

EXTREME WAVE RUN-UP ON STEEP ROCK SHORES

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INTRODUCTION

Rock coasts generally pose a greater risk to humans than sand or pebble beaches due to slippery conditions. This risk is particularly high where the sea floor slopes up steeply towards the shore due to the sudden and unexpected appearance of large waves, which seem completely out of proportion when compared to sea conditions visible to an observer. Such waves may suddenly flood a large portion of the rocks, potentially knocking by-standers off their feet and washing them into the sea during the back rush.

It is well established in the local lore on the Norwegian west coast that sudden large run-up occurs frequently. In particular, long waves of small steepness are able to penetrate the many shoals off the coast without significant energy loss through wave breaking. When these long swells hit the steeply sloping coastal bathymetry, unusually large run-up may occur without any warning (see for example Bjørnstad and Kalisch, 2020). One case, which made international headlines, was the perishing of two members of a film crew in Egersund, Norway after being washed into the sea by a large wave. Investigating the bathymetry near the film set shows a steep 1.5 slope near the shore. An in-depth look at the bathymetry along the Norwegian coast reveals that similar geometries occur in many places. In the present contribution, we use the Boussinesq Ocean and Surf Zone model, BOSZ, (Roeber and Cheung, 2012), a phase-resolving nearshore Boussinesq-type model create a large number of numerical datasets of waves running up on a steep straight slope. We show that the distribution of run-up heights has very heavy tails, indicating that outlying events are more likely to happen on steep slopes than in a traditional probability distribution for gentle slopes.

METHODS

The BOSZ model is used to compute a dataset of wave run-up on a 1/2 and 1/20 slope for 18 sea states based on the empirical spectral function by Pierson-Moskowitz. Each model created a 4-hour data set of wave and run-up conditions without bottom friction for $T_p = 12s, 15s,$ and $18s$, and significant wave heights, H_s , ranging from $0.5m$ to $3.0m$ in $0.5m$ intervals.

Time series were recorded for both an off-shore location and for run-up height. For the offshore signal, a standard zero-crossing segmentation was applied while the run-up data was determined from the maximum elevation of the waterline, from which statistical quantiles were then computed.

RESULTS

The off-shore time series yielded a Rayleigh distribution in wave height as expected. The run-up height for the gentle slope also followed a Rayleigh distribution although less

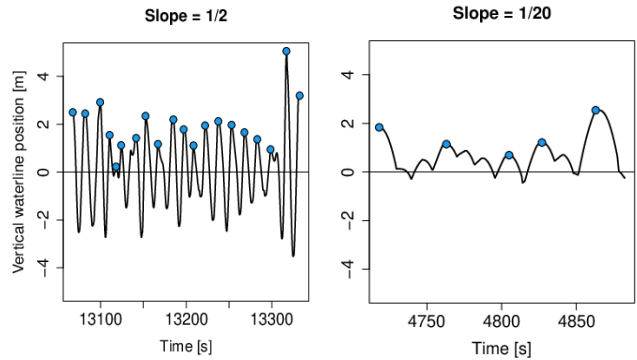


Figure 1 – 400-second data burst of the run-up time series for the steep 1 : 2 slope (left panel) and 200-second data burst for the gentle 1 : 20 slope (right panel) for $H_s = 1.0m$ and $T_p = 15s$. Blue dots indicate the high watermark for each individual run-up. On the steep slope, the maximum of each run-up is higher, and peaks are more frequent. On the gentle slope in the right panel, run-up peaks are less frequent and take more time to build up on top of the wave set-up. The near 5m run-up at ~ 13316 seconds appears exceptional and unexpected given the otherwise lower maximum run-ups of about 2 meters in the time series on the left.

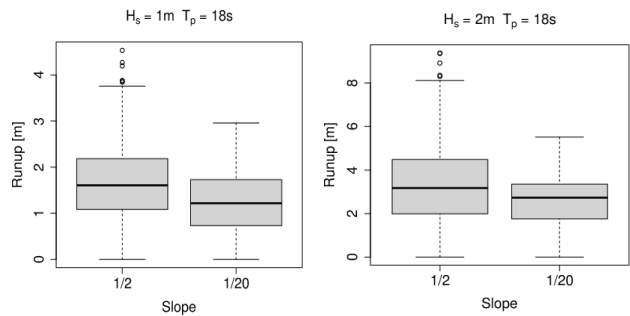


Figure 2 – Distribution of run-up heights at a 1:20 (left box/whisker) and a 1:2 slope (right box/whisker) for two specific sea states: $H_s = 1m, T_p = 18s$ (left panel) and $H_s = 2, T_p = 18s$ (right panel). Boxes are drawn from the first to the third quartile of the distribution, with a bold horizontal line indicating the median. Dots indicate outliers, that is observations beyond 1.5 times the inter-quartile range.

accurately than the offshore values. The run-up height on the steep slope features heavy tails. Comparing run-up behavior at a steep slope to a gentle slope, one can conclude that steeper slope generally feature higher run-up than gentle slopes for the same sea state (see Figure 2). One additional finding of this study is that run-up is generally higher for sea states with lower overall wave steepness. One possible explanation for this feature is that steeper waves tend to break before they reach the shore so that the waves arriving at the beach are already tempered by wave breaking.

REFERENCES

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