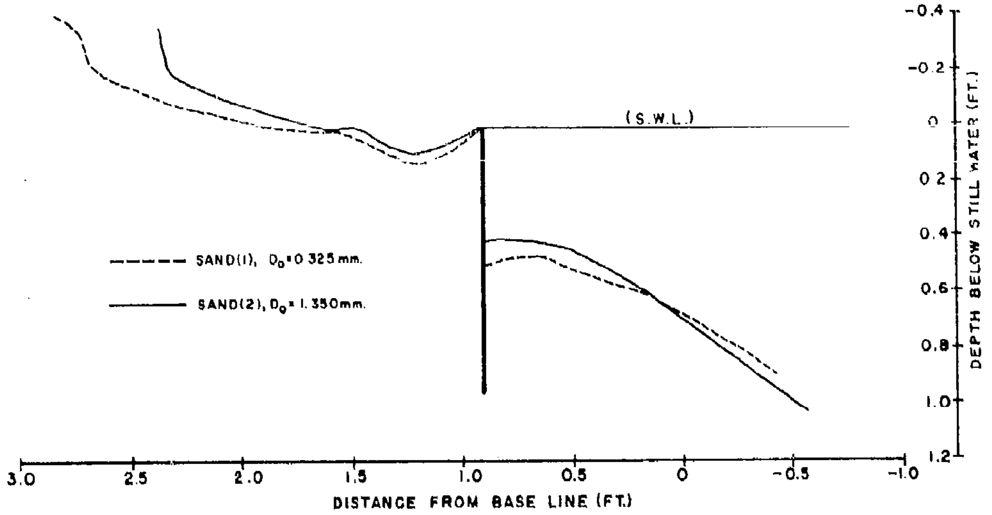


FIGURE 26 – EQUILIBRIUM PROFILES H_0=0.18; L_0=2.28 (FT.)
EFFECT OF GRAIN SIZE OF THE BED H_0/L_0=0.079; h=0

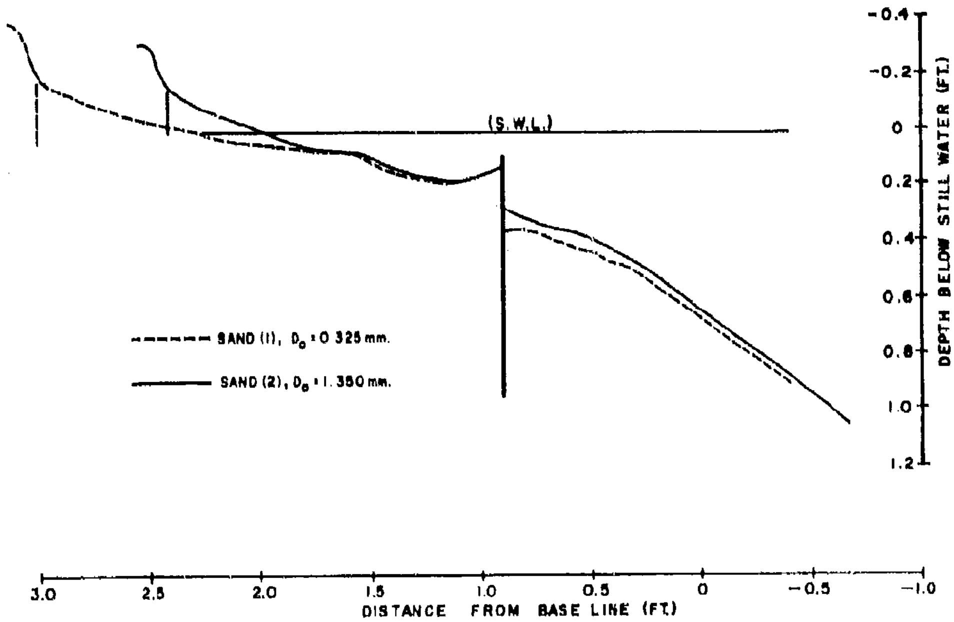


FIGURE 27 – EQUILIBRIUM PROFILES H_0=0.18'; L_0=2.28'
EFFECT OF GRAIN SIZE OF THE BED H_0/L_0=0.079; h=−0.5 H_0

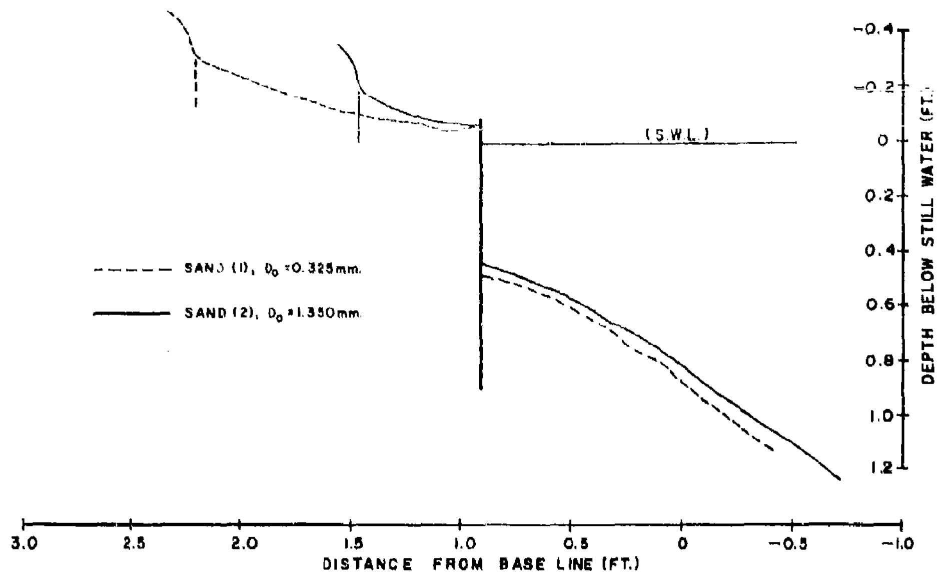


FIGURE 28 - EQUILIBRIUM PROFILES H_o = 0.18'; L_o = 2.28'
EFFECT OF GRAIN SIZE OF THE BED H_o/L_o = 0.079; h = +0.5 H_o

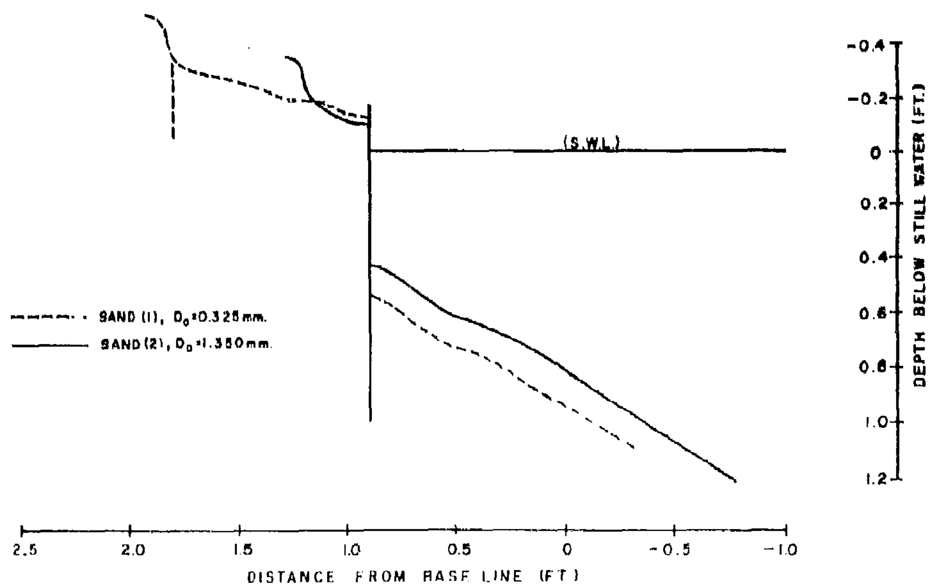


FIGURE 29 - [illegible]JILIBRIUM PROFILES H_0 = 0.18'; L_0 = 2.28'
EFFECT OF GRAIN SIZE OF THE BED H_0/L_0 = 0.079; h = 1.0 H_0

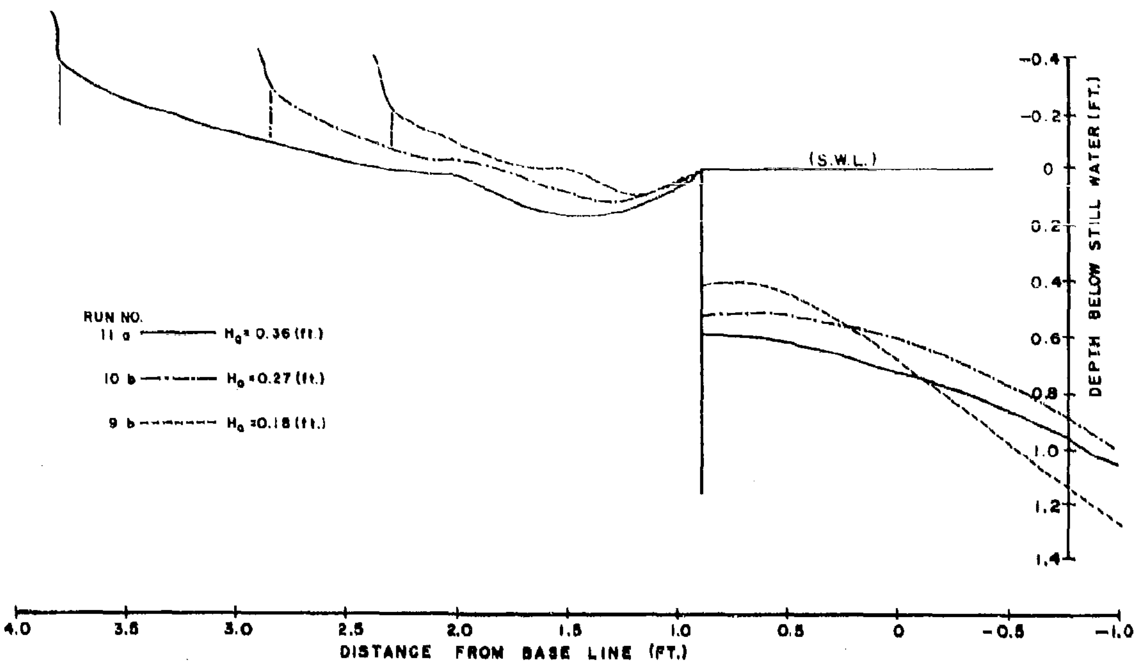


FIGURE 30 - PROFILES FOR DIFFERENT SCALES RATIOS
1, 1.5 and 2.0 H_0 ; $H_0/L_0 = 0.079$, $h = 0$

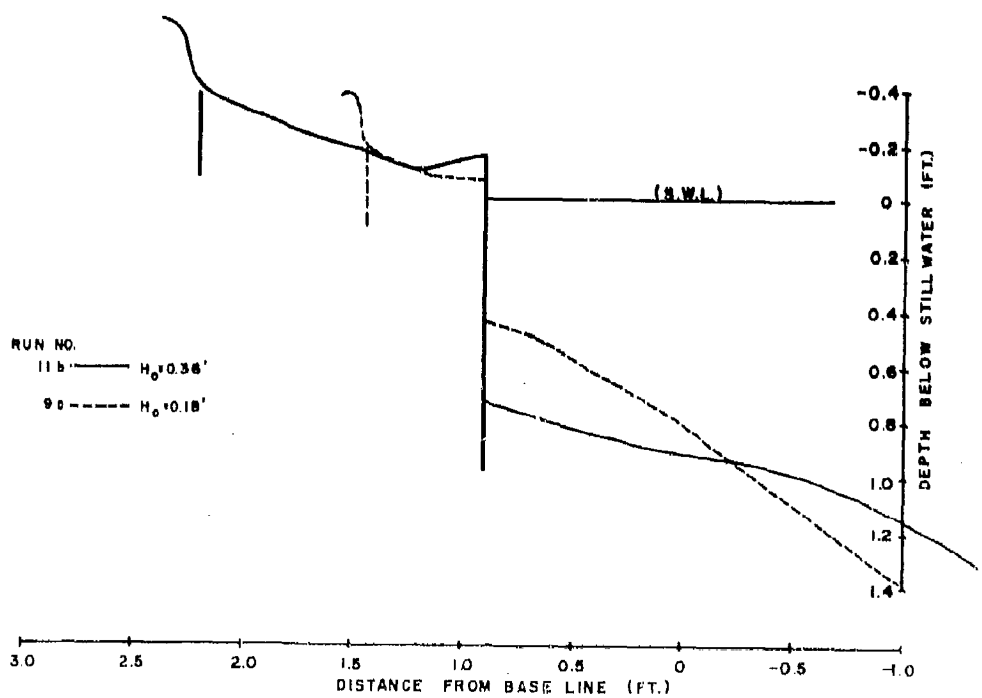


FIGURE 31 - PROFILES FOR DOUBLING SCALE RATIO H_0, $2H_0$
$H_0/L_0 = 0.079$, $h = 0.5H_0$

CHAPTER VII

SUMMARY

This investigation is an attempt to study some aspects of the flow characteristics and wave attack on beaches. The effect of vertical wall top elevation, bed material, and different wave scale ratios were also investigated.

A vertical wall placed at some locality on the beach was used (Figure 6). From the foregoing discussions, it can be concluded that:

1. Under all conditions of waves and relative wall height studied, an equilibrium profile of approximately the same shape was obtained behind the wall.

2. The equilibrium profile behind the wall was found to depend upon:

a. The top elevation of the wall with respect to the still-water level.

b. It was also found that the wave steepness has only a slight effect.

3. The least wave attack behind the wall was observed to occur when the top elevation of the wall was one wave height above the still-water level. However, this condition gave the largest scour depth, Z, in front of the wall.

4. The smallest scour in front of the wall was observed when the top elevation of the wall was at a half wave height below the still-water level. However, this condition gave the largest attack on the area behind the wall.

5. Increasing the mean diameter of the bed material approximately four times (from 0.325 mm to 1.35 mm), while all the other conditions were kept the same, was found to have the following effects:

a. The scour depth, Z, in front of the wall was decreased about 15 percent.

b. The maximum distance of the limit of the uprush, S, was decreased about 40 percent.

c. The relative runup value, R/H_0, was decreased about 25 percent.

d. The dimensions of the scour pool behind the wall were decreased about 20 percent.

e. A gravel layer placed in the scour pool behind the wall does not seem to have a significant effect on the limit of the uprush.

6. The similarity of the profiles behind the wall obtained from comparable setups of different wave scale ratio and the close agreement between the values of R, S, and ξ resulting from these tests using the same sand as bed material are indicative of the fact that a small-scale study of the equilibrium profiles and the extent of the limit of the uprush in this region could be used in studying full-scale wave action on identical materials.

7. The mechanism of sediment motion in the vicinity of the wall was believed to be affected by the interaction of the wave action, and the vortex created by the backflow of the water over the wall.

8. Practical application. The results of this investigation may prove useful in some practical situations where it is required to restrict the wave attack within certain limits. Some of these situations are the protection of the sides of navigable canals, waterways, and levees where the erosion of the banks due to wave attack is a critical problem. It is always desired, as in the case of the Suez Canal, to prevent the scour in front of protection works, erosion of sand behind the vertical walls, and limiting the amount of sediments entering the navigable channel which necessitates continuous dredging.

9. Design criteria. Although the scope of this investigation is restricted to particular waves and beach conditions, the following design procedure may be applied generally in situations where it is required to limit the wave attack:

Assuming a required limit to the wave attack, one could assume a certain position for the wall and then check both the equilibrium depth in front of the wall and the wall top elevation. By making several trials, and guided by the results included herein, one may find a reasonable solution for the situation considered.

CHAPTER VIII

RECOMMENDATIONS

Some suggestions for future work on this subject may be summarized as follows:

1. A very much smaller grain sand (D_0 = 0.05 mm) should be tested under similar conditions.

2. Large-scale tests should give more reliable results.

3. Incident wave attack on the beach at different angles should be used.

ACKNOWLEDGEMENTS

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APPENDIX

TABLE 1

SUMMARY OF THE TEST PROGRAM

Series	Run Number	Sand	Gravel Blanket	H_o (ft)	$\frac{h}{H_o}$	$\frac{H_o}{L_o}$	d (ft)
Series A	1-B-a	1	No	0.18	0	0.079	2.02
	1-C-a	1	No	0.18	+ 1.0	0.079	2.02
	1-D-a	1	No	0.18	+ 0.50	0.079	2.02
	1-E-a	1	No	0.18	- 0.50	0.079	2.02
	1-F-a	1	No	0.18	+ 0.25	0.079	2.01
	1-G-a	1	No	0.18	- 0.25	0.079	2.01
	2	1	No	0.235	0	0.084	2.01
	3	1	No	0.270	0	0.073	2.01
	4	1	No	0.205	0	0.085	2.01
	5	1	No	0.26	0	0.104	2.01
	6	1	No	0.18	0	0.054	2.01
	7	1	No	0.20	0	0.064	2.01
	8-a	1	No	0.22	0	0.096	1.99
	8-b	1	No	0.22	+ 0.5	0.096	1.99
	8-c	1	No	0.22	- 0.5	0.096	2.01
	8-d	1	No	0.22	+ 1.0	0.096	2.00
Series B	1-B-b	1	Yes	0.18	0	0.079	2.01
	1-D-b	1	Yes	0.18	+ 0.50	0.079	2.01
	1-E-b	1	Yes	0.18	- 0.50	0.079	1.99
	1-G-b	1	Yes	0.18	- 0.25	0.079	2.01
Series C	9-b	2	No	0.18	0	0.079	2.00
	9-c	2	No	0.18	+ 0.5	0.079	2.00
	9-d	2	No	0.18	+ 1.0	0.079	2.00
	9-e	2	No	0.18	- 0.50	0.079	1.99
Series D	10-a	2	No	0.27	- 0.33	0.079	1.99
	10-b	2	No	0.27	0	0.079	1.99
	11-a	2	No	0.36	0	0.079	2.28
	11-b	2	No	0.36	+ 0.50	0.079	2.275

TABLE 2

EFFECT OF WALL RELATIVE HEIGHT $\frac{h}{H_o}$

SAND (1)

Run Number	$\frac{h}{H_o}$	R (ft)	S (ft)	Z (ft)	δ (ft)	ξ (ft)	$\frac{R}{H_o}$	$\frac{S}{H_o}$	$\frac{Z}{H_o}$	$\frac{\delta}{H_o}$	$\frac{\xi}{H_o}$
1-B-a	0	0.24	1.80	0.49	+0.13	0.90	1.36	10.20	2.78	+0.74	5.10
1-C-a	+1.00	0.33	0.90	0.51	-0.13	0.20	1.88	5.10	2.90	-0.74	1.13
1-D-a	+0.50	0.30	1.30	0.49	-0.05	0.50	1.70	7.40	2.78	-0.28	2.84
1-E-a	-0.50	0.195	2.10	0.35	+0.20	0.65	1.10	11.90	1.99	+1.14	3.70
1-F-a	+0.25	0.255	1.60	0.60	+0.06	0.70	1.45	9.10	3.40	+0.34	3.98
1-G-a	-0.25	0.21	1.94	0.445	+0.15	0.70	1.19	11.05	2.53	+0.86	3.98

TABLE 3

EFFECT OF GRAVEL BLANKET

SAND (1)

Run Number	$\frac{h}{H_o}$	R (ft)	S (ft)	Z (ft)	$\frac{R}{H_o}$	$\frac{S}{H_o}$	$\frac{Z}{H_o}$
1-B-b	0	0.24	1.70	0.51	1.36	9.65	2.90
1-D-b	+0.50	0.28	1.40	0.56	1.59	7.95	3.18
1-E-b	-0.50	0.17	1.90	0.30	0.965	10.8	1.70
1-G-b	-0.25	0.195	2.00	0.36	1.10	11.30	2.04

TABLE 4

EFFECT OF WAVE STEEPNESS, h = O

SAND (1)
Data for Different Ho/Lo

Run No.	h (ft)	Ho (ft)	T (Sec)	Lo (ft)	$\frac{Ho}{Lo}$	R (ft)	S (ft)	δ (ft)	Z (ft)	ξ (ft)	$\frac{R}{Ho}$	$\frac{S}{Ho}$	$\frac{\delta}{Ho}$	$\frac{Z}{Ho}$	$\frac{\xi}{Ho}$
1-B	0	0.180	0.67	2.28	0.078	0.24	1.80	+0.13	0.49	0.9	1.365	10.21	.74	2.78	5.1
2	0	0.235	0.74	2.80	0.084	0.28	2.50	+0.11	0.70	1.20	1.190	10.60	.47	2.98	5.1
3	0	0.270	0.85	3.70	0.073	0.31	2.95	+0.20	0.66	1.60	1.150	10.90	.74	2.44	5.9
4	0	0.205	0.69	2.43	0.085	0.26	2.00	+0.11	0.62	0.80	1.265	9.80	.54	3.01	3.9
5	0	0.260	0.70	2.52	0.104	0.30	2.48	+0.12	0.61	1.10	1.151	9.55	.46	2.35	4.25
6	0	0.180	0.805	3.32	0.054	0.24	2.05	+0.10	0.58	1.0	1.330	11.40	.56	3.22	5.55
7	0	0.200	0.785	3.14	0.064	0.29	2.25	+0.12	0.69	0.95	1.45	11.25	.60	3.45	4.75
8	0	0.220	0.67	2.28	0.096	0.28	2.10	+0.13	0.48	0.96	1.27	9.55	.60	2.18	4.40

TABLE 5

EFFECT OF WAVE STEEPNESS

SAND (1)

Run No. 8

Ho = 0.22'; Lo = 2.28'; Ho/Lo = 0.096

Run No.	$\frac{h}{Ho}$	$\frac{R}{(ft)}$	$\frac{S}{(ft)}$	$\frac{Z}{(ft)}$	δ (ft)	ξ (ft)	$\frac{R}{Ho}$	$\frac{S}{Ho}$	$\frac{Z}{Ho}$	$\frac{\delta}{Ho}$	$\frac{\xi}{Ho}$
8-(a)	0	0.28	2.10	0.48	+0.13	1.00	1.27	9.55	2.18	5.92	4.55
8-(b)	+ .5	0.36	1.60	0.53	-0.03	0.50	1.50	7.30	2.50	-1.36	2.27
8-(c)	- .5	0.18	2.32	0.31	+0.24	0.750	.82	10.55	1.41	+1.09	3.40
8-(d)	1.0	0.36	1.1	0.51	-0.17	0.40	1.64	5.00	2.32	- .775	1.81

TABLE 6

EFFECT OF THE GRAIN SIZE OF THE BED

SAND (2)

Run No. 9

Ho = 0.18; Lo = 2.28; T = 0.67 sec; Ho/Lo = 0.079

Run No.	$\frac{h}{Ho}$	$\frac{R}{(ft)}$	$\frac{S}{(ft)}$	$\frac{Z}{(ft)}$	δ (ft)	ξ (ft)	$\frac{R}{Ho}$	$\frac{S}{Ho}$	$\frac{Z}{Ho}$	$\frac{\delta}{Ho}$	$\frac{\xi}{Ho}$
9-b	0	0.18	1.40	0.415	+0.10	0.70	1.00	7.80	2.30	+0.56	3.90
9-c	+0.5	0.20	0.55	0.44	-0.07	0.25	1.11	3.06	2.44	-0.39	1.38
9-d	+1.0	0.24	0.30	0.42	-0.10	0.25	1.33	1.67	2.33	-0.56	1.38
9-e	-0.50	0,16	1.50	0.27	+0.19	0.60	0.89	8.35	1.50	+1.05	3.00

TABLE 7

DOUBLING WAVE SCALE RATIO

SAND (2)

Run No. 11

Ho = 0.36'; Lo = 4.56'; Ho/Lo = 0.079

Run No.	$\frac{h}{Ho}$	R (ft)	S (ft)	Z (ft)	δ (ft)	ξ (ft)	$\frac{R}{Ho}$	$\frac{S}{Ho}$	$\frac{Z}{Ho}$	$\frac{\delta}{Ho}$	$\frac{\xi}{Ho}$
11-a	0	0.37	2.9	0.61	+0.17	1.40	1.03	8.06	1.695	+.473	3.90
11-b	+0.5	0.405	1.30	0.725	-0.12	0.54	1.125	3.63	2.01	-.334	1.50

TABLE 8

1.5 WAVE SCALE RATIO

SAND (2)

Run No. 10

Ho = 0.27'; Lo = 3.42'; Ho/Lo = 0.079

Run No.	$\frac{h}{Ho}$	R (ft)	S (ft)	Z (ft)	δ (ft)	ξ (ft)	$\frac{R}{Ho}$	$\frac{S}{Ho}$	$\frac{Z}{Ho}$	$\frac{\delta}{Ho}$	$\frac{\xi}{Ho}$
10-a	$\frac{1}{3}$	0.23	2.65	0.32	+0.21	1.20	0.855	9.84	1.185	+.778	4.45
10-b	0	0.27	1.95	0.53	+0.12	1.00	1.00	7.25	1.96	+.445	3.70

TABLE 9

EFFECT OF WAVES OF DIFFERENT SCALE RATIO USING THE SAME SAND AS BED MATERIAL

Run	Ho (ft)	Lo (ft)	Ho/Lo	h (ft)	Scale Ratio	R (ft)	S (ft)	Z (ft)	δ (ft)	ξ (ft)	$\frac{R}{R_1}$**	$\frac{S}{S_1}$	$\frac{Z}{Z_1}$	$\frac{\delta}{\delta_1}$	$\frac{\xi}{\xi_1}$
9-b	0.18	2.28	0.079	0	1.00	0.18	1.40	0.415	+0.10	0.70	1.00	1.00	1.00	1.00	1.00
10-b	0.27	3.42	0.079	0	1.50	0.27	1.95	0.53	+0.12	1.00	1.50	1.40	1.28	1.20	1.44
11-a	0.36	4.56	0.079	0	2.00	0.37	2.90	0.61	+0.17	1.40	2.05	2.07	1.47	1.70	2.00
*	0.18	2.28	0.079	-0.33	1.00	0.16	1.41	0.32	+0.16	0.65	1.00	1.00	1.00	1.00	1.00
10-a	0.27	3.42	0.079	-0.33	1.50	0.23	2.65	0.32	+0.21	1.20	1.43	1.88	1.00	1.31	1.84
9-c	0.18	2.28	0.079	+0.5	1.00	0.20	0.55	0.44	-0.07	0.25	1.00	1.00	1.00	1.00	1.00
11-b	0.36	4.56	0.079	+0.5	2.00	0.405	1.30	0.725	-0.12	0.54	2.02	2.36	1.64	1.72	2.16

*These values are taken from curves Figure 13, and not from experiment.

**R_1 S_1, Z_1, δ_1 and ξ_1 are values of R, S, Z, δ, and ξ for wave height = .18', Ho/Lo = 0.079; a scale ratio of one was given for this case.

TABLE 10

EFFECT OF GRAIN SIZE

$\frac{Do_2}{Do_1}$	$\frac{h}{Ho}$	$\frac{R_2}{R_1}$ %	$\frac{S_2}{S_1}$ %	$\frac{Z_2}{Z_1}$ %	$\frac{\delta_2}{\delta_1}$ %	$\frac{\xi_2}{\xi_1}$ %
4.12	0	75.0	78.0	85.0	77.0	78.0
4.12	+0.50	67.0	42.0	90.0	140.0**	50.0
4.12	+1.00	73.00	33.0	82.0	77.0	125.00**
4.12	-0.50	82.0	71.0	78.0	95.00	92.0
Average		74.0	56.0	84.0	83.0	72.0

* 1 refers to sand no. (1), Do = 0.325 mm.

2 refers to sand no. (2), D_o = 1.350 mm.

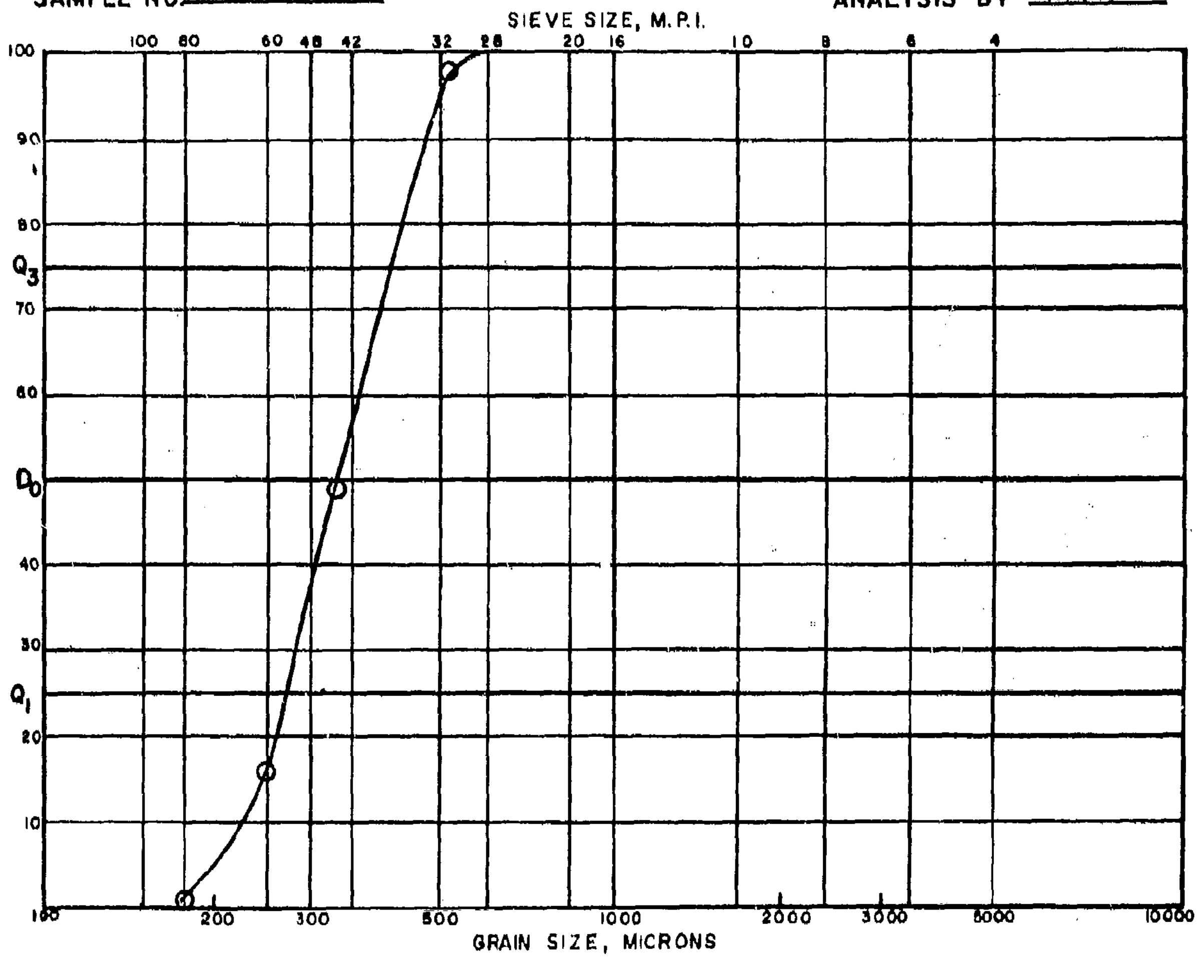
** These data were excluded.

FIGURE 32 – MECHANICAL ANALYSIS

DATE 7-14-62

SAMPLE NO. SAND (1)

ANALYSIS BY KADIB



Sieve Size MPI	Gross	Tare	Net	% Retained	Cum. % Finer Than	Sieve Size MPI
32	25.6	14.8	10.8	1.75	98.25	32
45	322.3	14.8	307.5	49.55	48.70	45
60	220.5	14.8	205.7	33.05	15.65	60
80	104.4	14.8	89.6	14.40	1.25	80
200	17.8	14.8	3.0	0.40	0.85	200
pan	19.8	14.8	5.0	0.85	0	
TOTAL			621.6	100.00		

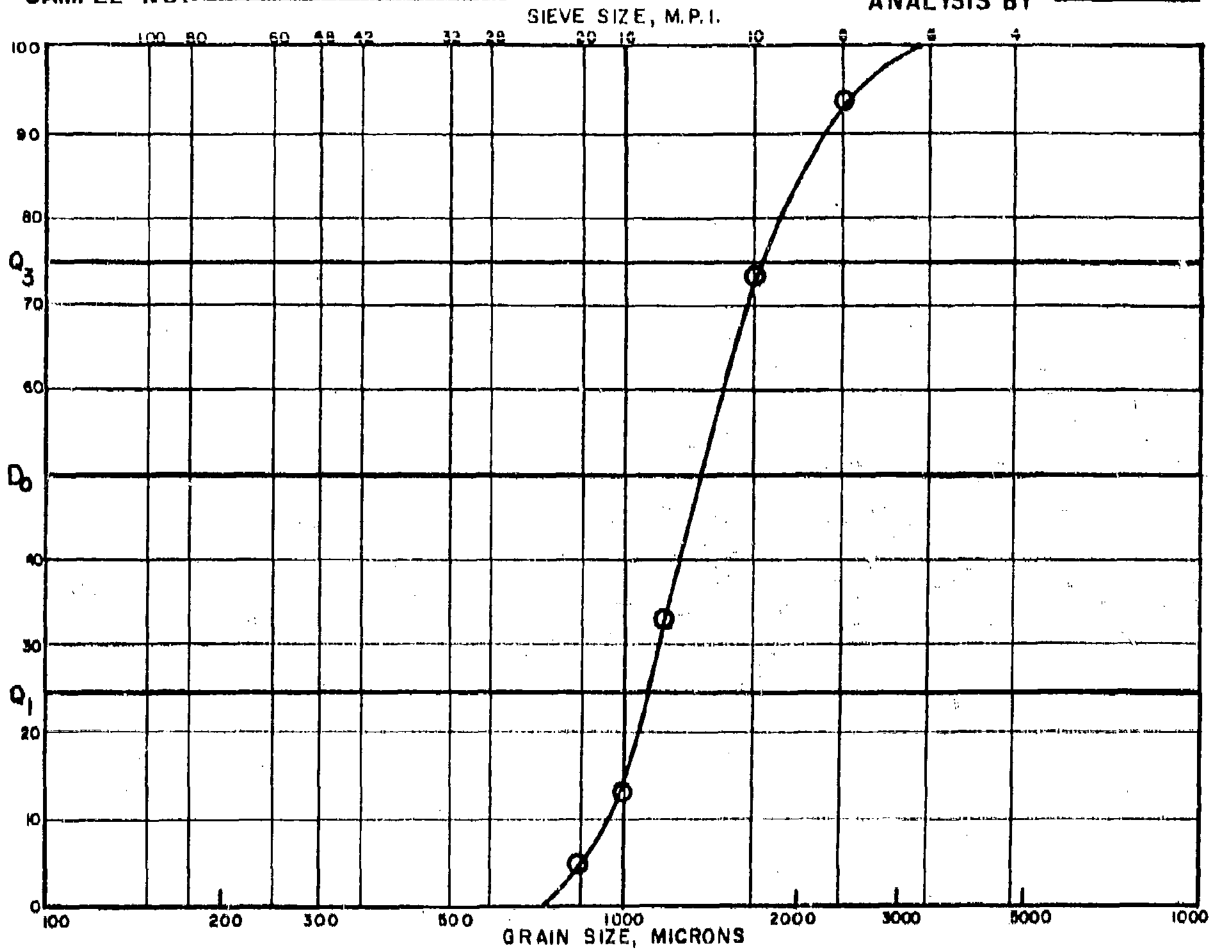
D_e = .325 mm.

FIGURE 33 - MECHANICAL ANALYSIS

DATE 7-14-62

SAMPLE NO. SAND 2

ANALYSIS BY KADIB



Sieve Size MPI	Gross	Tare	Net	% Retained	Cum. % Finer Than	Sieve Size MPI
8	42.10	14.50	27.60	5.62	94.38	8
10	116.6	14.50	112.10	20.80	73.58	10
14	223.4	14.50	208.90	42.50	31.08	14
16	98.1	14.50	83.60	17.03	14.05	16
20	52.4	14.50	37.90	7.75	6.30	20
pan	45.40	14.50	30.90	6.30	0	
TOTAL			491.00	100.00		

D_o = 1.350 mm.

BEACH EROSION BOARD, C.E., U.S. ARMY, WASHINGTON, D.C.

BEACH PROFILE AS AFFECTED BY VERTICAL WALLS by Abdel-Latif Kadib, June 1963, 41 pp., 30 illus. and appendix with 10 tables and 2 illus.

TECHNICAL MEMORANDUM No. 134 UNCLASSIFIED

Results of a laboratory investigation of some aspects of the flow characteristics and wave attack at sand beaches protected by a vertical seawall are reported. The effects of the top elevation of the vertical wall, bed material characteristics, and different wave scale ratios were also investigated. Some conclusions are drawn regarding relative wall height and beach profile stability in front of and behind the wall.

1. Seawalls
2. Equilibrium Profile
3. Scour
4. Scale effects

I Kadib, A. L.
II Title

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