CHAPTER 47

WAVE RUN-UP PREDICTION VS. MODEL TEST RESULTS: A COMPARISON

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ABSTRACT

Large-scale physical model test measurements of wave run-up are compared with wave run-up prediction derived from the Shore Protection Manual (SPM). Noteworthy discrepancies between the results of these two methods have been identified that include substantial overestimation of wave run-up elevations using the SPM approach, and computation of roughness coefficient values that vary as a function of wave steepness. The slope armors tested in the study at model scales of 1:3 and 1:4 include linked concrete matting and overlapped gravel-filled fabric bags.

INTRODUCTION

Accurate prediction of wave run-up elevation is an important element in the design of coastal and offshore structures. Should the design process result in a run-up elevation prediction that is too low, serious flooding of the structure work surface may result. Conversely, if the predicted wave run-up is too high, the cost of the structure will be unnecessarily expensive due to the implementation of fill quantities and slope armor that are not truly required. The methods available to predict wave run-up on a particular structure include empirical techniques, such as those set forth in the Shore Protection Manual (U.S. Army Corps of Engineers, 1984), and the performance of a physical model to simulate wave run-up for the structure and oceanographic conditions under study.

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In recent years, we have collected large-scale physical model data of breaking wave run-up. This data can be used to determine the accuracy with which empirical prediction techniques match results from the large-scale modelling efforts.

The objective of this presentation is two-fold:

1) To provide a direct comparison of large-scale physical model study results of wave run-up to estimated values generated from conventional wave run-up prediction techniques as presented in the Shore Protection Manual.

2) To provide large-scale wave run-up values for two relatively obscure shore protection armors--large overlapped gravel-filled bags and linked concrete block matting. These armor types have proven to be useful in providing protection against moderate wave impact at project sites where more substantial materials (quarrystone, large concrete units) are unavailable and/or uneconomical.

LARGE-SCALE WAVE RUN-UP DATA

Figure 1 provides a definition sketch for the wave run-up process. A wave exhibiting an unrefracted deepwater wave height and wavelength (H_o' and L_o) and period (T), impacts a slope having an inclination angle (θ) in a still water depth (d_s). The height of wave run-up (R) on the slope of the structure is measured as a vertical elevation above the still water line (SWL).

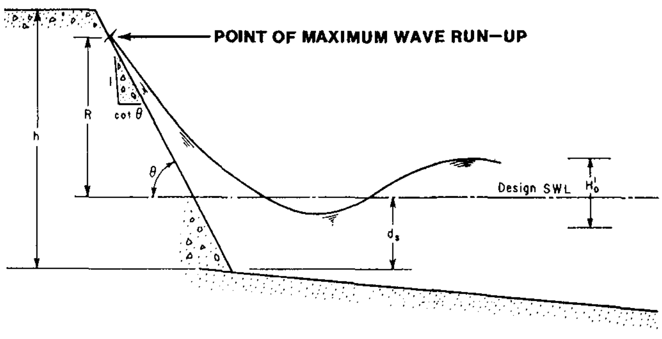


FIGURE 1: WAVE RUN-UP DEFINITION SKETCH

The model tests summarized herein were performed at the Oregon State Wave Research Facility, Corvallis, Oregon, U.S.A., in February-March, 1984. The wave tank is 104 m (340 ft) in length, 3.7 m (12 ft) wide, and the water depth was varied to accurately simulate the 2.5 - 5.2 m (8 - 17 ft) water depth range that was expected to exist at the prototype location. The size of the wave tank allowed the model tests to be conducted at scales of 1:3 and 1:4. Wave heights under study ranged from prototype values of 1.5 - 3.0 m (5 - 10 ft). While both monochromatic and irregular wave trains were studied during the course of the model test program, only the results of the monochromatic breaking wave tests are reported herein. The range of values of the Surf Similarity Parameter (= $\tan\theta \ (H/L_o)^{-1/2}$) exhibited by the waves in this study was 1.1 - 3.5, corresponding primarily to plunging and collapsing breakers.

Wave height in the model test was measured using an acoustic water level profiler secured above the wave tank. A graduated tape was firmly affixed to the slope allowing the investigator to carefully observe the position of the still water level prior to testing, and the elevation of wave run-up. Conventional surveying of the slope allowed a correlation to be developed between each value noted from the graduated tape and the corresponding elevation relative to the still water level.

Slope armors that were tested in the model study included linked concrete matting of two different types, and large gravel-filled fabric bags (prototype bag weight = 6,000 kg (13,200 pounds)). These armor types have been extensively used in the Alaskan Arctic offshore, the site of the structure under consideration (Gadd, 1988; Leidersdorf, 1988). In addition, gravel bags and concrete matting have been studied and utilized in moderate wave climates in more temperate areas of the world (Breteler, et al., 1988; Heerten, et al., 1988; for example), where more durable armor types are unavailable, too costly, or inappropriate due to the temporary nature of the slope protection required.

The concrete mat exhibits a very smooth slope surface, interrupted only by the regular voids at the spaces between adjacent blocks. The gravel bag slopes exhibit a substantial bag overlap of 50% of the bag length. The resulting slope is "stair-stepped", a cross-section that is effective in dissipating wave run-up. Both armors studied were placed on permeable filter fabric overlying a smooth gravel slope inclined at an angle of 1V:3H (18.4^{o} from horizontal).

CONVENTIONAL WAVE RUN-UP PREDICTION

In the absence of physical model study data collected for a particular structure and ocean environment, the coastal engineer must rely on predictive techniques developed for more generalized structures and oceanographic conditions. While numerous methods exist world-wide for this engineering task, perhaps the most popular means in the United States is the use of the wave run-up diagrams presented in the Shore Protection Manual (SPM). The basis for the methods presented in the

SPM are the numerous model tests of wave run-up undertaken by the U.S. Beach Erosion Board in the 1950's. These studies dealt only with the idealized conditions of monochromatic waves impacting structures in which the slopes were planar, smooth, and impermeable. The majority of these model tests can be considered to have been performed at "small scale" (typically, model scales of 1:17 or 1:30 were employed) (Saville, 1987).

Wave run-up prediction taken from the SPM curves requires computaion of the wave steepness parameter, H_o'/gT^2. The value of the wave run-up elevation, R, for a particular structure slope angle and wave steepness parameter is given in the SPM for relative depth values, d_s/H_o', of 0.0, 0.45, 0.8, 2.0, and $\geq$ 3.0. The family of curves given for a relative depth $\geq$ 3.0 is shown in Figure 2. As dictated by the SPM, wave run-up values taken from these curves require modification to account for scale effect and slope roughness and permeability prior to establishing the predicted run-up value.

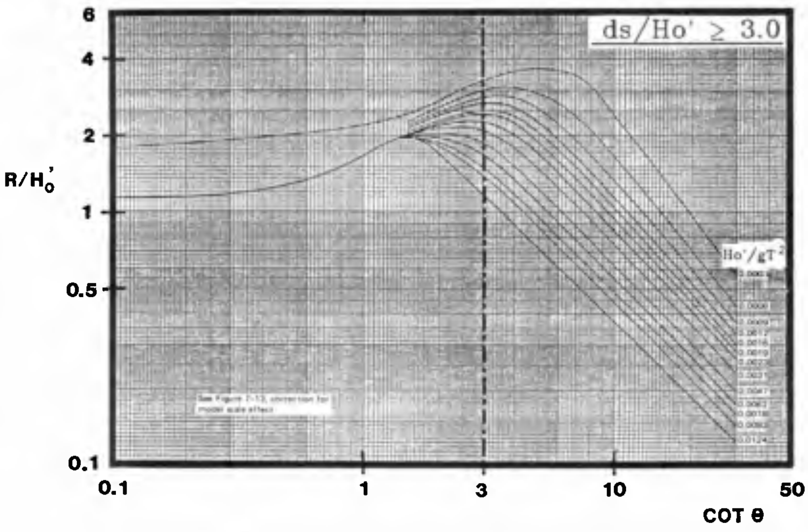


FIGURE 2: EXAMPLE OF SPM RUN-UP CURVES

The scale effect correction prescribed for use in the SPM is presented in Figure 3. This relationship that indicates an increasing scale effect with increasing structure slope was developed using limited test data collected at three values of structure slope: 1:3, 1:6, and 1:15. A description of the large-scale testing and the rationale supporting the selection of this scale effect correction has been recently presented by Saville (1987).

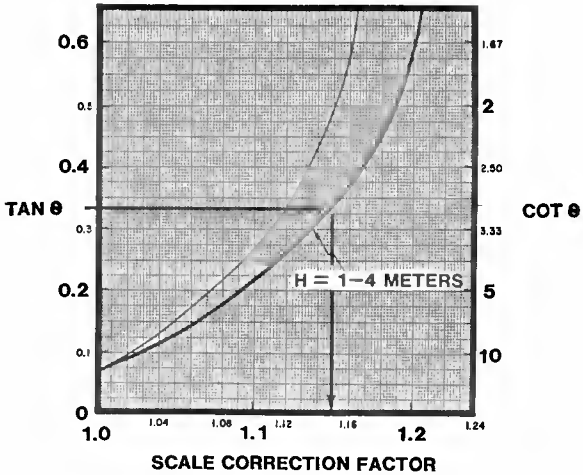


FIGURE 3: SPM RUN-UP CORRECTION FOR SCALE EFFECTS

The wave run-up reduction from the SPM curves necessitated by slope roughness and permeability is expressed by the "roughness coefficient", r. Based on research by Battjes (1974), the SPM specifies an individual value of "r" for a variety of armor types, as indicated in Table 1. As is evident, the maximum value of run-up coefficient for a permeable slope is 0.9, given for concrete blocks. For highly permeable quarrystore slope armor, the SPM suggests that the roughness coefficient can be as low as 0.45. While no value is given in the SPM for gravel bag armor, we presume that the value given for rounded quarrystone (r = 0.60 - 0.65) is most appropriate for use in the comparison presented herein.

TABLE 1: ROUGHNESS COEFFICIENTS FOR VARIOUS ARMORS

Slope Surface Characteristics	Placement	r
Smooth, impermeable	------	1.00
Concrete blocks	Fitted	0.90
Basalt blocks	Fitted	0.85 to 0.90
Gobi blocks	Fitted	0.85 to 0.90
Grass	------	0.85 to 0.90
One layer of quarrystone (impermeable foundation)	Random	0.80
Quarrystone	Fitted	0.75 to 0.80
Rounded quarrystone	Random	0.60 to 0.65
Three layers of quarrystone (impermeable foundation)	Random	0.60 to 0.65
Quarrystone	Random	0.50 to 0.55
Concrete armor units (~ 50 percent void ratio)	Random	0.45 to 0.50

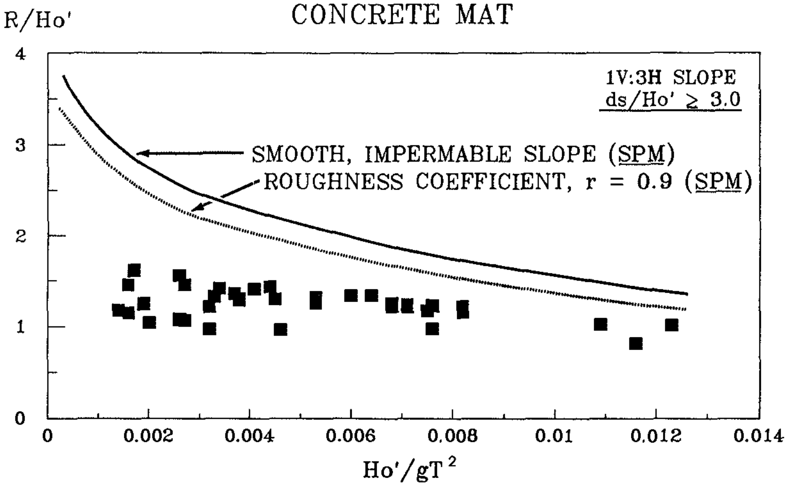
COMPARISON OF RESULTS

A number of figures have been prepared to illustrate the comparison between the predicted run-up values as determined by the SPM techniques and the actual data measured in the physical model study performed at scales of 1:3 and 1:4. As is the case in the SPM, the relative run-up (R/H_o') is plotted against the wave steepness parameter, H_o'/gT^2. All of the data collected represents the single side slope value of 1V:3H (18.4^o from horizontal).

Concrete Mat Armor

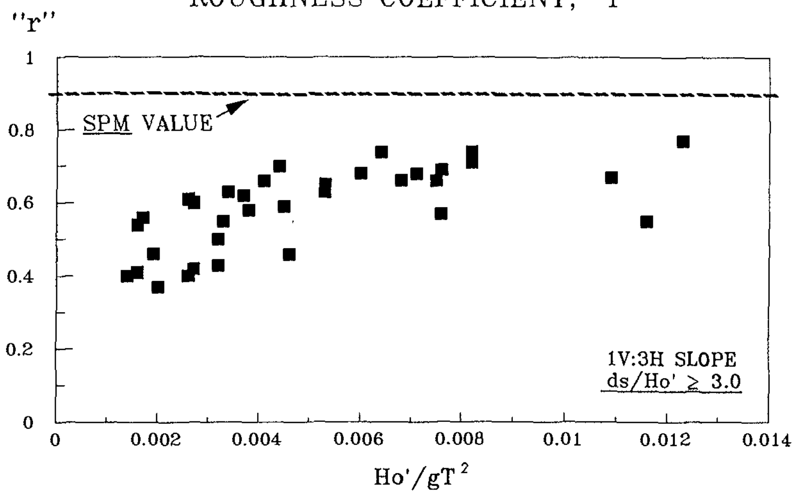
Figure 4 shows the wave run-up diagram for linked concrete mat armor and a relative depth, d_s/H_o', greater than or equal to 3.0. The solid curve indicates the smooth slope SPM prediction with the scale effect correction applied. A constant roughness coefficient, r = 0.9, is applied to the smooth slope curve to yield the dotted curve which represents the SPM run-up prediction for concrete mat armor. As is evident, the measured data lies below the predicted curve. As the wave steepness parameter, H_o'/gT^2, decreases, the discrepancy increases between the SPM prediction and the measured data. Indeed, for small values of wave steepness parameter, the SPM technique overpredicts the wave run-up elevation by nearly 100% relative to the model test data.

FIGURE 4:
WAVE RUN-UP
CONCRETE MAT



A determination of the measured roughness coefficient, r, for each data point has been plotted as a function of wave steepness parameter in Figure 5. While the SPM methods suggest a constant "r" value of 0.9 for the concrete mat, the data indicates that the value of "r" varies from 0.4 to 0.8 over the range of wave steepness that was tested. While scatter does exist in the data, it seems clear that the SPM overpredicts wave run-up relative to the data measured, and the roughness coefficient, "r", increases with increasing wave steepness.

FIGURE 5:
CONCRETE MAT
ROUGHNESS COEFFICIENT, "r"



Figures 6 and 7 are presented to show wave run-up and roughness coefficient characteristics for the concrete mat armor for relative depths, d_s/H_o', of approximately 2.0. While both the predicted wave run-up and the measured data are marginally larger for this case, a similar trend is indicated as that noted previously for the value of relative depth, d_s/H_o', $\geq$ 3.0. In this case, the value of the roughness coefficient, r, suggested by the SPM (r = 0.9) fits the data for values of the wave steepness parameter, H_o'/gT^2, that exceed 0.011. Below this value, however, "r" decreases to as low as about 0.4.

Overlapped Gravel Bags

For gravel bag armor, similar trends exist as those noted previously for concrete mat armor. To predict wave run-up using the SPM approach, we have selected a roughness coefficient value of 0.60 from the SPM to typify the gravel bag slope. Due to the irregular nature of the gravel bag armor, a greater degree of data scatter is indicated than that seen previously for the concrete

FIGURE 6:
CONCRETE MAT WAVE RUN-UP

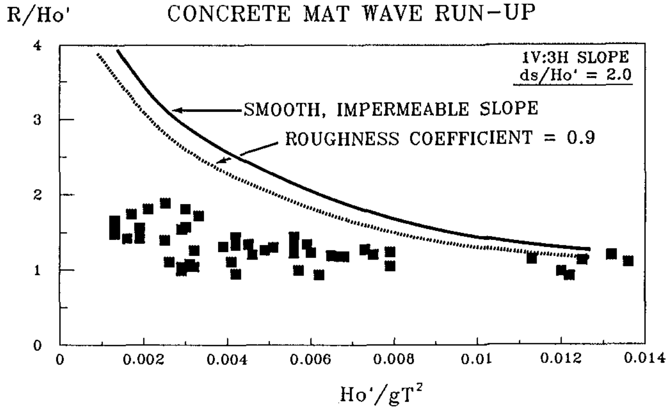
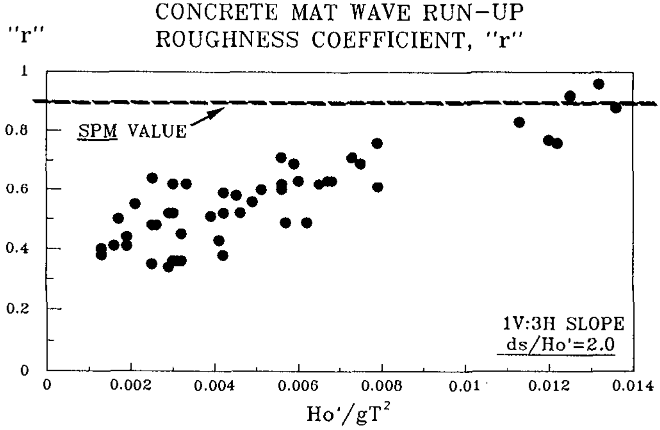


FIGURE 7:
CONCRETE MAT WAVE RUN-UP
ROUGHNESS COEFFICIENT, "r"



mat. In Figure 8, for the relative depth value, $d_s/H_o' \geq 3.0$, most of the data falls below the SPM prediction, although the trend of the data appears to suggest that the SPM methods represent an upper bound for the model test results. Figure 9 indicates that the roughness coefficient value for this case appears to be less dependent on wave steepness with a constant value of 0.45 being applicable. Should a greater degree of conservatism be desired, a value of "r" of 0.60 is a reasonable choice.

FIGURE 8:
WAVE RUN-UP
OVERLAPPED GRAVEL BAGS

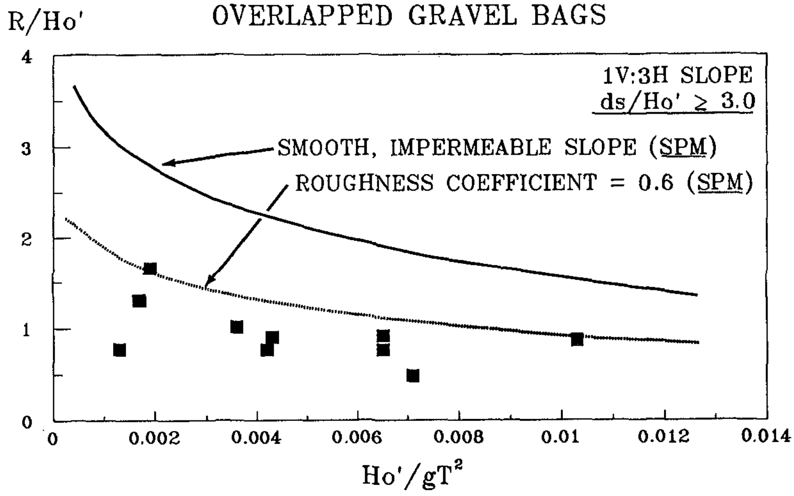
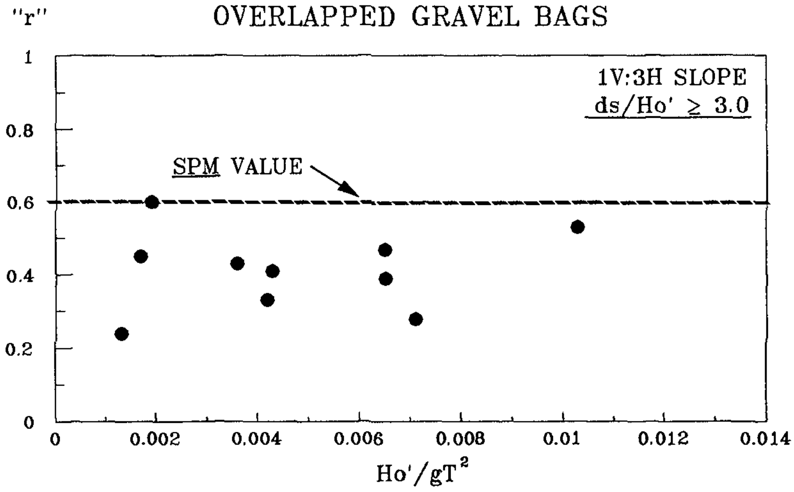


FIGURE 9:
ROUGHNESS COEFFICIENT, "r"
OVERLAPPED GRAVEL BAGS



As shown in Figure 10, in which the relative depth value is approximately 2.0, the gravel bag slope again indicates overprediction of wave run-up using the SPM methods, however, the functional dependence on wave steepness is not clearly defined. A constant value of "r" of 0.50 seems to be applicable to gravel bag slopes for this relative depth value, as shown in Figure 11.

FIGURE 10:
WAVE RUN-UP
OVERLAPPED GRAVEL BAGS

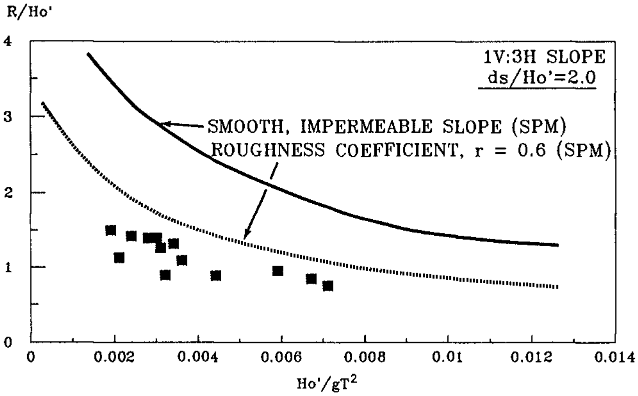
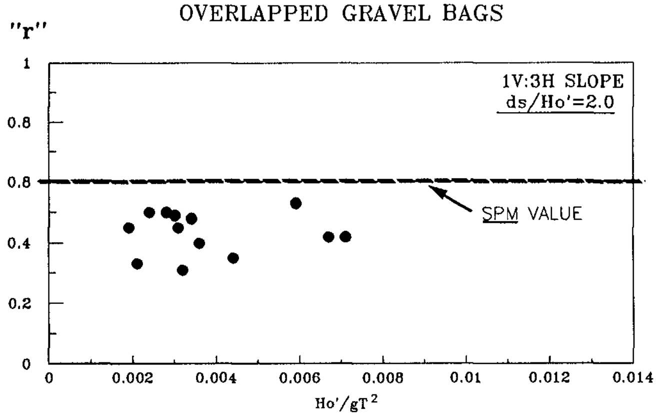


FIGURE 11:
ROUGHNESS COEFFICIENT, "r"
OVERLAPPED GRAVEL BAGS



CONCLUSIONS

For two specific slope armor types, overlapped gravel bags and linked concrete matting, comparison of measured data from large-scale physical model studies with wave run-up prediction methods presented in the SPM suggests the following:

1) The SPM predictive methods overpredict wave run-up. Particularly in the case of concrete mat slope protection, the degree of discrepancy between the results of the SPM methods and the measured data appears to be dependent on the wave steepness. For small values of the wave steepness parameter, H_o'/gT^2, the measured data is on the order of one-half of the predicted value.

2) For concrete mat armor, a variable roughness coefficient, "r", is indicated. The value of "r" varies from about 0.4 for H_o'/gT^2 = 0.002, to 0.9 for $H_o'/gT^2 = 0.13$.

3) Because no value of roughness coefficient for overlapped gravel bags is given in the SPM, it is not possible to precisely judge the predictive accuracy of the SPM for this armor type. Use of an "r" value of 0.6 (suggested by the SPM for rounded quarrystone) slightly overpredicts wave run-up for gravel bag armor. The discrepancy between the predicted and measured run-up values is not as great as that noted for concrete mat armor. Unlike the results of the concrete mat research, the roughness coefficient for gravel bags does not appear to be strongly dependent on wave steepness. Selection of a constant roughness coefficient of 0.5 - 0.6 for overlapped gravel bag armor seems appropriate over the range of our experimental data.

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