# REMR Technical Note CO-RR-1.3

(Supersedes CO-RR-1.3 1986)

# Reduction of Wave Runup on a Revetment by Addition of a Berm

## Purpose

To provide design guidance for reducing wave runup on a riprap revetment by the use of a riprap berm fronting the revetment.

## Background

Numerous factors, including rising water levels, increased wave activity, or additional property development behind the revetment, may make it necessary to reduce the height of runup on an existing riprap revetment. One method for reducing the runup is to construct a berm in front of the revetment to disrupt the wave action and absorb a portion of the wave energy. A series of wave flume tests was conducted at the Waterways Experiment Station to quantify the influence of various berm profiles on the wave runup.

## Development

A typical profile of a revetment with a horizontal fronting berm is shown in Figure 1. Measurements of wave runup for use as reference values in determining the effectiveness of the berm were collected on a riprap revetment

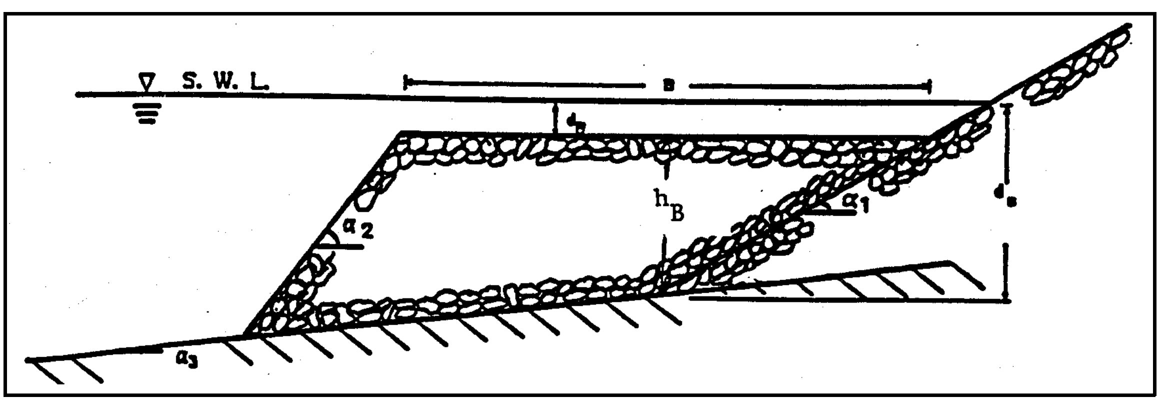


Figure 2. Typical profile of a riprap revetment with horizontal fronting berm

with a plane 1V:2H slope ($\alpha_1$). Additional tests were conducted with a dumped riprap berm fronting the revetment. Two berm widths were tested (B = 0.7 ft and 1.4 ft); each berm was horizontal with a seaward slope ($\alpha_2$) of 1V:1H. The revetment was designed in compliance with the *Shore Protection Manual* (1984) and Engineer Manual 1110-2-1614 (U.S. Army Corps of Engineers 1985). Riprap used to construct the berm was the same size and gradation as the armor layer on the revetment. Slope of the wave flume bottom ($\alpha_3$) was 1V:100H. All tests were conducted with irregular waves using Joint North Sea Wave Project (JONSWAP) spectra (Hasselmann et al. 1973).

It is generally agreed that a berm is most effective when it is near the still-water level (SWL) (Battjes 1974). This test series envisioned that a berm would be constructed near the normal SWL, but higher water levels during design storm conditions would slightly submerge the berm. The tests were therefore conducted with berm depths ($d_B$) of 0.00, 0.10, and 0.20 ft, with depth at the revetment toe ($d_s$) of 0.68, 0.78, and 0.88 ft, respectively.

In analyzing the data, the primary effort was directed toward developing a reliable method of predicting a runup reduction factor, $r$, defined as the ratio of runup on the revetment with a berm to runup on the plane riprap revetment. Analysis was complicated by a high degree of scatter in the data.

This excess scatter is consistent with other investigations, as Battjes (1974) reported large amounts of scatter for the much simpler case of runup from monochromatic waves on a smooth impermeable slope with a fronting berm, and Owen (1982) encountered similar problems in developing an overtopping model for embankment-type seawalls with a fronting berm. Two terms were identified, however, that appeared to account for the observed trends: a berm width parameter and a berm depth parameter.

The berm width parameter was determined as $B/(H_{mo}L_o)^{1/2}$, where $H_{mo}$ is the zeroth moment wave height at the toe of the plane revetment and $L_o$ is the linear wave theory deepwater wavelength given by

$$L_o = \frac{gT_p^2}{2 B} \tag{1}$$

where $g$ is gravitational acceleration and $T_p$ is the period of peak energy density. This parameter may be thought of as a relative roughness parameter which quantifies the ability of the berm to disrupt wave action and runup flow. As wave conditions become more severe, the ability of the berm to interfere with the runup is reduced as the structure becomes hydraulically smoother. A similar berm width parameter was recommended by Battjes (1974).

A berm height parameter was identified as $h_B/d_s$, where $h_B = d_s - d_B$. This term accounts for the difference in the ability of the bermed breakwaters to dissipate wave energy as the height of the berm increases or decreases. Generally, the effectiveness of the berm in reducing runup improved as the wave height increased.

## Method

The reduction factor may be calculated from the equation

$$r = \exp\left[-0.152\,\frac{B}{(H_{mo}L_o)^{1/2}} \cdot \frac{h_B}{d_s}\right] \tag{2}$$

Runup may be calculated by the method presented in Ward and Ahrens (Ward and Ahrens 1993),

$$\frac{R_{max}}{H_{mo}} = \frac{a\,\xi}{1.0 + b\,\xi} \tag{3}$$

where $R_{max}$ is maximum wave runup, $a$ and $b$ are regression coefficients with values of 1.022 and 0.247, respectively, and $\xi$ is a surf parameter defined as (Battjes 1974):

$$\xi = \frac{\tan \alpha_1}{(H_{mo}/L_o)^{1/2}} \tag{4}$$

Approximating the first coefficient as 1.0 and multiplying the equation by the berm reduction factor yields

$$\frac{R_{max}}{H_{mo}} = \frac{r\,\xi}{1.0 + b\,\xi} \tag{5}$$

Note that the berm reduction factor reduces to 1.0 when no berm is present; therefore the equation may be used either with or without a berm.

## Sample Problem

The following example illustrates the use of the reduction factor to design a berm for an existing revetment.

A certain revetment was designed to prevent overtopping during a 50-year storm event, which was predicted to have $T_p$ = 10 sec, $H_{mo}$ = 8 ft, and $d_s$ = 20 ft, including storm surge which raises SWL during the storm event 2 ft higher than current SWL. Built at a 1:2 slope, the revetment had a predicted $R_{max}$ = 22.4 ft. The revetment design allowed some overtopping during extreme events, with expected damages being offset by lower revetment construction costs. Increased development of the land behind the revetment has modified the cost/benefit ratio to the extent that the potential damage is unacceptable and $R_{max}$ needs to be lowered by 2 ft. Determine the dimensions of a berm that will provide the necessary reduction in runup.

Reducing $R_{max}$ to (22.4 - 2.0) 20.4 ft requires a reduction factor of (20.4/22.4) 0.91. If the berm is built at the current water level, the berm height will be 18 ft. Equation 2 may be solved for berm width, yielding

$$B = -\frac{(H_{mo}L_o)^{1/2}\, d_s \ln(r)}{0.152\, h_B} \tag{6}$$

All parameters in the equation are known, and berm width is calculated as

$$B = 44\ ft$$

## Limitations

This technical note presents findings on a limited set of data, and all tests were conducted using a 1:2 plane slope revetment. It is anticipated that the berm reduction factor presented herein is applicable to other revetment slopes, but this has not been tested. Additional information on the test series and results, including effects of the berm on revetment stability, may be found in Ward and Ahrens (1993).

## References

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