CHAPTER 96

HYDRAULIC MODEL EXPERIMENTS ON SEAWALLS

by
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ABSTRACT

The preliminary analysis of a set of three-dimensional tests on an infinite beach backed by a seawall is presented. The longshore sediment transport rate in front of the seawall was found to decrease as the beach in front of the seawall eroded. The location of the breaker peaks in the suspended and bed load sediment transport rate moved slightly offshore, and the bedload peak in the swash zone disappeared as the beach eroded. The local ratio of H/d approached a constant value as the beach eroded for most of the tests, however the erosion depth in front of seawalls cannot be simply related to offshore wave height.

INTRODUCTION

The function of a seawall is to protect the land behind it by fixing the land-sea boundary. It does not protect either the beach fronting it or adjoining unprotected beaches. Since seawalls are usually built along eroding rather than stable shorelines, they have commonly been perceived as causing or contributing to erosion rather than simply responding to a pre-existing erosion problem. When a seawall is constructed on an eroding coast, existing erosion processes will continue to decrease the size of the beach in front and eventually the beach in front of the seawall will disappear if there is inadequate sediment supply. The seawall protection solution prevents further recession of the coastline; it does not stop the physical processes which cause erosion. The extent to which a seawall affects the processes on

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the fronting and adjacent beaches at any one time largely depends on the location of the seawall relative to the active shoreface and only indirectly on the level of wave action to which it is subjected.

Kraus (1988) presented an extensive review of approximately 100 technical papers on the effect of seawalls. Since most laboratory studies used wave flumes and investigated cross-shore sediment transport processes only, the effect of the seawall on the longshore sediment transport rate could not be deduced.

The set of experiments presented here was performed as a part of a comprehensive three-dimensional study of the effects of seawalls on the nearshore processes. The fundamental case of an infinite beach backed by a seawall is considered here. Wave heights, wave setup, longshore velocity distributions, longshore sediment transport rates, and longshore sediment transport distributions were measured. Preliminary analysis of the data is presented here.

EXPERIMENTS

Five tests were carried out in a three-dimensional model basin (Figure 1). These tests are an extension of previous three dimensional sediment transport studies carried out in the same facility (Kamphuis, 1991a, 1991b, 1991c). A vertical seawall was constructed on a sandy beach of median grain size 0.12 mm. The test conditions are summarized in (Table 1). A time series of waves, simulating a Jonswap wave spectrum was used with a 10 degree incident wave angle, a peak period of 1.15 seconds and wave heights varying from 0.05 to 0.09 m. The random wave signal repeated itself after 200 waves.

A plane beach of initial slope 1:10 was first prepared for each test. This initial profile was allowed to reshape itself under wave action to approach equilibrium. The water level in the basin was chosen so that only about one percent of the incident waves impacted on the seawall at the top of the beach when the beach approached equilibrium, thus simulating a seawall well back on the beach. The water level was then raised in all tests except Test A to simulate storm surge. This resulted in the initial percentages of wave impact on the seawall as shown in Table 1. The tests were continued until a new equilibrium profile in front of the seawall was approached.

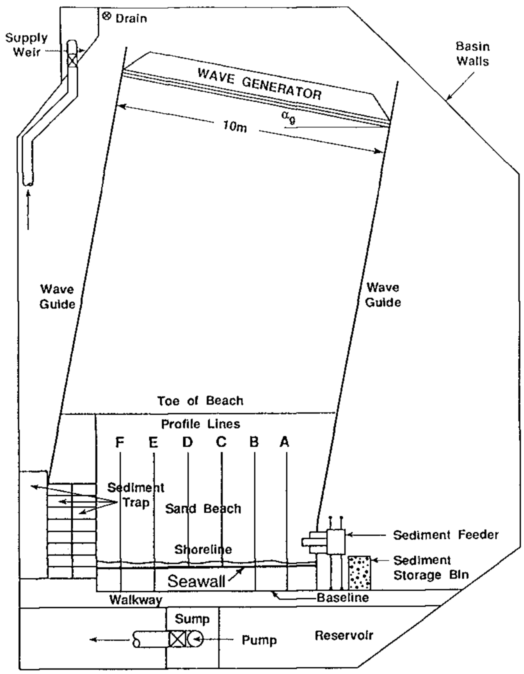


FIGURE 1 EXPERIMENTAL FACILITY

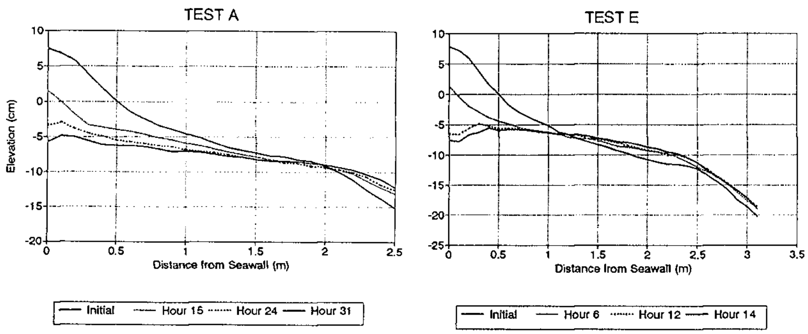


FIGURE 2 PROFILE DEVELOPMENT

TABLE 1
TEST SUMMARY

TEST	GENERATED WAVE CONDITIONS			SURGE	TEST DURATION	
	Height Hs (cm)	Period Tp (sec)	Angle α (deg)	S (cm)	t (hr)	% touch
A	7	1.15	10.0	0.0	32	1.0
D	7	1.15	10.0	2.2	12	20
E	9	1.15	10.0	-	14	10
F	5	1.15	10.0	-	22	10
G	7	1.15	10.0	1.6	18	10

Each test consisted of a series of hourly segments. Wave heights, longshore velocity distributions, and beach profiles were measured during each segment. Wave heights were recorded using capacitance type wave gauges. One wave gauge was mounted offshore to record the incident wave height. Fifteen wave gauges were mounted on a horizontal beam at regular intervals of 0.2 m through the breaking zone. Longshore velocities were measured using a mini electro-magnetic current meter. Profiles of the beach in front of the seawall were measured along six parallel lines evenly spaced along the seawall. The profiles presented here are the average of profiles B,C,D, and E (Figure 1).

A sediment trap was located at the downdrift end of the beach but within the wave guides. It was designed to separate the bedload from suspended load and to measure their distributions across the swash and surf zone. Sediment Transport rates were measured every 15 minutes. Sediment transport distributions were measured every 4 hours. A detailed description of the sediment trap layout can be found in Kamphuis (1991c).

To represent an "infinitely long" beach, it is necessary to maintain parallel contours along the study area. For this purpose, sediment was supplied at the updrift end of the beach by a feeder at a rate comparable to the sediment transported along the beach.

RESULTS

The tests essentially consist of two groupings. There are 3 tests with 7 cm high incident waves, with 1, 10, and 20 % of the waves directly impacting the seawall at the beginning of the test (Tests A,G, and D). Then there are 3 tests in which 10 % of the waves are initially incident on the seawall but in which the nominal incident wave height is 9, 7, and 5 cm (Tests E,G, and F). Test G is common to both sets. Figure 2 shows examples of the profile change with time. Figure 3 shows the initial and final profiles for all the tests.

The beach in front of the seawall gradually disappeared and the sand was eroded to well below the water level. The eroded sediment was deposited offshore, and a nearly horizontal plateau was formed. The horizontal plateau extended seaward to the breaker location. Very near the seawall a local scour hole was also observed in all the tests.

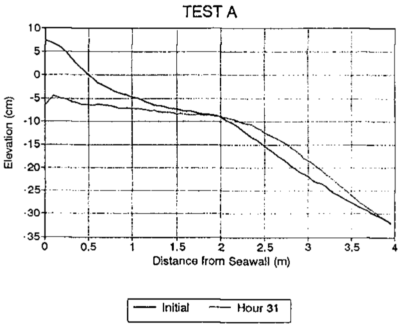
Figure 4 shows examples of the suspended, bed, and total longshore sediment transport rates as they evolved in time. All rates decreased as the foreshore eroded, because energy dissipation resulting from breaking decreased towards the end of the test. As the depths increased, more wave reflection and less breaking occurred. The longshore sediment transport rates tended toward equilibrium values.

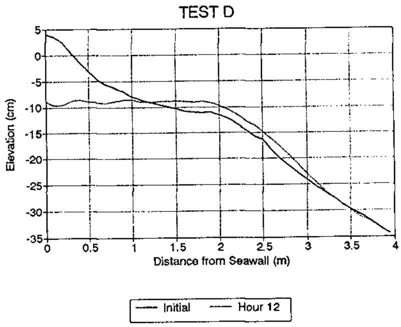
Figure 5 shows an example of the development of the suspended and bed load distributions with time. The peaks of the distributions moved slightly offshore, following a slight offshore movement of the breaker location. As the test progressed the bedload peak in the swash zone disappeared and both distributions tended to have one single peak near the breaker location.

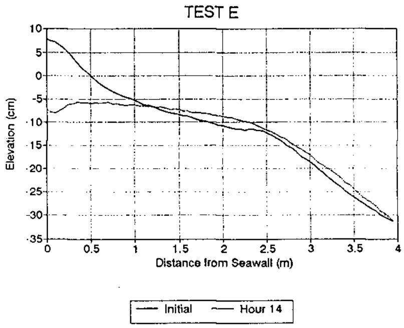
PRELIMINARY ANALYSIS OF RESULTS

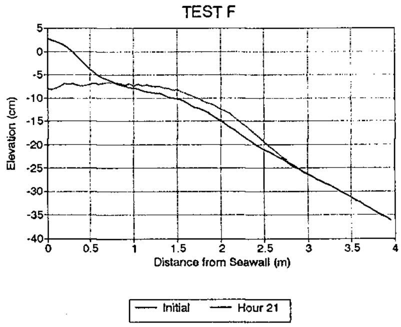
The present data set together with additional tests will be used to develop a Quasi-3D numerical model. This model will be an extension of the work of Briand (1990) by including wave reflection off the seawall. In the present paper a preliminary, general analysis of the data will be presented.

Figure 6 shows the wave height profiles at the ends of the tests. It is seen that the wave heights increase up to the breaking point and then decrease as wave energy dissipates. Up to breaking, the wave height profile is entirely predicted by combining small









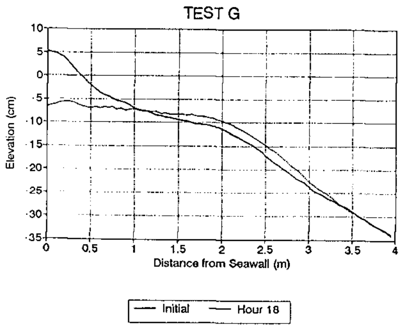


FIGURE 3

INITIAL AND FINAL PROFILES

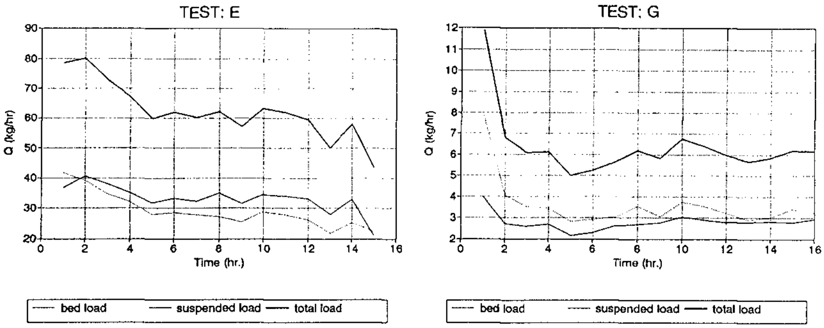


FIGURE 4 SEDIMENT TRANSPORT RATE

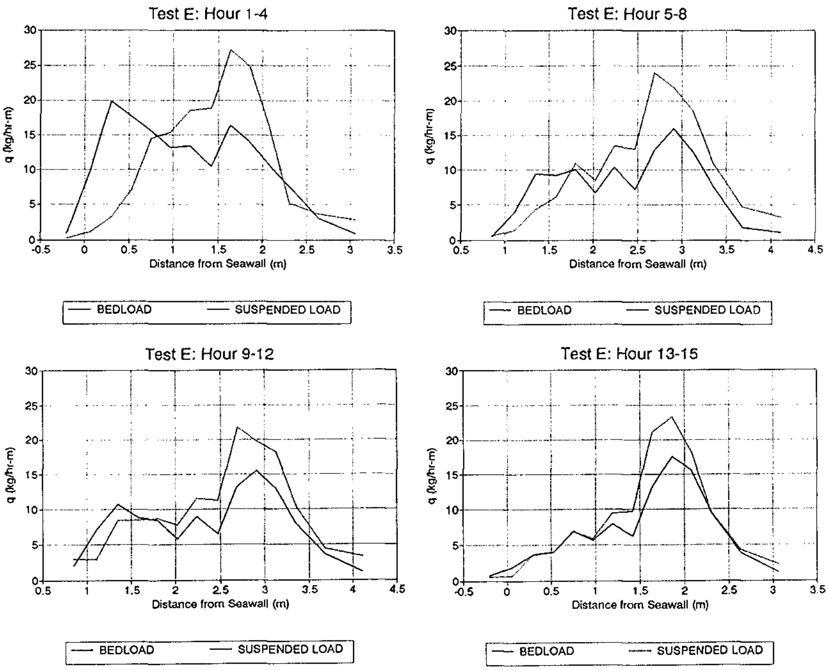


FIGURE 5 SEDIMENT TRANSPORT RATE DISTRIBUTION

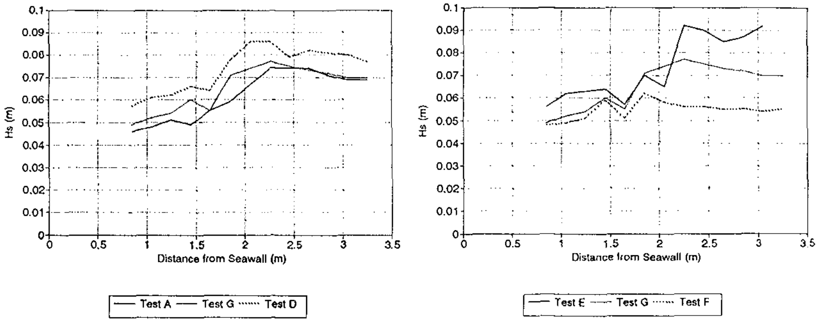


FIGURE 6 WAVE HEIGHT DECAY

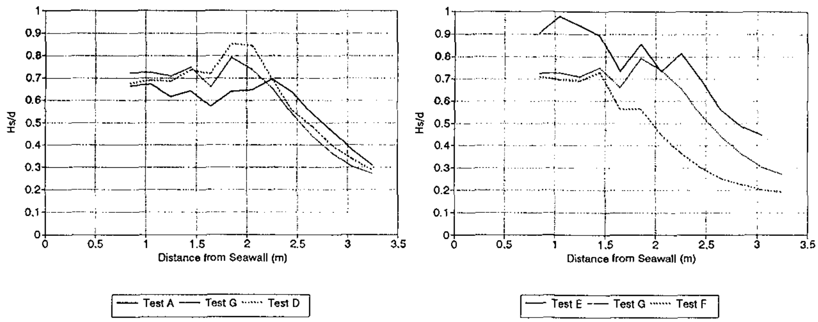


FIGURE 7 WAVE HEIGHT TO LOCAL DEPTH RATIO

amplitude shoaling theory, Snell's law and bottom friction (Kamphuis 1991a). Breaking is predicted by the incipient breaking criterion of Kamphuis (1991b) and the decrease in wave height is predicted by Kamphuis' (1993) adaptation of the energy dissipation rate proposed by Dally et al (1984). At about 1.5 m from the structure, however, the profile indicates a substantial reduction in wave energy dissipation rate. The remaining wave energy is simply reflected back to sea.

the simple ratio H_s/d and it is seen that near the structure water depth is indeed directly related to the wave height. In fact the ratio is about the same (0.7) for all tests except Test E (which is thought to contain a small error in depth measurement).

The average depth over the plateau from the seawall to the breaker (d_p) is shown in Table 2.

TABLE 2
SUMMARY OF PROFILE RESULTS

TEST	INPUT CONDITIONS			FINAL RESULTS		
	Hs (cm)	S (cm)	% touch	H_{sb} (cm)	X_b (m)	d_p (cm)
A	7	0.0	1	7.4	2.5	7.4
G	7	1.6	10	7.7	2.3	7.7
D	7	2.2	20	8.7	2.2	9.2
E	9	-	10	9.2	2.6	7.7
G	7	1.6	10	7.7	2.3	7.7
F	5	-	10	6.2	1.9	7.5

For Tests A,G, and D, it was found to be approximately equal to the breaking significant wave height. This seems to support the idea that scour depth is related to incident deep water wave height (Kraus, 1988). For Tests E,G and F, however, d_p is almost constant, even though the wave height decreases from 9 to 5 cm. This would tend to indicate that depth is not related to wave height in a simple manner.

Depth of water over the plateau is actually a complex interaction between wave height, water level, the beach, and the seawall. This interaction may be explained using the conceptual model in Figure 8.

Assume that a beach profile is in equilibrium with the incident wave climate, as in Figure 8a. Its depth (d) is defined everywhere out to a closure depth, d_c. If a storm surge (S) raises the water level, the whole equilibrium profile will rise to follow the new water

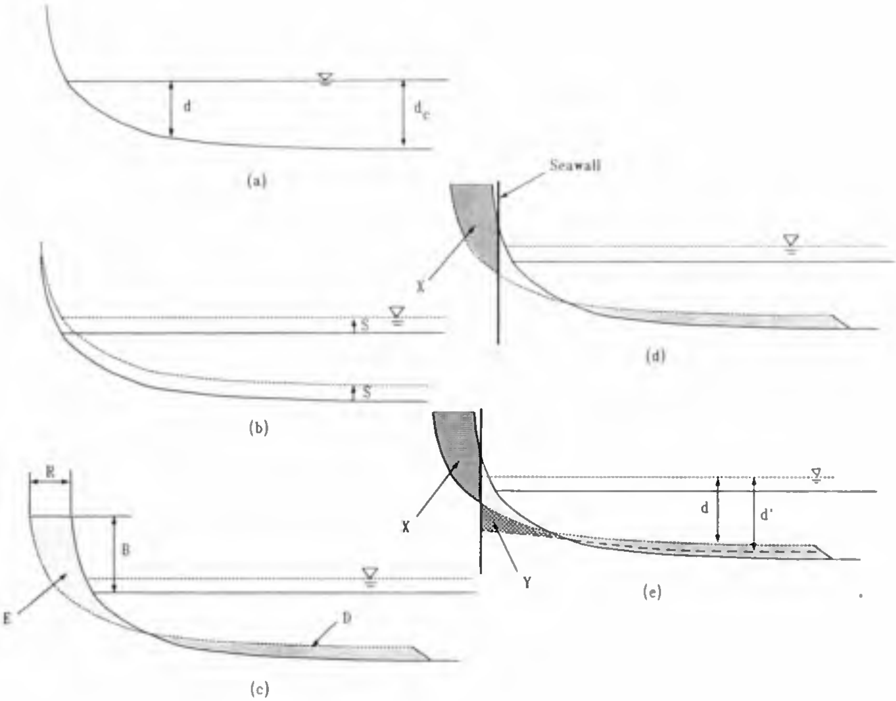


FIGURE 8 CONCEPTUAL MODEL OF EROSION NEAR A SEAWALL

level (Figure 8b). To raise the beach profile, however, requires additional sand and normally the existing profile must supply this, resulting in a profile recession (R) as shown in Figure 8c. The eroded area (E) must balance the area of deposition (D) and hence R is a function of B, the berm or dune height above the water. This mechanism has been described by Bruun (1962) and others.

If a seawall is introduced (Figure 8d), a portion of the erosion zone (X) is now no longer available to feed the deposition zone. The thickness of the deposition layer will be less and hence the water depth will be greater. Reflection off the seawall, however, causes an increase in depth near the structure adding a volume of sand (Y) to the erosion volume. The total erosion volume with a seawall in place is therefore (E-X+Y). Since Y is normally less than X, as shown for example by Barnett (1988), d' is normally greater than d. Storm surge therefore results in greater water depth near the structure (relative to the raised water level). Similarly, it may easily be shown that the depth increases when S increases.

Tests A,G and D began on the same equilibrium profile. Storm surge increased the depth over the plateau. Larger storm surge resulted in larger depths of water. This in turn permitted larger wave heights to occur over the plateau and interaction with these larger wave heights produced the final profiles.

Tests E,G and F began with different initial profiles; the wave height varied from 9 to 5 cm. The larger wave heights produced a larger runup which means that the seawall was placed relatively further back in Figure 8. This implies that X was smaller and Y was larger, causing (E-X+Y) to be larger and the resulting water depth to be smaller. At the same time to increase the percent of waves impacting the structure from the 1% on the original equilibrium profile the test value of 10% required a larger storm surge for the larger wave heights. This caused the depths to be larger. Here we have two processes which compensated for each other in Tests E,G and F, resulting in the almost constant value of d_p.

The breaker location X_b moved further offshore for the larger wave heights (Table 2). This provided a longer distance for energy dissipation to occur. A calculation using the Kamphuis (1993) modification of the Dally et al (1984) wave dissipation model shows that a distance of 0.3 m is required to reduce the wave height from 9 cm to 7 cm in Test E, and 0.48 m to reduce the wave height from 7 cm to 5 cm in Test G. The actual differences between the breaker locations were found to be 0.3 m for Tests E and G, and 0.4 m for Tests G and F. Thus, a longer breaker distance permitted the higher offshore wave heights to reduce to the same heights close to the seawall, as shown in Figure 7. This resulted in similar depths over the plateau.

The depth of scour to wave height relationship is simple, but physically rather meaningless. Our research (not presented here because of page limits) has shown that scour depth can also be related to the wave climate using energy dissipation and critical shear stress concepts.

To determine whether seawalls accelerate erosion, a comparison with beaches without structures is required. (Kraus, 1988). Long term tests are underway to make such comparisons. Preliminary results indicate that seawalls do not create disastrous increases in erosion rates, but this work is not complete at the present time.

CONCLUSIONS

The equilibrium profile developed in front of the seawall is a complex function of the initial profile, the storm surge, and the wave climate.

The longshore sediment transport rate decreased as the beach eroded in front of the seawall.

The location of the breaker peaks in the longshore suspended and bed load sediment transport rate distribution moved slightly offshore as the beach eroded. The bedload peak in the swash zone disappeared as the foreshore eroded.

The local depth was found to be closely related to the local wave height; the ratio H/d approached a constant value as the beach approached an equilibrium condition. However, average scour depth in front of a seawall can not be simply related to offshore wave height.

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