CHAPTER 110

Perched Beach Profile Response to Wave Action

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Abstract

Wave tank experiments were conducted to investigate the response of a perched beach profile to storm wave attack. Irregular waves having a JONSWAP spectrum were used for all of the test runs. Beach profile erosion was measured initially for a 1:20 slope nourished profile without a toe structure in place. This established base test profiles for comparison with subsequent erosion profiles with a toe structure or sill in place. The subsequent tests with a sill were conducted with the sill placed at a range of depths along the nourished profile slope.

Each of the test conditions was subjected to erosive wave attack for 42 hours with periodic interruptions for measurement of resulting beach profiles. Test results are presented and interpreted to evaluate the effect of the sill structure on beach profile response and the effectiveness of the structure in retaining the beach. Scaling of the results to prototype conditions is also discussed.

Introduction

A common solution to beach erosion problems is to periodically nourish the beach by the placement of sand fill. Often a structure is constructed to compliment nourishment - the structure increasing the stability of the fill to storm wave attack and/or deficiencies in longshore sediment transport. Common types of beach stabilization structures include groins and offshore breakwaters. The perched beach concept is a variation on the use of offshore breakwaters for stabilizing nourished beaches and protecting shore facilities.

A low submerged sill is constructed offshore and parallel to shore. Sand fill is placed landward of the sill, creating the perched beach (see Figure 1). The toe structure retains the perched beach, greatly reducing the

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volume of sand required to nourish the beach. The sill also triggers breaking of the larger waves thereby providing a measure of protection to the shore even if the fill were not in place.

Most commonly, the sill structure would be constructed of a homogeneous mound of stones. A preceeding study (Givler and Sorensen, 1986 and Sorensen, 1987) investigated stability requirements for a submerged homogeneous stone sill structure. This investigation is concerned with the response of a nourished perched beach profile to storm wave attack. It involves two-dimensional wave tank experiments using irregular waves and a sand beach with and without a sill structure in place. Additional information on several aspects of this study are given in Beil and Sorensen (1988).

Research Facility

The experiments were conducted in a 32.7 m long, 0.91 m wide, 0.91 m high wave tank with a programmable spectral wave generator. The wave generator has an absorption capability, i.e. reflected waves are sensed at the generator paddle and subtracted from the primary wave being generated. This capability allows for long term generator operation without the buildup of troublesome reflected waves.

A parallel-wire resistance wave gage was installed 8.23 m from the wave generator and seaward of the toe of the sand beach. Output from the wave gage was recorded in analog form on chart paper and in digital form (0.12 hz) on a portable PC.

Beach profiles were measured along the tank centerline by a point gage mounted on a carriage that moved along the wave tank rails. Gage readings were made at 0.03 m horizontal intervals along the active portion of the beach profile.

The beach was made of a fine, uniformly graded sand having a median diameter of 0.145 mm and a corresponding median diameter fall velocity (Vf) of 0.018 m/s (calculated for 20 degrees C, S.G. = 2.65).

Experimental Set-up and Procedure

The experimental set-up is summarized schematically in Figure 2. All tests were run with a tank water depth of 0.483 m. A bulkhead was installed at a distance of 24.7 m from the wave generator. The sand beach was placed in front of the bulkhead with a berm crest elevation of 0.57 m above the tank floor and extending 2.44 seaward from the bulkhead. The nourished beach face extended sea-

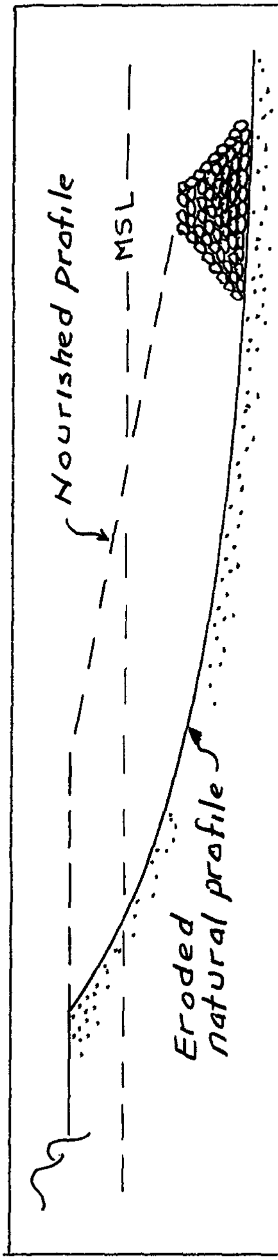


Figure 1- Perched beach concept

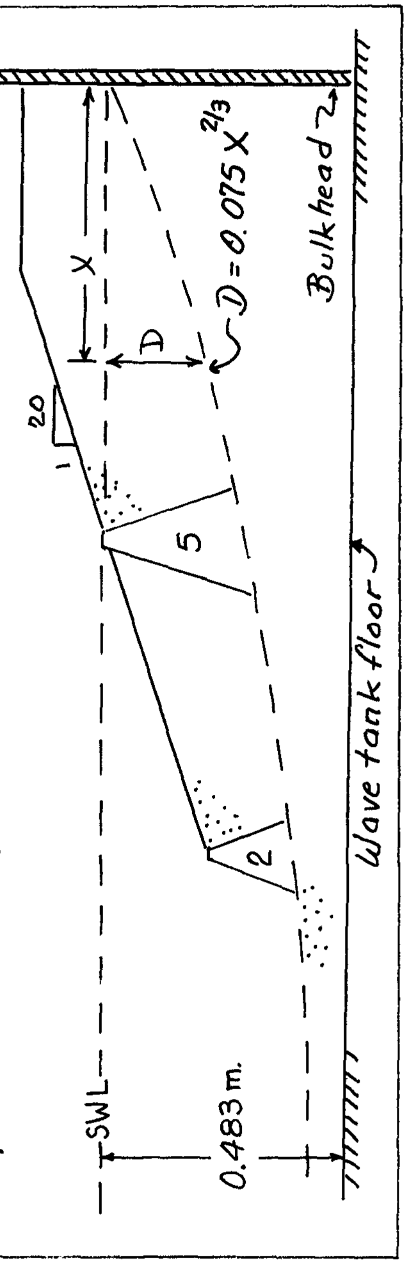


Figure 2- Summary of experimental setup

ward from the berm at a 1:20 slope for all of the tests with and without the sill structure. The 1:20 slope was selected based on a review of recent beach nourishment projects in the U.S. (Hobson, 1981).

The same wave conditions were used for all of the tests. They were JONSWAP spectrum waves with a significant height (Hs) of 0.09 m and a peak period (Tp) of 1.6 sec measured at the toe of the beach slope. These waves yield a fall time parameter (Hs/Vf*Tp) equal to 3.1. Kriebel et al. (1986) show that waves having a fall time parameter in excess of 2.0 to 2.5 should produce an erosive or storm type beach profile. This was confirmed by the resulting beach profile behavior.

Five test cases were investigated (Figure 2). The first consisted of a 1:20 nourished profile without a toe structure. The remaining four cases (2 through 5) were perched beach conditions with a sill located at various depths below the SWL and along the 1:20 beach face slope. The four sill crest depths were 1.0, 0.5, 0.25 and 0 times the incident significant wave height (i.e. 0.091, 0.046, 0.023, and 0 meters below SWL). For the four perched beach conditions, the beach profile seaward of the sill was a typical natural profile (Dean, 1977) as shown in Figure 2.

The sill structure was constructed of plywood with a crest width of 7.62 cm and 1:1.5 front and rear slopes. The seaward slope of the sill was covered with a plastic artificial turf material to reduce wave agitation in front of the sill.

Waves were run for a total of 42 hours for each of the five test cases. After the first six hours of waves the generator was stopped and the beach profile was measured. The profile was measured again at 12 hours, 18 hours, 24 hours, and 42 hours. At the 42 hour time period profile change was still occurring for each test case but the beach had approximately reached an equilibrium condition.

Experimental Results

The experimental data for the five test cases consists of beach profiles for the 0, 6, 12, 18, 24, and 42 hours of wave attack for the selected storm wave condition. Those portions of the measured profiles that are of primary interest are shown in Figures 3A to 3E. The profile for the first case (without a structure) is truncated at the seaward extreme of profile erosion. The profiles for the other cases are truncated a short distance seaward of the structure. These give sufficient scale in the figures to see what changes occurred from the structure to the beach face, the area of greatest interest. The regions seaward of the point of truncation just show successive accumulations of sand tapering seaward.

Table 1 is a tabulation of horizontal retreat distances for the point on the beach profile at the still water line. The distances are measured from the original filled profile position before the start of wave attack and are for the given time intervals. Note that initially (0 - 6 hrs) the retreat is the least for the nonperched profile and increases as the structure crest moves up the profile to the SWL. Also note that the total retreat after 42 hours follows the same pattern, primarily owing to the large early retreat rates. However, after the initial 6 hour period, the retreat rate is reversed for the four perched cases with the retreat rate being minimum from hour 6 to hour 42 for the case with the structure crest at the SWL. It appears that, after the initial adjustment (which could be allowed for in the initial fill placement) location of the sill crest at the still water line results in the least recession of the beach face. Particularly in comparison to the nonperched profile, there is a significant reduction of later retreat with a sill installed near the SWL.

Figure 4 shows the initial fill profile, the 42-hour nonperched profile and the 42-hour perched profile with the sill crest at the SWL. Comparison of these profiles largely summarizes the effect of the sill structure on the resulting beach response and demonstrates the greatly reduced volume of fill required for the perched beach. A larger net volume of sand is transported further seaward for the nonperched condition.

Figure 5 is a summary of the 42 hour profiles landward of the sill structure for each of the four perched beach test cases. The beach face had a consistent slope of 1:5. There was a platform fronting the beach face that had a less consistent slope (but one that did not change with a noticeable trend) of about 1:50. As discussed above, the distance from the sill to the beach face progressively decreased for decreasing submergence of the sill crest as did the depth to the break between the beach face slope and the platform slope.

Scale Effects

The storm wave characteristics employed in these tests were limited largely by the wave amplitude generating capability of the wave generator. This in turn largely dictated the spectral peak period employed so that the resulting wave steepness was similar to typical prototype storm waves. An indication of the scaled prototype conditions represented by these tests can be obtained from

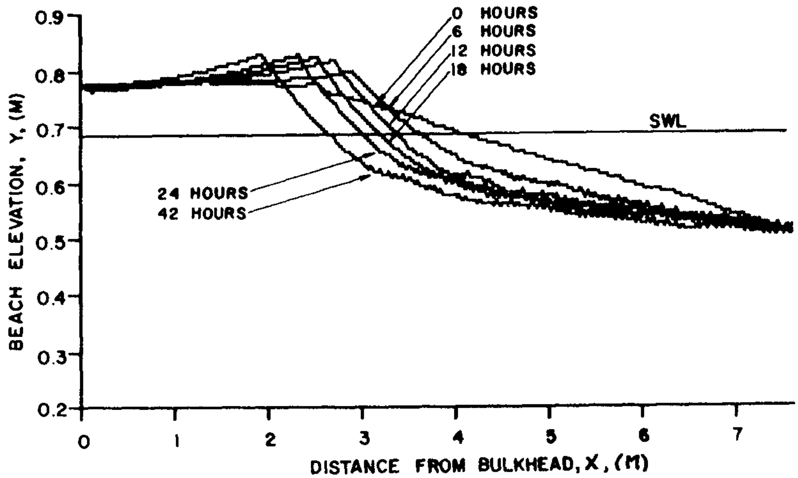


Figure 3A - Nourished beach, no structure.

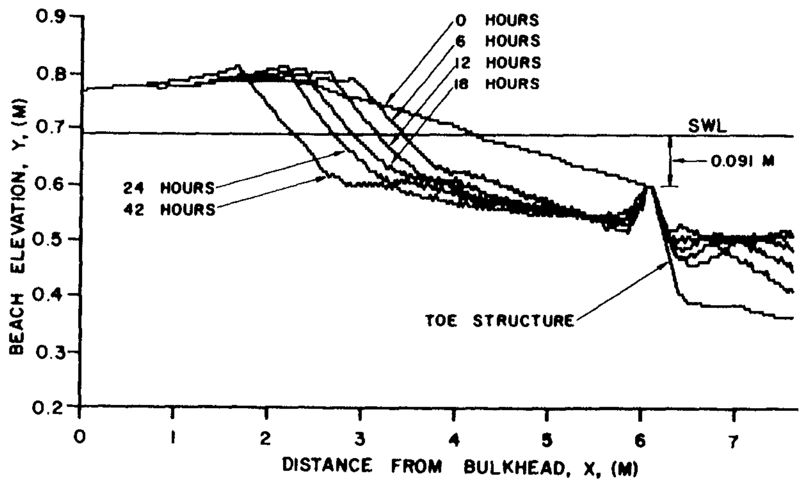


Figure 3B - Perched beach, structure crest depth 0.091 meters.

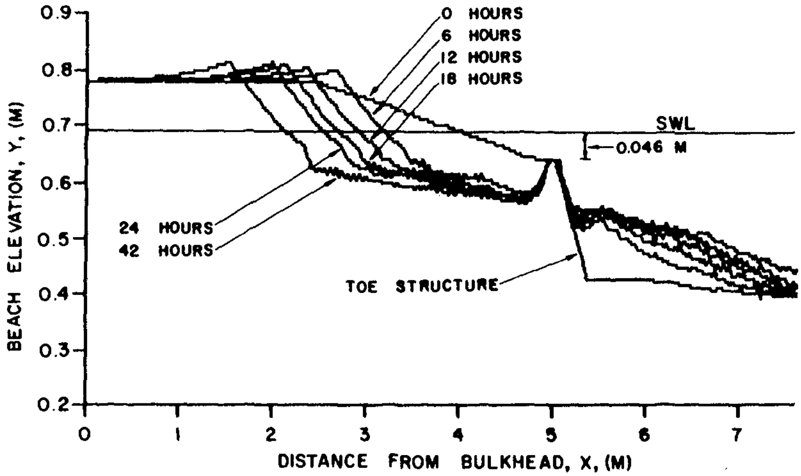


Figure 3C - Perched beach, structure crest depth 0.046 meters.

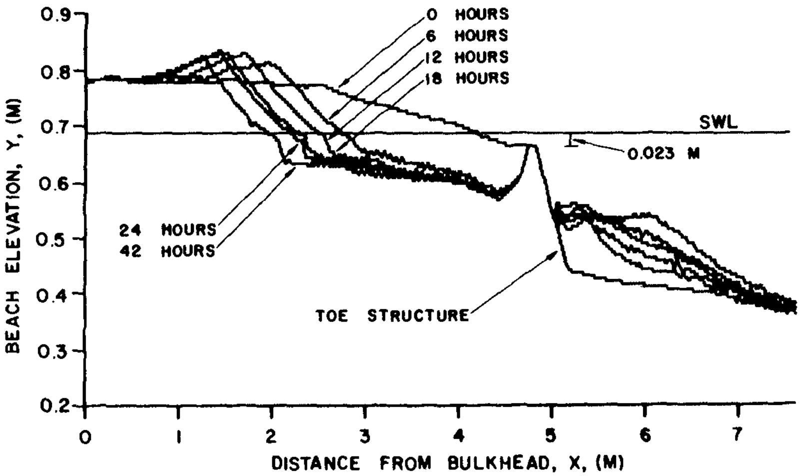


Figure 3D - Perched beach, structure crest depth 0.023 meters.

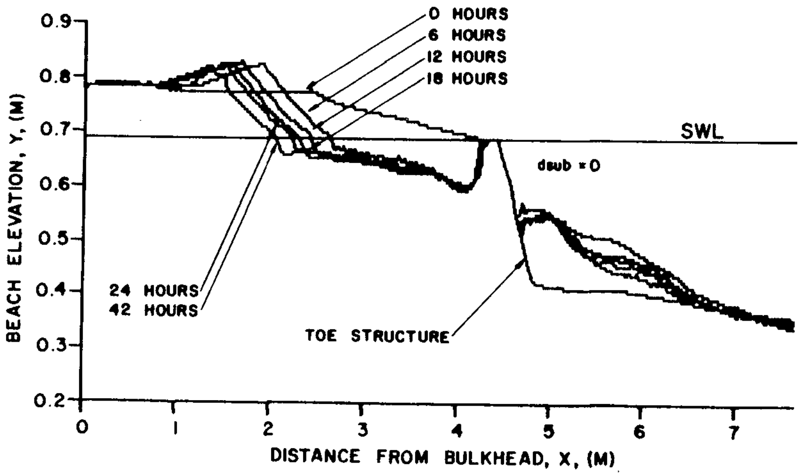


Figure 3E - Perched beach, structure crest depth 0.0 meters.

Test	dsub/Hs	0-6 hrs	6-12 hrs	12-18 hrs	18-24 hrs	24-42 hrs	Total
1	-	.498	.234	.186	.198	.480	1.596
2	1.0	.786	.264	.270	.216	.552	2.088
3	0.5	.816	.258	.222	.162	.552	2.010
4	0.25	1.428	.246	.216	.072	.336	2.298
5	0	1.662	.216	.120	.066	.168	2.232

Table 1 - Retreat of SWL point (meters) for time intervals shown.

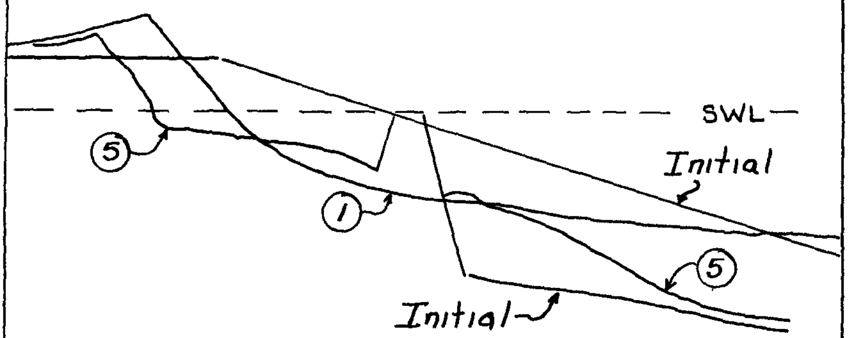
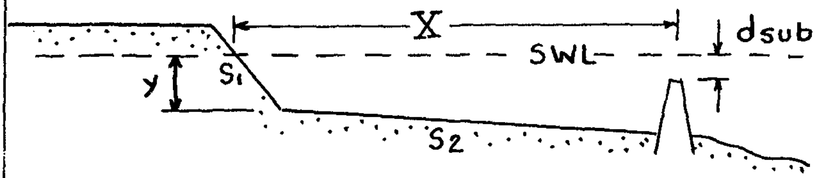


Figure 4 - Initial and 42 hour profiles for Cases 1 and 5



Test	dsub (m)	S_1	S_2	X (m)	Y (m)
2	0.091	0.19	0.015	3.79	0.09
3	0.046	0.19	0.023	3.06	0.06
4	0.023	0.20	0.014	2.78	0.045
5	0.0	0.19	0.023	2.47	0.015

Figure 5- 42 hour profile geometries, for Cases 2 through 5

the recent work of Kriebel et al. (1986). They showed that erosive beach profiles can be scaled using Froude similarity (equal model and prototype Froude Numbers) and equal fall time parameters in model and prototype. With these two criteria, the model profile can be scaled up to prototype dimensions without distortion of profile geometry.

Assuming a prototype median sand diameter of 0.45 mm (Vf = 0.065 m/s) which is typical for beaches on the north shore in New Jersey and the model fall time parameter value of 3.1, along with Froude similarity requirements, yields an equivalent prototype significant wave height of 1.2 meters and a spectral peak period of 5.8 seconds (i.e. length ratio = 13.04, time ratio = 3.61). These values are somewhat low for typical storm wave conditions on the New Jersey shore which would be more in the order of 7 seconds period and 2 meters or more in height. Higher and longer waves than those used in the experiments would likely have resulted in a somewhat flatter beach face slope and more sand loss, in turn resulting in a greater distance between the sill and the beach face.

Discussion and Conclusion

The experiments presented herein are for only one wave condition and thus do not provide the range of data needed for the design of a perched beach under various conditions. However, the results suggest that a perched beach with the sill crest near the still water level can be an effective concept for beach nourishment under appropriate conditions - for example, where there is a steep offshore slope or a narrow shelf width. Significantly less fill volume is required with a sill in place and offshore losses should be reduced. So, a perched beach may be cost effective for many locations. Additional data, covering a much wider range of conditions, are needed.

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