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EVALUATION OF BED CHANGE AT SEAWALL TOE

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ABSTRACT

The effect of construction of seawalls on the beach profile attracts the researchers - in the field of coastal engineering - a lot.

Although there is a great need for construction of seawalls in many places along the shoreline, this construction causes great number of drawbacks in the coastal zone.

Throughout this paper the effect of the existance of seawalls on bed change at the toe was studied using different wave steepnesses and different wall slopes incase of both a beach slope 1: 10 and 1: 20.

The experimental results were expressed in a mathematical relations to be easily applied by engineers working in this field, the obtained mathematical relations can give an evaluation for scour or bed change at wall toe for different locations of seawall relative to shoreline.

I. Introduction

The feasibility of any proposed solution in many coastal engineering problems depends upon the quantitiative estimates of erosion and accretion within the problem area.

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The rate of the change of seabed profile depends upon many factors such as waves, currents, the physical properties of the bottom material and the position of seawall with respect to shoreline. This rate is very important for predicting both the natural coastline changes and the changes resulting from the man-made structures on the coastal zone.

As an important aspect in the design of shore improvement measures is the effect, resulting on the beach zone, of placing walls or any other defences in the zone reached by wave and current action.

In many cases, such structures may produce severe scour and loss of the seabed material at the toe of these structures. The change in bed at seawall toe may be considered among the menaces of nature which may cause damage to the existing onshore structures.

II. Laboratory Investigation

The experiments were carried out at the Suez Canal Authority Research center at Ismailia at the hydraulics laboratory in the existing wave flume.

Fig (1) shows a plan and a longitudinal section for the wave flume used during the experiemnts. The total length is 40.0 ms and the width is 1.5 m.

The wave flume is provided with a wave generator capable of gnerating deep or shallow waves.

In order to absorb the waves reaching behind the reciprocating plates and to prevent its interference with the main generating wave, a 4:1 gravel slope of 2.0 ms length and 0.50 m height was placed inside a meshed wire casing at the back of the plate.

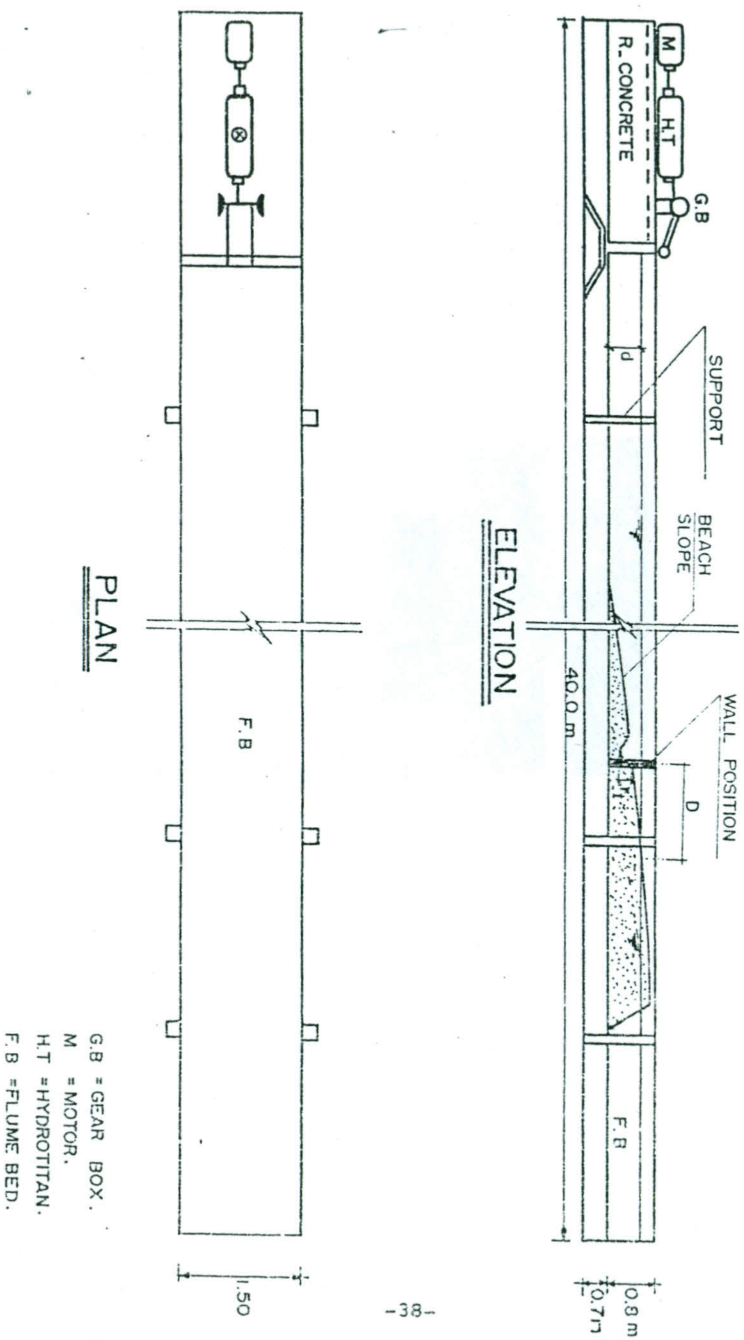

FIGURE (1) WAVE FLUME

Waves were measured using a Hellige type wave recorder and an electrode system. It must be noted that the waves used during the experiments are selected in such a way to represent the moderate and the severe storm conditions acting on the Egyptian coasts.

For more details concerning the wave flume, its description and its facilities one can refer to refrence [8].

The beach profile was formed using sand having the following properties.

i. The mean diameter = 0.33 mm.
ii. Dry density = 1.335 kg/cm^3
iii. Specific weight = 2.67
iv. Angle of internal friction "ϕ" = 32°
v. Coefficient of conductivity "K" = 1.486 cm/sec. Using the falling head permeameter.
vi. Voids ratio at losse state "e_{max}" = 1.00
Voids ratio at dense state "e_{min}" = 0.555
Using modified proctor test.

To study the effect of the seawall construction on the bed change at seawall toe, nine series of tests were carried out using wave steepnesses ranging from 0.023 to 0.043 and the beach slopes 1:10 and 1:20, the study was done for both vertical and inclined seawalls. When reaching the equilibrium state the bed profiles were measured and plotted for each test.

Equilibrium time ranged between 150 to 300 minutes. Details concerning methods of measurements and bed profiles plotting, are explained in reference [3].

III. Analysis of the Experimental Results

To explain the relations between different measured variables measured experimentally, and their effect on each other, the obtained data have been plotted using dimensionless parameters and then the technical comments and analysis were introduced.

The measured parameters are:

d : water depth at deep water
D : seawall distance measured from shore line
r_t : vertical change in bed profile at wall toe.
H : wave height
L : wave length
T : wave period

The above variables were put in a dimensionless form as follows:

D/d : Relative seawall distance.
r_t/d : Relative change in bed profile at wall toe.

Also the wave steepness H/L was added to these measured dimensionless terms.

Relations between seawall location w.r.t. the shoreline represented by D/d and the change in bed profile at wall toe represented by r_t/d were plotted by straight lines joining the different points as shown in figures (2,3, and 4).

It was noticed that as relative seawall distance increases the net change in bed at wall toe increases towards the - ve sense (scour) because of the increase of wave energy as we go seaward.

Figure (4) shows a relation, same as the above, comparing 1:20 and 1:10 beach slopes for the case of vertical wall.

Also it was noticed that the net change in bed profile at wall toe is bigger in case of 1:20 than 1:10 beach slope, because of the fact that the rate of increase of water depth in case of 1:20 beach slope is less than that of 1:10 beach slope and thus the wave has a greater effect (positive or negative) on the bed in the first case.

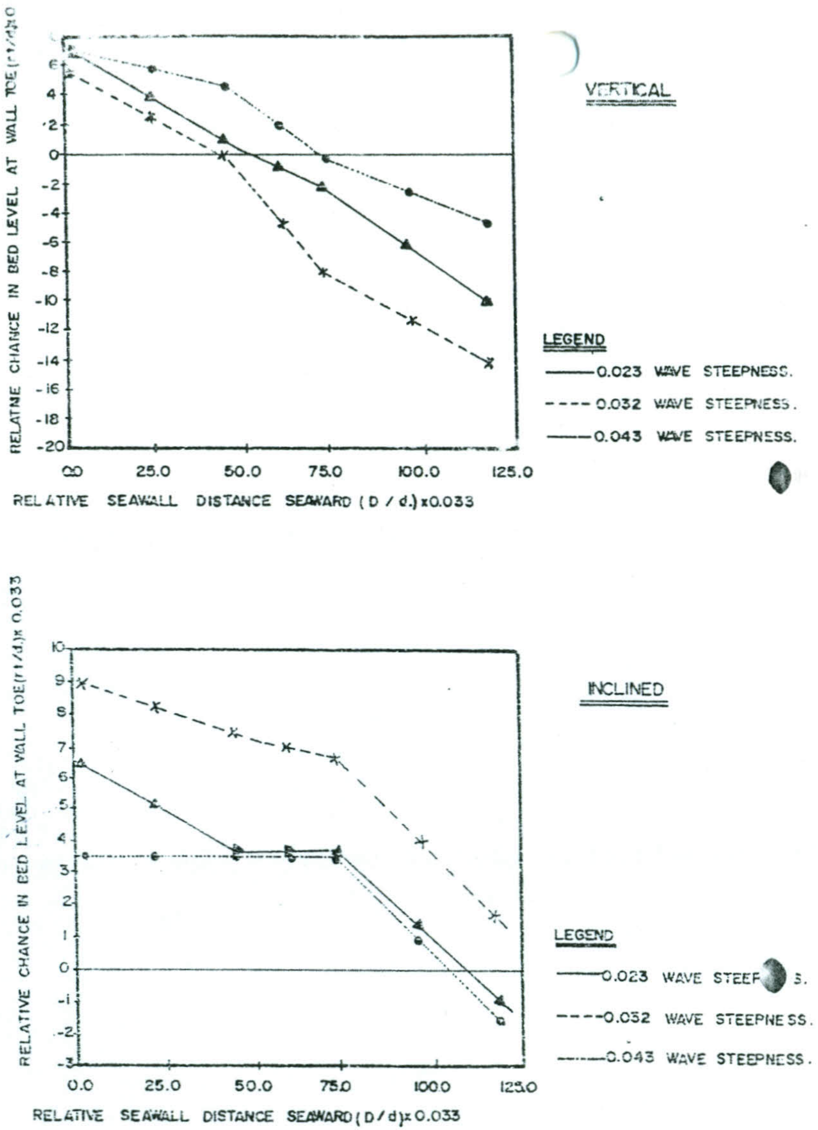

FIG: (2) RELATION BETWEEN RELATIVE SEA WALL $\frac{D}{d}$ & THE BED CHANGE AT WALL TOE. SLOPE 1:20

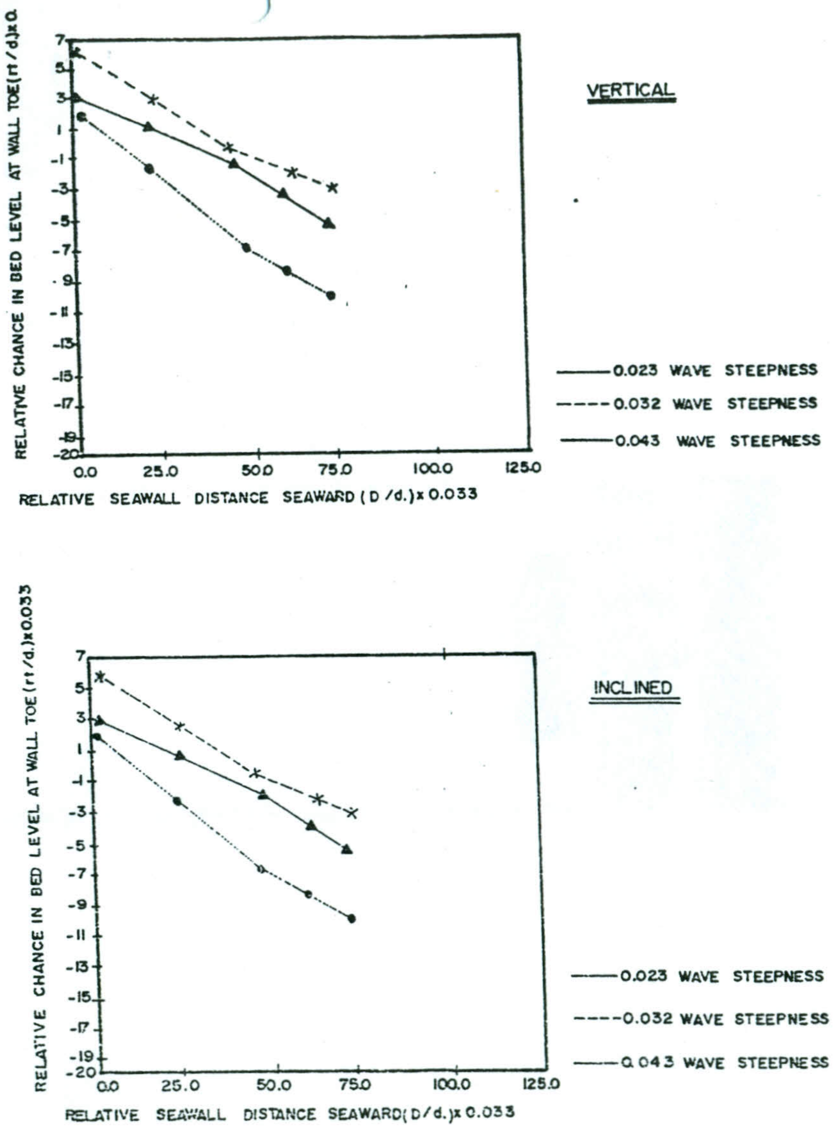

FIG: (3) RELATION BETWEEN RELATIVE SEA WALL $\frac{D}{d}$ & THE BED CHANGE AT WALL TOE. SLOPE 1:10.

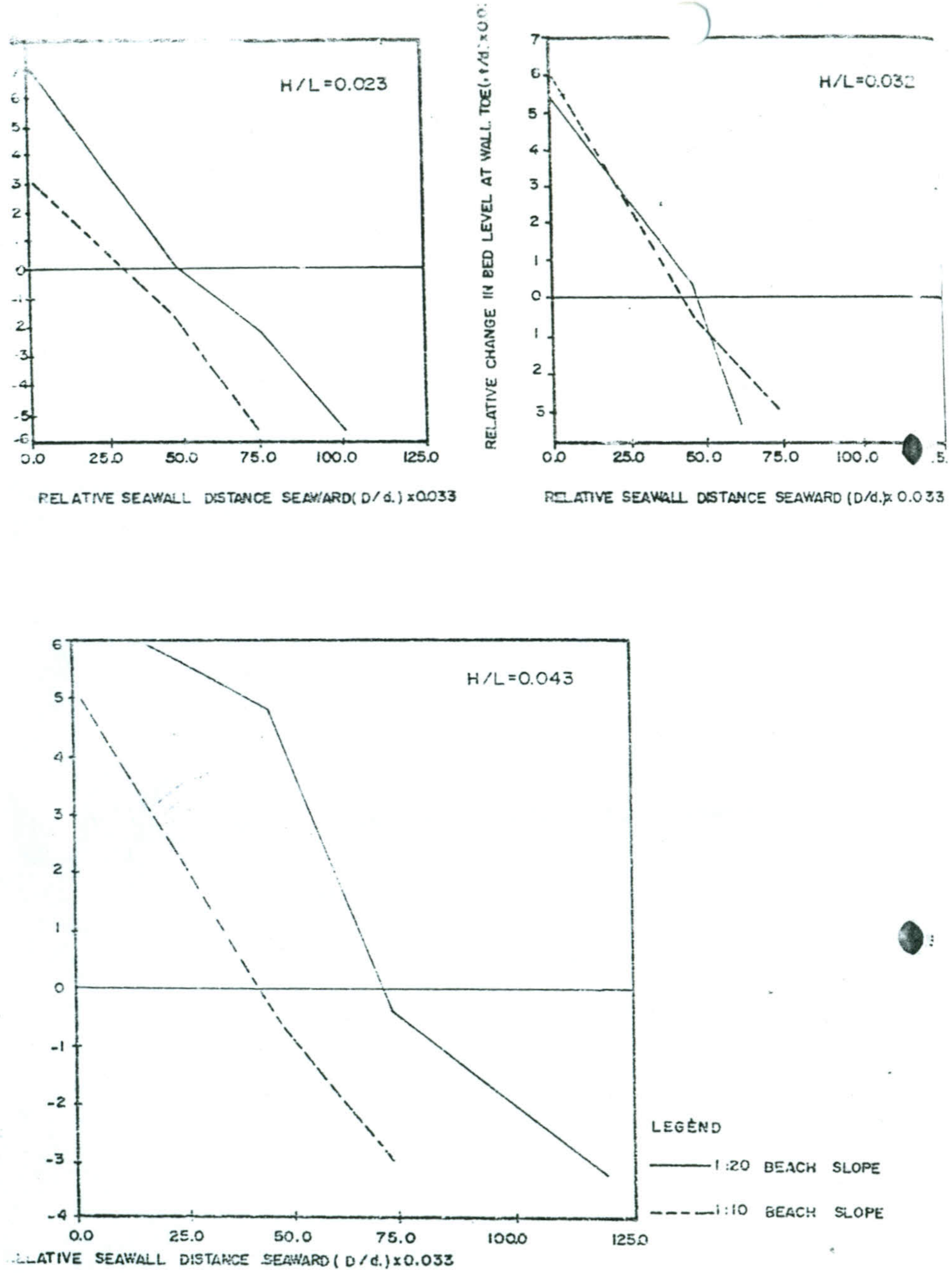

FIG: (4) CHANGE OF BED AT WALL TOE FOR DIFFERENT BEACH SLOPES AND DIFFERENT H/L.

IV. Mathematical Relations

The diffemt variables measured during the experimental tests and the dimensionless terms introduced in the analysis were arranged in such a way to give a suitable mathematical form to be easily adopted.

The computer program used is the "microstat" by Ecosoft Inc. The computer used is an IBM PC/XT.

1: Relations Between Different Terms

The following analysis shows the different relations between the terms in a mathematical form.

The regression analysis of the data; mean value, standard deviation, relative correlation "r^2" and analysis of variance table were done.

The computer program used to plot the points shown on both experimental and mathematical curves on figures 5,6,7 and 8 is the "microstat" using automatic scaling. These figures are used to illustrte the difference between the experimental and the mathematical curves and not to be used for measuring.

Vertical Wall - 1:20 Beach Slope

Direct linear relation was found to give low corerlation (r^2), so we chose relations of 2nd degree which gave an acceptable correlation (r^2).

these relations are:

$$\left(\frac{D}{d}\right)^2 = -47.6\left(\frac{r_t}{d}\right) + 9.52 \quad \text{for } H/L = 0.023 \qquad (1)$$

$$\left(\frac{D}{d}\right)^2 = -58.57\left(\frac{r_t}{d}\right) + 15.13 \quad \text{for } H/L = 0.032 \qquad (2)$$

$$\left(\frac{D}{d}\right)^2 = -75.84\left(\frac{r_t}{d}\right) + 18.51 \quad \text{for } H/L = 0.043 \qquad (3)$$

To show the compatibility of the above mathematical relations, with those obtained experimentally the mathematical relations relating $\left(\frac{D}{d}\right)^2$ and r_r/d for different steepnesses (H/L) were plotted comparing the experimental results curve and the adopted mathematical one (Fig. 5).

45˚ Inclined Seawall - 1:20 Beach Slope

As the above relation, the direct linear relation was found to give low correlation (r^2), so we have also chosen relations of 2nd degree which gave an acceptable correlation (r^2), these relations are:

$$\left(\frac{D}{d}\right)^2 = -55.57\left(\frac{r_t}{d}\right)+11.06 \qquad \text{for } H/L = 0.023 \qquad (4)$$

$$\left(\frac{D}{d}\right)^2 = -62.47\left(\frac{r_t}{d}\right)+15.13 \qquad \text{for } H/L = 0.032 \qquad (5)$$

$$\left(\frac{D}{d}\right)^2 = -68.46\left(\frac{r_t}{d}\right)+17.05 \qquad \text{for } H/L = 0.043 \qquad (6)$$

Also the comparison between the mathematical and the experimental results relating $\left(\frac{D}{d}\right)^2$ and r_t/d for different steepnesses (H/L) was shown in figure (6).

Vertical Wall - 1:10 Beach Slope

For this case, the direct linear relation was adopted as it was found to give an acceptable correlation (r^2). the following are the obtained relations:

$$\frac{D}{d} = -4.85\left(\frac{r_t}{d}\right)+0.50 \qquad \text{for } H/L = 0.023 \qquad (7)$$

$$\frac{D}{d} = -4.6\left(\frac{r_t}{d}\right)+0.88 \qquad \text{for } H/L = 0.032 \qquad (8)$$

$$\frac{D}{d} = -4.27\left(\frac{r_t}{d}\right)+0.87 \qquad \text{for } H/L = 0.043 \qquad (9)$$

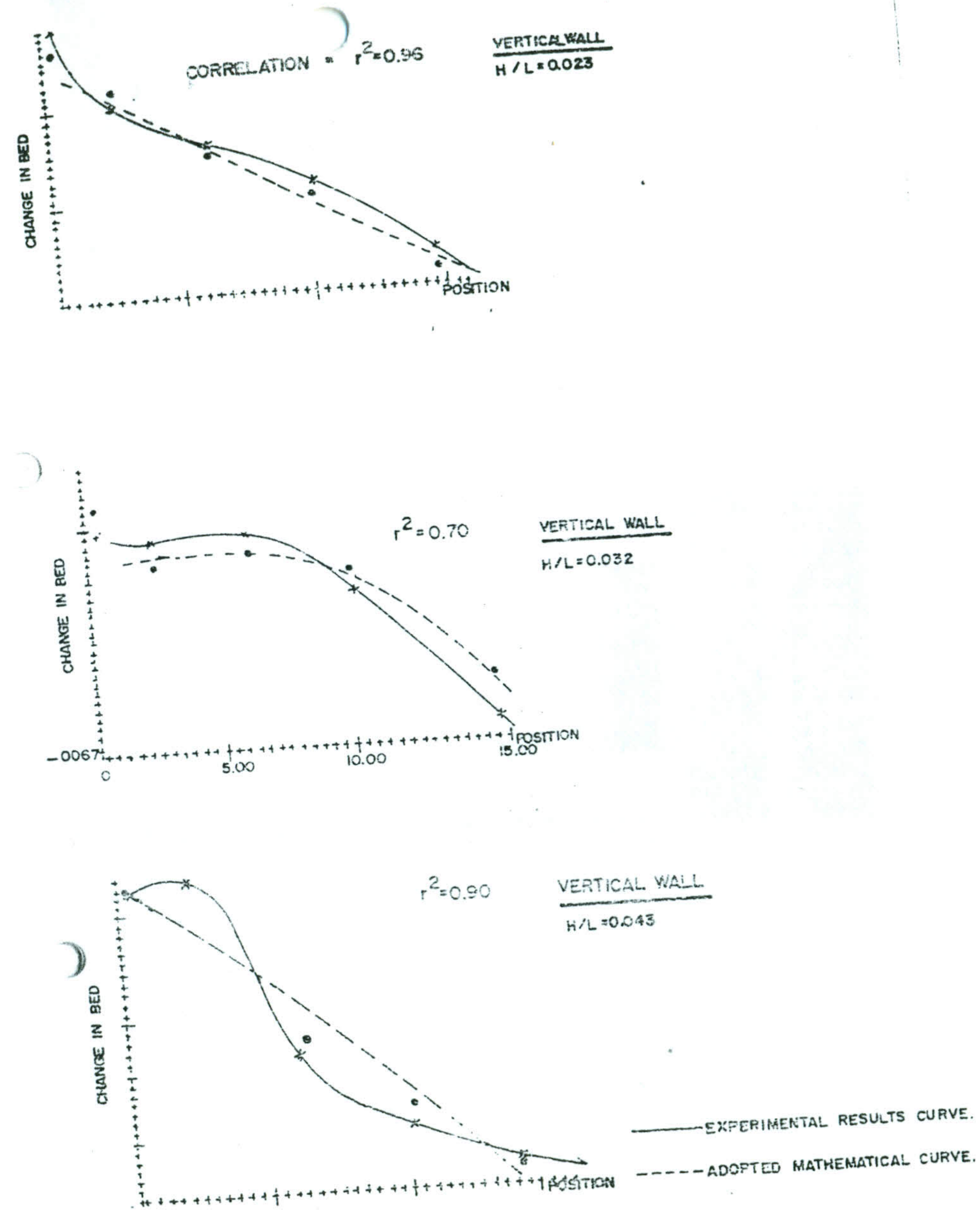

FIG:(5) WALL POSITION VS. PROFILE LEVEL AT WALL TOE FOR BEACH SLOPE 1:20 AND VERTICAL WALL.

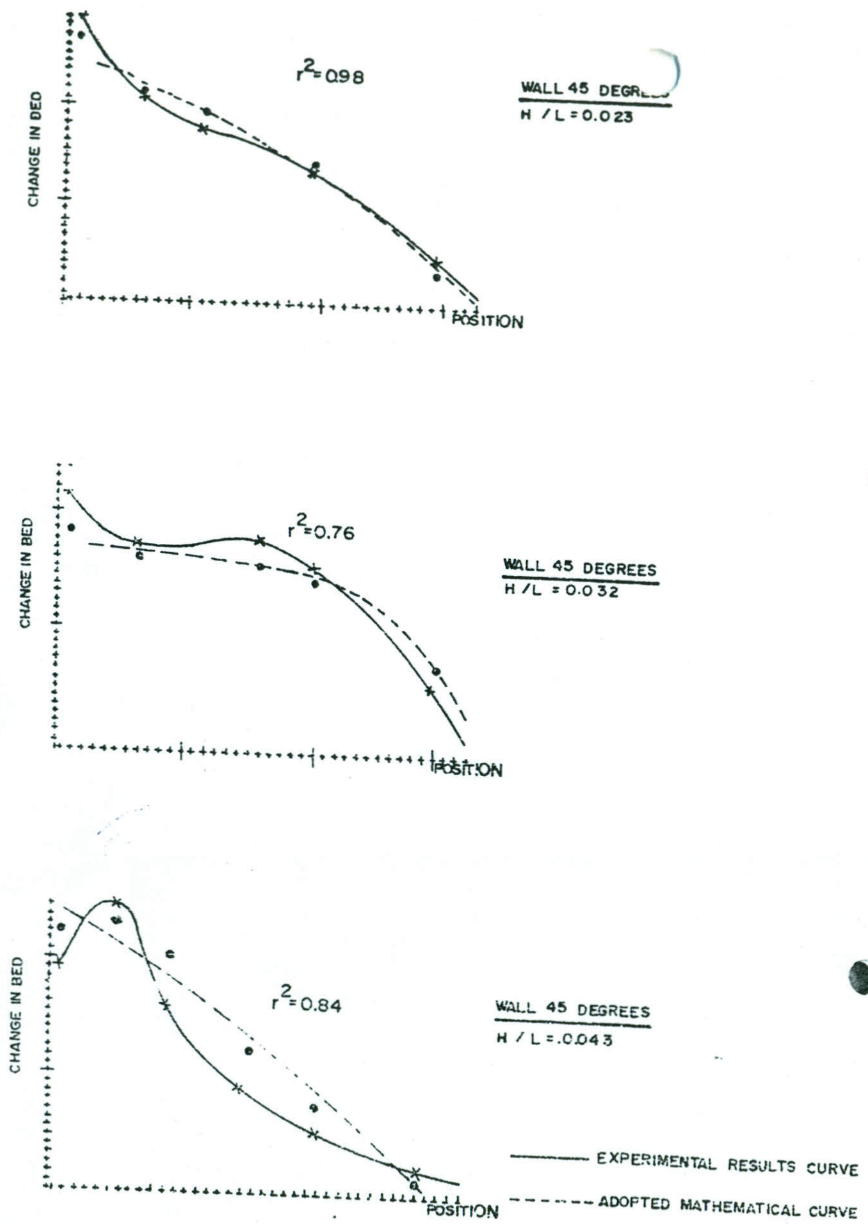

FIG: (6) WALL POSITION VS PROFILE LEVEL AT WALL TOE FOR BEACH SLOPE 1:20 AND INCLINED WALL.

To show the reliability of the above relations, they were plotted relating D/d and r_t/d for different steepnesses (H/L) and compared with the experimental results curve relating the same dimensionless variables (Fig. 7).

45° Inclined Wall - 1 : 10 Beach Slope

The direct linear relation was found to give an acceptable correlation (r^2), the following are the obtained relations:

$$\frac{D}{d} = -5.85\left(\frac{r_t}{d}\right) + 0.442 \qquad \text{for } H/L = 0.023 \qquad (10)$$

$$\frac{D}{d} = -5.19\left(\frac{r_t}{d}\right) + 0.92 \qquad \text{for } H/L = 0.032 \qquad (11)$$

$$\frac{D}{d} = -4.87\left(\frac{r_t}{d}\right) + 0.92 \qquad \text{for } H/L = 0.043 \qquad (12)$$

Also the comparison between the mathematical and the experimental results relating D/d and r_t/d for different steepnesses H/L and compared with the experimental results curve relating the same dimensionless variables (Fig. 8).

From the above study it was noticed that the relations and figures showed good and reliable results within the range of our experiments and with average correlation (r^2) not less than 85%.

V. Illustrative Example

In order to show the applicability of the above deduced relations the following example is given.

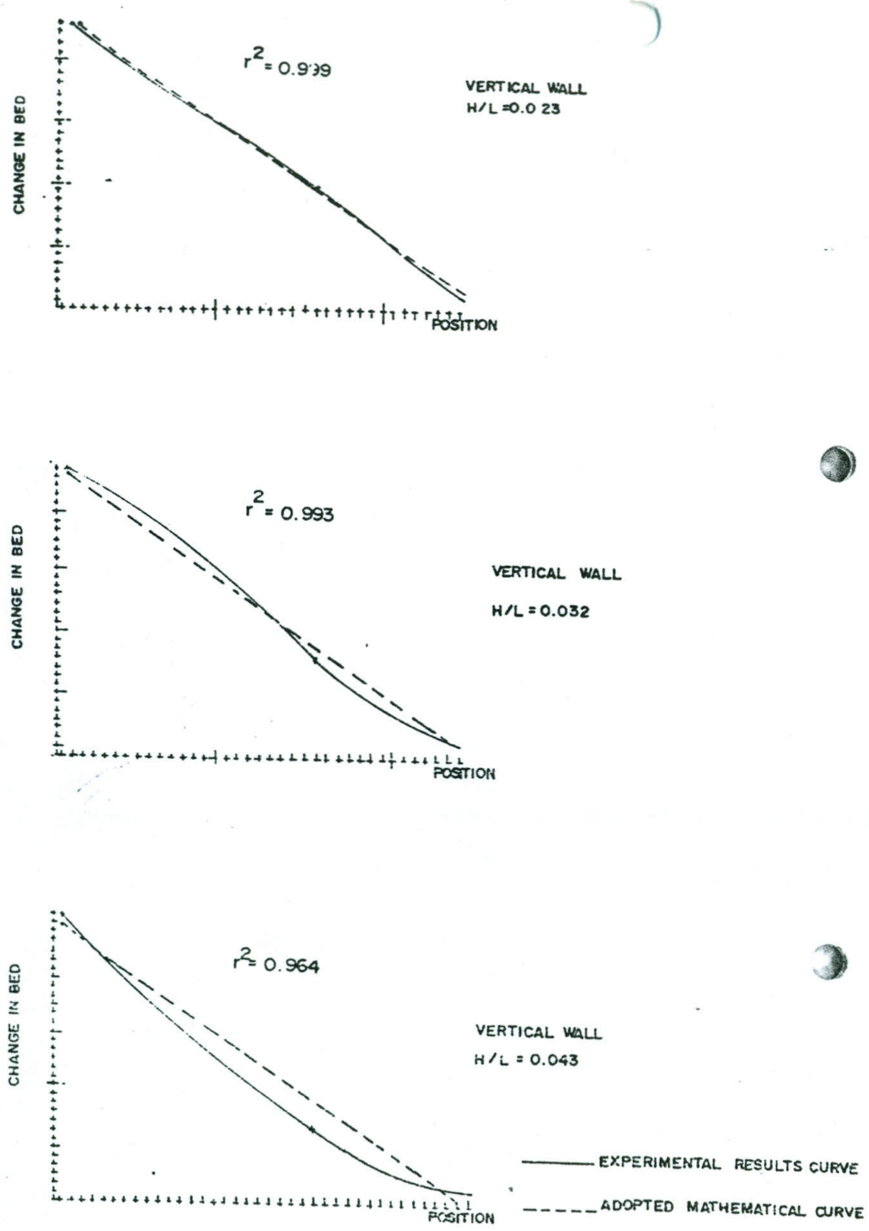

FIG: (7) WALL POSITION VS PROFILE LEVEL AT WALL TOE FOR BEACH SLOPE 1:10 AND VERTICAL WALL.

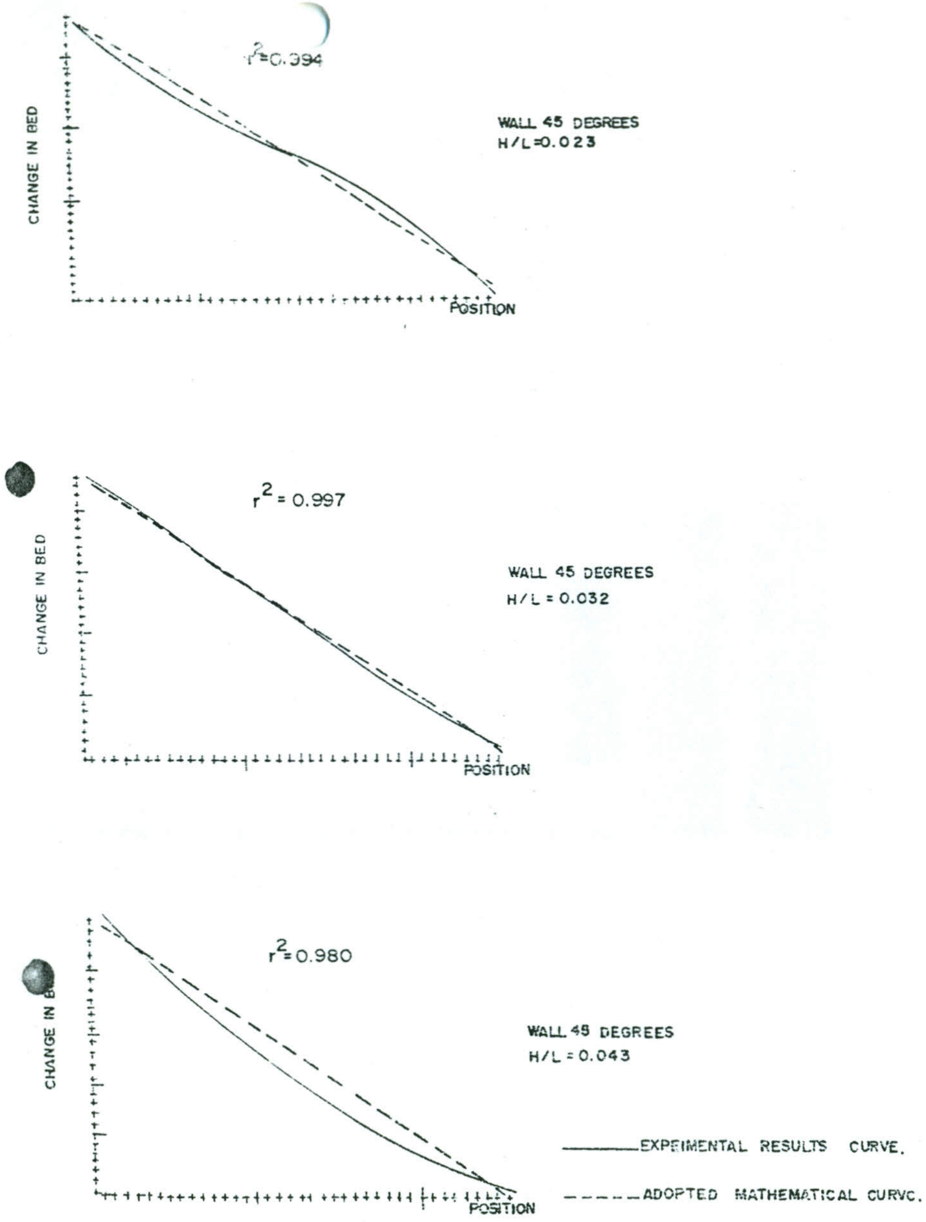

FIG: (8) WALL POSITION VS PROFILE LEVEL AT WALL TOE FOR BEACH SLOPE 1:10 AND INCLINED WALL.

A vertical wall is recommended to be constructed on one of the Egyptian beaches. The beach slope at that area is continuous for a long distance.

Given that the beach slope is 1 : 10, wave period is 4 sec. and the steepness is 0.032. Find the position at which the relative change of bed level at wall toe is minimum $r_t \simeq 0$.

Solution

Given wave period,

T	=	4 sec.
L_0	=	$1.56 \times T^2$
L_0	=	$1.56 \times (4)^2 = 24.96$ ms
d	=	$L_0/2$
d	=	24.96/2 = 12.48 ms
r_t	=	0
H/L	$\simeq$	0.032

By using equation no. 8

$$\frac{D}{d} = -4.6\frac{r_t}{d} + 0.88$$

By substitution

$$\frac{D}{12.48} = -4.6 \times \frac{0}{d} + 0.88$$

$\therefore$ D = 10.98 ms.

This means that if the wall is constructed at a distance of 10.98 ms from the shore there will be a minimum change in bed level at the wall toe.

In case of 1:20 beach slope, using equation no 2.

$$\left(\frac{D}{d}\right)^2 = -58.57\left(\frac{r_t}{d}\right) + 15.13$$

By substitution

$(D/12.48)^2$ = - 58.57 x \f(o/d) + 15.13

$\therefore$ D = 48.54 ms.

This means that if the wall is constructed at a distance of 48.54 ms from the shore ther will be a minimum change in bed level at the wall toe.

The above figures show that in case of1 : 20 beach slope the effective position of seawall is more seaward than in case of 1 : 10 beach slope.

If we constructed the wall at a distance of 20 ms from shore then the estimated change in bed level will be:

In case of 1: 10 beach slope

$D/d = -4.6\, r_t/d + 0.88$

By substitution

$20/12.48 = -4.6\, r_t/12.48 + 0.88$

$\therefore$ $r_t = -1.96$ ms.

The - ve sign means that the change in bed level at wall toe is scour. This scour is estimated to be 1.96 ms. The more the wall is constructed near the shore the less the scour will be, till we reach the effective position of seawall (at a distance of 10.98 ms from shore) and then accretion takes place.

In Case of 1: 20 Beach Slope

$$\left(\frac{D}{d}\right)^2 = -58.57\left(\frac{r_t}{d}\right) + 15.13$$

By Substitution

$(20/12.48)^2 = - 58.57\ r_t/12.48\ + 15.13$

$\therefore r_t = + 2.67$ ms

The + ve sign means that the change in bed level at wall toe is accretion. The more the constructed wall is seaward the less the accretion will be, till we reach the effective position of seawall (48.54 ms from shore) and then scour takes place.

The above example illustrates the applicability of the obtained relations.

VI. Conclusion

1. From the experimental work the mathematical expressions relating the wall position with the bed change at wall toe was deduced. These relations can be easily applied within the range of experiments.
2. In the range of these experiments it was found that as relative seawall distance increases the net change in bed at wall toe increases towards the -ve sense (scour) because of the increase of wave energy as we go seaward.
3. It was found that for the same wall location, by using inclined seawall the scour of bed level at wall toe is less than the cases of using vertical wall.

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