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EVALUATION OF A CONCRETE BUILDING BLOCK REVETMENT.(U)
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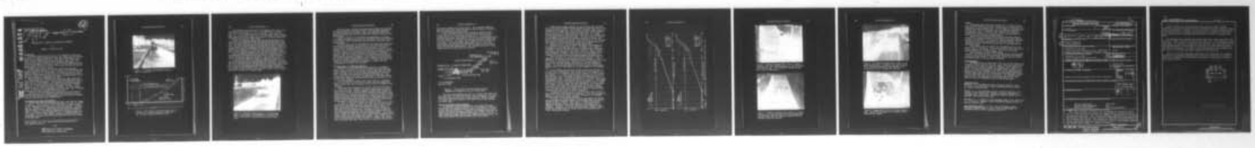

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EVALUATION OF A CONCRETE BUILDING BLOCK REVETMENT

by

MICHAEL L. GILES*, AM, ASCE

Introduction

This paper presents the results of a two-dimensional laboratory evaluation of a beach revetment plan that uses common concrete building blocks as the revetment armor unit. This type of revetment is appropriate for use along semi-protected shorelines of bays, reservoirs, lakes and other areas exposed to low to moderate wave attack. The research was conducted at prototype scale in the two-dimensional Large Wave Tank (LWT) facility at the U.S. Army Coastal Engineering Research Center (CERC), Ft. Belvoir, Virginia.

Several methods now exist which can be utilized to protect eroding shorelines, but they are usually costly and installation often requires special skills and equipment. Therefore, to aid the owner of property situated along a sheltered coast in the selection and installation of a shoreline protection plan, common concrete building blocks have been evaluated as revetment armor units.

The building block revetment was tested using wave, beach, and water level conditions similar to those a property owner would face in construction of the revetment. The revetment was evaluated to determine: a) the maximum breaking wave height for which the revetment is effective, b) the nature and cause of revetment failures, c) the extent of toe scour for various wave conditions, d) filter requirements, e) effect of wave overtopping of the revetment, and f) the ease of installation under simulated field conditions.

Results of this two-dimensional prototype scale evaluation of a concrete building block revetment indicate that the plan as tested could be installed easily by a homeowner and would effectively protect a beach from 0.90 meter high breaking waves.

Experimental Test Setup and Procedure

The building block revetment was evaluated in the CERC LWT, shown in Figure 1. This facility is 193.5 meters (635 ft.) long, 6.1 meters (20 ft.) deep, and 4.5 meters (15 ft.) wide and is capable of generating a 1.8 meter (6 ft.) high wave at the wave generator. The revetment was constructed on a graded beach section having the dimensions shown in Figure 2. The beach was composed of 0.4 mm sand placed to form a 1 on 5 beach slope, fronted by a 1 on 15 foreshore slope, with a 3.5 meter (11.5 ft.) water depth. Heights of breaking waves were determined by reading crest and trough elevations from scales painted on the tank walls.

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Figure 1. A 1.8 meter wave breaking on the sand beach in the CERC LWT.

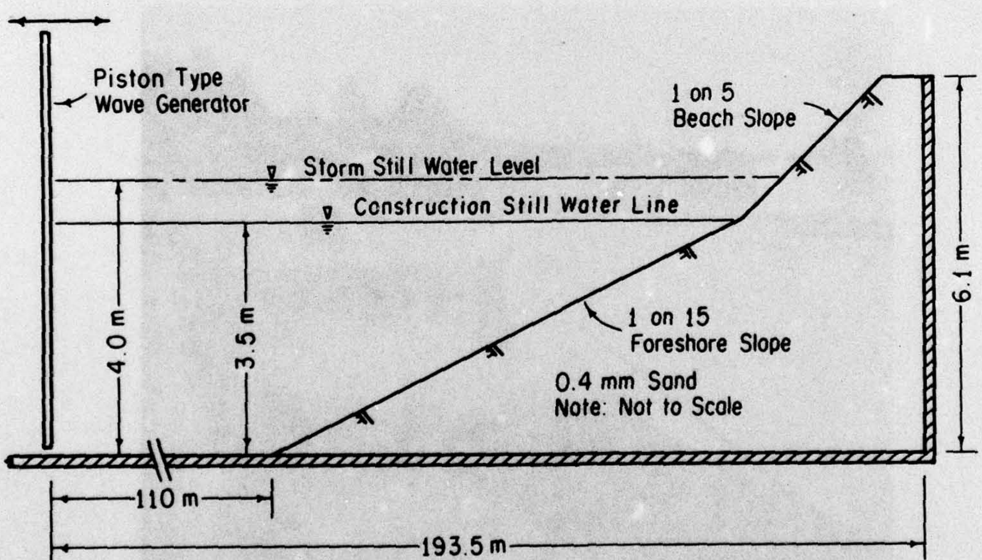

Figure 2. Cross section of 0.4 mm sand beach test set up in the LWT. Protection schemes are installed on the 1 on 5 beach portion of the test section.

The revetment evaluation tests were conducted with a tank still water depth of 4.0 meters (13.1 ft.). The additional 0.5 meter (1.6 ft.) of water depth was used to represent a storm setup of 0.1 meter (0.3 ft.) and a 0.8 meter (2.6 ft.) tide range. This increased water depth also allowed larger wave heights to be tested than would be possible with the 3.5 m water depth.

Before the revetment plan was constructed and tested the unprotected beach was subjected to the same wave height and period conditions that would later be used to evaluate the building block revetment. The resulting beach profile was measured to allow a comparison of the behavior of the unprotected and protected beaches in order to determine the degree of protection afforded by the revetment plan for eroding beach conditions. In all cases the unreveted beach eroded back to form a flatter slope and scarp condition as shown in Figure 3.

These revetment evaluation tests used wave conditions which are representative of storm waves that could occur in fetch and depth limited areas such as bays and estuaries. Wave periods of 3.5, 4.6, and 6.0 seconds were chosen as typical of these storm conditions.

Initially, for each of the three wave periods tested, 0.5 meter high incident waves were run continuously for three hours. Then with the period remaining fixed, the wave height was increased approximately 20 cm (0.65 ft.) and waves were generated for another three hours. This procedure was continued until a 1.8 meter breaking wave height was reached, or the revetment failed beyond the point at which repairs could easily be made by a property owner.

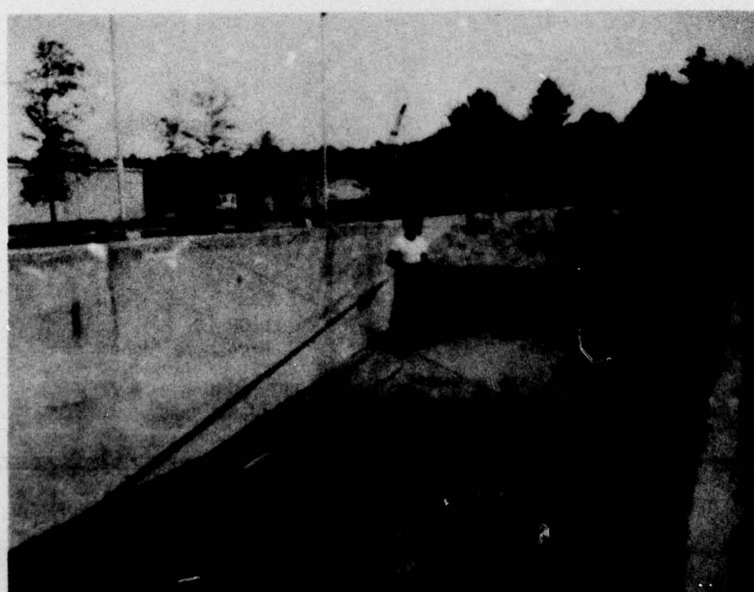

Figure 3. Results of wave action on a 1 on 5 eroding beach. The original 1 on 5 beachline is shown by the line on the tank wall connecting the scarp and water line.

During the test, incident and breaking wave heights were measured by visual observations and observations of the revetment response to the breaking waves were recorded. After each three hour period the beach and revetment profile was surveyed and revetment conditions were photographed.

Since the revetment was evaluated two-dimensionally, no effect of longshore transport or currents was considered during the evaluation. Also, because of the limitations of the tank width, end effects were not evaluated.

Since the waves were run continuously for a given wave height and period, wave reflections from the beach for very steep waves caused the incident and breaking heights to vary with time. In natural settings, this reflected wave from the beach would continue to travel offshore. However,in the wave tank this wave was re-reflected,combining at varying phases with the generated wave to produce a beat wave pattern. When this situation occurred, the breaking wave heights and resulting wave runup were irregular. The effect on the test results was minimal except that overtopping of the revetment occurred that may not occur for similar conditions in nature. This beat type wave also caused the offshore topography to become very irregular and less representative of natural bar formations.

Building Blocks as a Revetment Material

Advantages of using concrete building blocks as a revetment material are: the blocks are readily available from local building supply companies, they are low in cost (usually less than fifty cents each), and they can be installed without the need for skilled labor. Also, a revetment constructed with building blocks does not limit recreational access to the water, and each cell in the blocks offers an area where vegetation can become established and increase the stability of the revetment.

The Shore Protection Manual (1977) shows that for a protection scheme to be effective, three distinct parts--the armor protection layer, a stable toe, and an effective filter--must be included in the revetment.

McCartney (1976) suggested that the most effective toe design is one in which the toe is placed in as great a water depth as possible and covered with sand. Several attempts to develop and construct an effective toe in the LWT which could be installed by one person using common hand tools, indicated that the toe could not be placed in water depths greater than fifteen centimeters, or effectively buried in sand. An apron toe formed by placing three rows of sand-cement bags out to a depth of fifteen centimeters was found to be the most effective type of toe capable of being constructed by a property owner.

A filter is required to prevent the beach sand from being pulled through the armor protection layer and at the same time to allow the water which accumulates behind the structure to drain freely. For major construction works the filter system is usually composed of multilayers of well-graded stone. This type of filter is expensive and its construction requires strict tolerance procedures which are usually beyond the capability of a small property owner. As an alternative, commercially available filter cloths provide an adequate filter system at less cost than graded stone filters. These filter cloths can be installed easily by one or two people. However, some caution must be employed when using filter cloths to insure that they are not torn during placement of the armor units. Also, Barrett (1966) has shown that armor units should be placed so that differential settling does not overstress the filter cloth.

A beach revetment employing the modified toe design, plastic filter cloth (Poly-Filter X) and concrete building blocks was constructed on the 1 on 5 sand slope (see Figure 4). Each concrete building block weighed approximately 15 kg (33 lbs.) and was placed with the cells facing up. Initially, an apron toe consisting of three rows of 31.8 kg (70 lbs.) sand-cement bags, stacked to form a pyramid, was constructed. Each bag, having a sand-cement ratio of 4 to 1, was placed while the sand-cement mixture was still soft so that the bags would interlock when they hardened. This revetment plan costs on the average of $6.50 a square meter for materials.

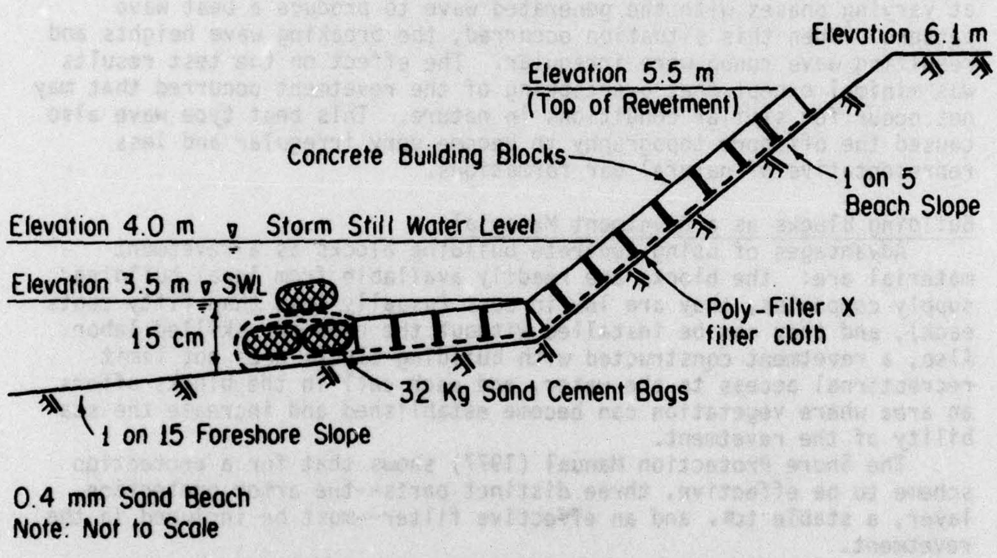

Figure 4. Cross section of concrete building block revetment as installed on the 1 on 5 beach slope.

The top of the revetment was built to 1.5 meters above the storm mean water level to reduce the chance of wave overtopping. The block cells were turned up to provide a rough surface to reduce the height of the wave runup and to assist in the return flow of water through the filter cloth.

Results of Building Block Evaluation

A comparison of runup elevations on a sand beach with those obtained with the revetment showed little or no decrease in runup elevations when the concrete block cells were filled with sand or water. However, with the occurrence of damage to the revetment resulting from beach consolidation and bridging of the blocks to form a void, the water would drain freely from the cells between successive runups. This effect would reduce the runup elevation up to fifty percent.

Breaking wave heights obtained for the building block revetment were on the average eighteen percent higher than those obtained for the unprotected beach condition. The increase in breaker height caused the formation of a steeper, more distinct, plunging wave on the revetment toe as compared to the unprotected beach conditions. This larger breaking wave tended to cause scouring at the toe of the revetment that was not apparent during the beach tests. This can be seen in Figure 5 by comparing the protected and unprotected profiles at Station 160, which is the revetment toe location. Also (see Figure 5), for the same wave conditions the break point bar tends to be in approximately the same location for both a protected and unprotected beach.

During testing of the 6.0 second wave period the revetment was overtopped for nine consecutive hours. No damage to the revetment resulted even though the upper portion of the beach berm (above elev. 5.5 meters, Figure 5) was set back about 3 meters to form a sloping beach behind the revetment. The reason little or no damage occurred to the revetment was that the water did not accumulate behind the revetment but ran back down the revetment between overtopping waves.

After each test for a given wave height and period, a level of damage was assigned by visual inspection of the revetment. Little difference in the extent of damage was observed for the same wave height at 3.5 and 4.6 second periods. However, less revetment damage was observed for the same breaking wave height at the 6.0 second wave period. This was probably because the shorter periods formed steeper breaking waves that would impact on, or just seaward of, the revetment toe.

Typical damage resulting from minimum breaking wave heights for various levels of damage are shown in Figures 6-9. No damage or loss of integrity to the revetment occurred for 0.90 meter or less breaking wave heights. A 1.1 meter breaking height caused scouring at the toe and resulted in minor toe damage (Figure 6) by displacing several of the sand-cement bags. Breaking wave heights of 1.30 meters caused some displacement of the concrete block armor units (Figure 7). This damage resulted from previous toe damage or beach consolidation due to either wave action or return seepage from wave overtopping. At a wave height of 1.5 meters the armor units were displaced and the beach slumped (Figure 8) so badly that the revetment could not be easily repaired. For a 1.65 meter breaking wave height the revetment no longer offered protection from wave action, as shown in Figure 9.

If damage was going to occur, it would develop within the first hour of testing a given height and period wave. Also, while conducting tests with a given wave period, no repair was made to the revetment between successive wave height increases.

The tests also indicated that once the sand-cement bags forming the toe had been disrupted, damage to the revetment would increase as the wave heights increased. Also, once a 1.3 meter breaking wave height was reached, little reserve stability (see Ahrens, 1975) remained since smaller waves could continue to cause damage to the revetment. Therefore, if the toe could be buried or placed in deeper water, the revetment plan, as tested, would be more effective for larger breaking wave heights.

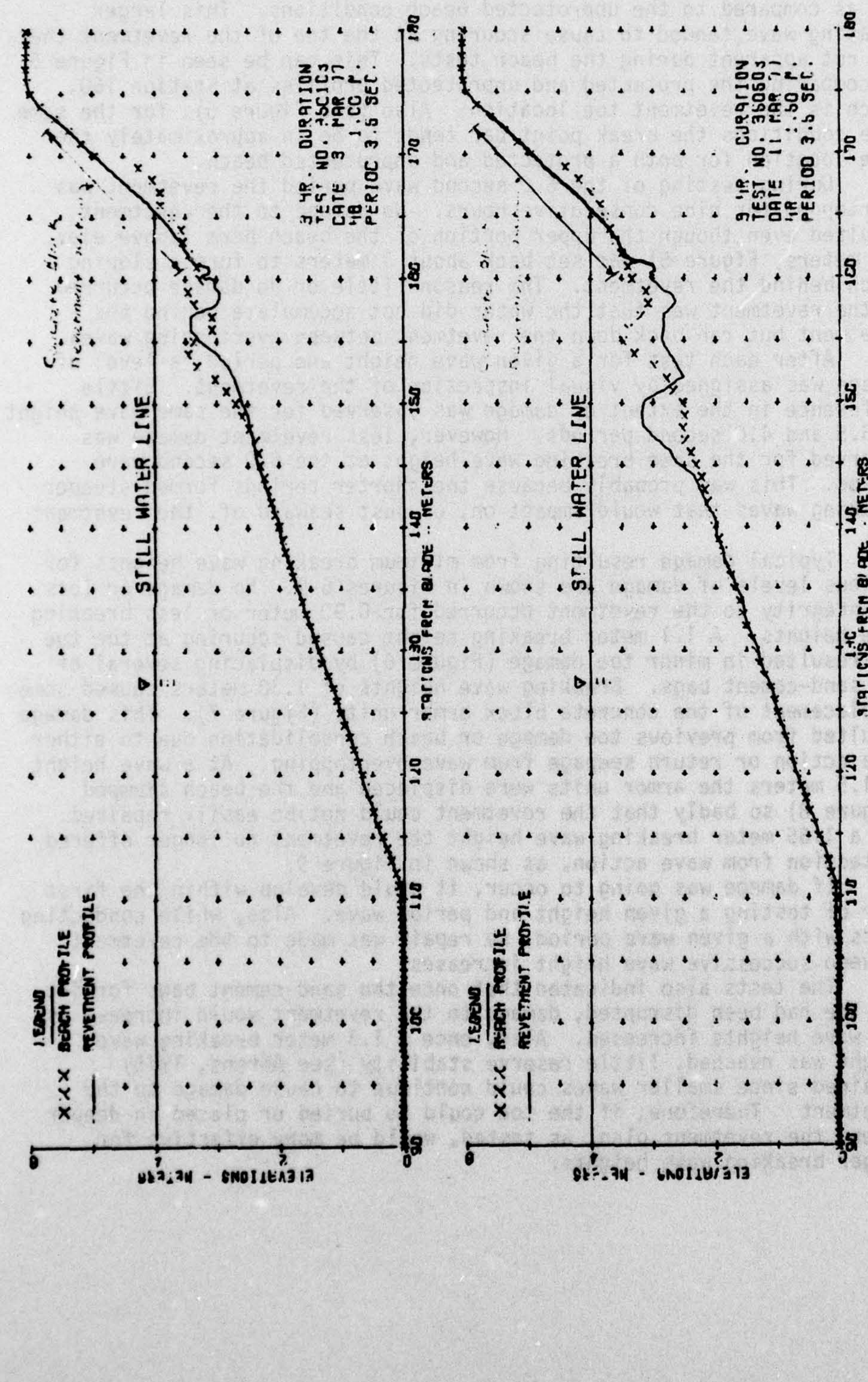

FIGURE 5 - COMPARISON OF UNPROTECTED AND PROTECTED BEACH PROFILES

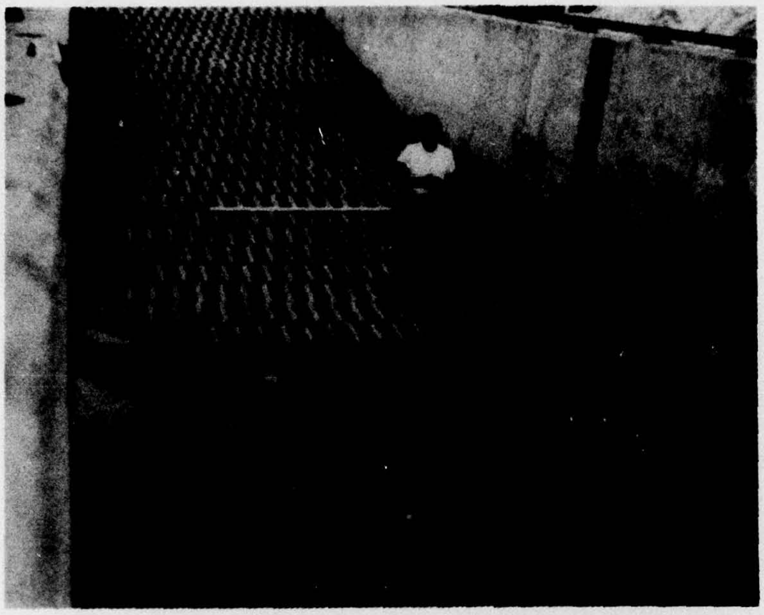

Figure 6. Example of damage level 1 for a 1.1 meter breaking wave. Note the displacement of the sand-cement bags below the SWL. (The storm SWL is marked by the white line in each photo.)

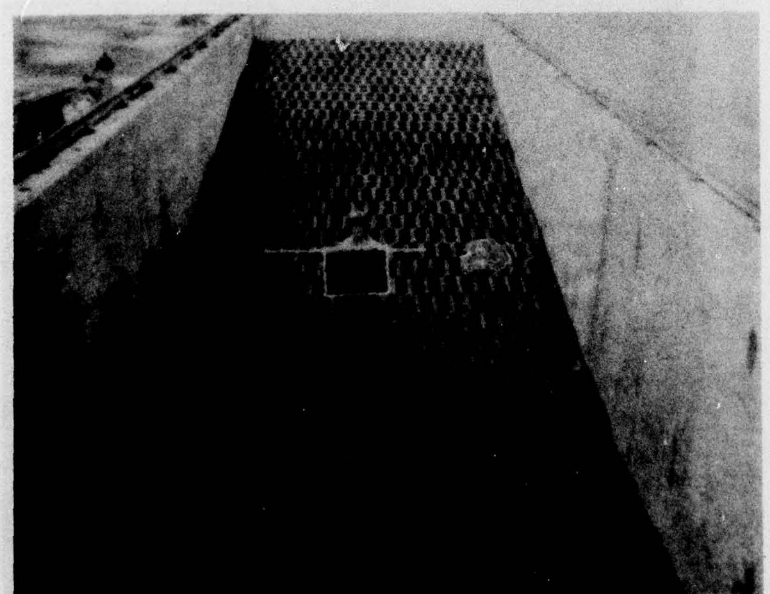

Figure 7. Example of damage level 2 after a 1.3 meter breaking wave. Note that most of the sand-cement bags have been displaced and slumping of the first row of concrete blocks has occurred.

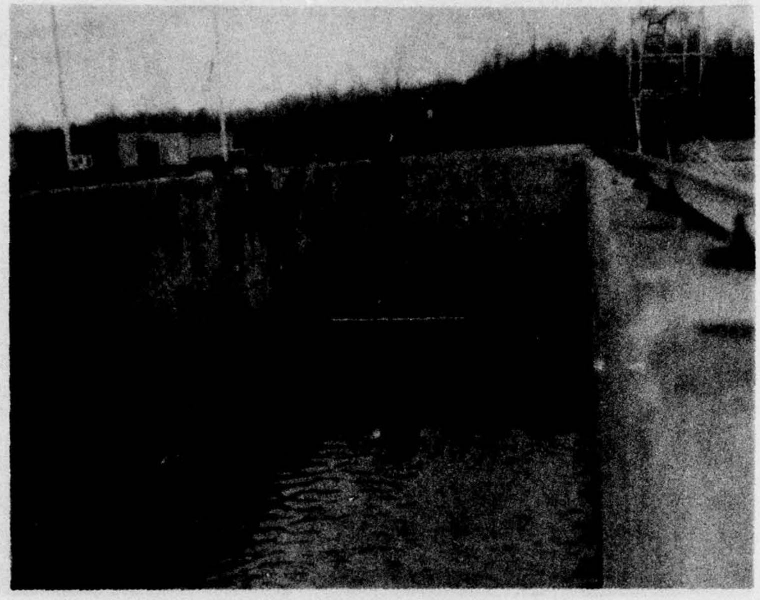

Figure 8. An example of damage level 3 after a 1.50 meter breaking wave. Portions of the lower building blocks have been removed and some slumping to the upper portion of the revetment has occurred.

Figure 9. Damage level 4 after a 1.65 meter breaking wave. Note the displacement of the blocks and the area that has slumped.

Summary

A two-dimensional laboratory evaluation of a concrete building block revetment indicated that the revetment plan as tested could be employed by a small property owner. For no damage the revetment should be used along sheltered shorelines where the breaking wave height is 0.90 meters or less. In addition, the revetment could withstand breaking wave heights up to 1.65 meters with increasing degrees of damage occurring as the wave height increased.

Results of the evaluation showed that the revetment tended to increase the breaking wave height at the shoreline by about eighteen percent on the average. This increase in height should be taken into consideration when planning possible uses for the revetment. Wave reflection and wave runup were about the same for the protected and unprotected beach.

The revetment could be improved by strengthening the toe, the weakest point in the design. This could be done by either burying the toe or extending it into deeper water. This would allow larger breaking wave heights for the no damage level.

When designing a concrete block revetment for a particular beach situation, care should be used to allow for end effects and longshore currents and sand transport. Both of these effects were not investigated here because of the wave tank limitations.

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