Coastal Engineering Technical Note

Video Measurement of Wave Runup on Coastal Structures

by

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PURPOSE

To provide information describing procedures used for the video measurement of wave runup on the St. Paul Harbor, Alaska, breakwater. This method may be used similarly for other coastal structures.

INTRODUCTION

St. Paul Harbor, Alaska, was recently monitored under the Monitoring Completed Navigation Projects (MCNP) Program. The monitoring plan included measuring wave runup on the face of the breakwater. Runup data were to be correlated with incident wave conditions and compared to values obtained in a two-dimensional model investigation (Ward 1988) and values computed from guidance provided in the *Shore Protection Manual* (1984). These unique prototype measurements would aid in refining design predictions, which in turn would aid in future breakwater designs.

Wave runup was obtained using a video image processing system. The technique has been used previously to measure runup on beach slopes, but was modified for runup on the St. Paul breakwater. This technique has the advantage of being low-cost and logistically simple, and is capable of providing simultaneous runup measurements at several locations along a beach or structure. The remote sensing nature of this video technique has obvious advantages over in situ instrumentation: ease of installation, not being subjected to extreme wave forces, and being non-intrusive.

PROCEDURE

A monochrome video camera (Sony XC-75 with 50mm lens) was set up and mounted on a cliff overlooking the breakwater, providing an oblique view of the breakwater face. Transformation from two-dimensional (2-D) video images to three-dimensional (3-D) world coordinates requires a determination of camera geometry, typically accomplished with visually identifiable ground control points (GCP's). In this application, GCP's were established by applying white paint to four armor stones along the breakwater crest as shown in Figure 1. Runup measurements were desired for two profile locations across the breakwater face, with the approximate positions indicated in Figure 1.

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Horizontal and vertical coordinates of the camera location, the center of each GCP, and points along the profiles were surveyed to establish the required geometry. By using the GCP's as control and knowing the profile coordinates, a time series of wave runup may be generated from the video.

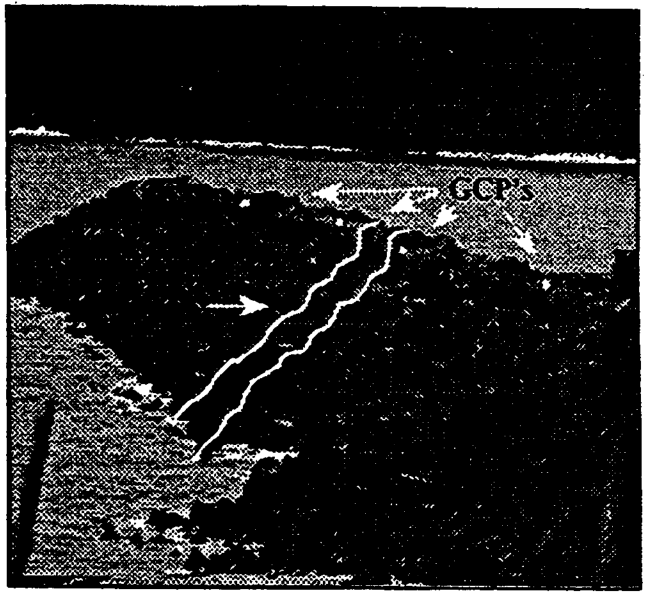

Figure 1. Ground control points (GCP's) and profile locations established on breakwater

Personnel onsite recorded video twice daily for 30-min durations during the October through December 1994 time period. The video output of the monochrome camera was transmitted via coaxial cable to a Hi-8 format video camcorder for recording. A logbook was maintained for recording video information and supplemental observations during data collection periods. Camera geometry and wave runup were computed at the U.S. Army Engineer Waterways Experiment Station, Coastal and Hydraulics Laboratory's Field Research Facility.

VIDEO ANALYSIS OF RUNUP

An improved method for runup measurements was developed using a video image processor to automate digitization of runup. An earlier video technique (CETN II-23) was capable of simultaneously measuring runup at several locations within the video field of view. However, that system relied on detecting changes in image contrast between beach and swash on a frame-by-frame basis and would occasionally misidentify the correct swash edge. It had particular difficulty in detecting swash positions when anomalous features entered the viewing field (e.g., birds, persistent sea foam, or people). The improved analysis technique, based on the "timestack" method described by Aagaard and Holm (1989), is more robust at detecting the swash edge but the analysis is also more time-consuming. The original technique generally works well with runup on beaches, but the "timestack" method is far superior for runup measurements on a rough (rubble) structure. A summary of the timestack analysis is presented below.

There are three basic steps to process video runup. First, the camera geometry is determined from a single video frame, with a new geometry computation for each collection. Next the video is digitized to create a timestack for a single profile using the camera geometry and profile coordinates. The final step is an edge detection of the runup position in the timestack image. Image coordinates of the edge detection are directly related to a time series of vertical runup excursion.

Camera geometry can be determined with as few as two GCP's if the camera's position is known. However, additional GCP's will improve the analysis by allowing a least square solution for the camera geometry. A general recommendation for selecting GCP's is to use three or four GCP's within the camera field of view that are spatially separated over at least a third of the image. GCP's near the edge of the image should be avoided, since lens distortions tend to be greater near the image edge. Lens distortion corrections were determined unnecessary for the video analysis of the St. Paul Harbor site since there was little distortion from the telephoto lens used in the measurements. A thorough description of camera calibration (e.g., lens distortion corrections) and this photogrammetric technique is presented in Holland et al. (1997). Since this data collection required a repositioning of the camera for each collection, a new geometry solution had to be computed for each timestack. When possible, video analysis can be simplified by securing the camera so its position and orientation are fixed, eliminating the need to recompute camera geometry for each timestack.

With the solution for camera geometry and the known profile coordinates, a transformation of the profile 3-D world coordinates to its 2-D image coordinates is relatively straightforward in the timestack generation program. This analysis uses an Imaging Technologies video image processor (model ITI-151) interfaced to a Sun-4 host computer. Linear interpolation between profile image coordinates generates a continuous line of pixels for the profile position, with each pixel having a corresponding 3-D world coordinate. Prior to digitizing, the profile is displayed in the video image for visual verification of its location. A timestack is created by digitizing every fifth video frame (6 Hz) and recording the pixel intensities on the profile line. These values are then "stacked" in a matrix and saved on disk. This results in a matrix of pixel intensities with one axis being the pixel position, directly related to the distance across the structure, and the other axis being time. In a typical timestack (Figure 2) the runup is clearly visible as a sharp change in pixel intensity, between the darker breakwater on the right, to the whiter foam of the runup on the left. Runup position in the timestack is found using edge detection algorithms combined with manual refinements when edge detection fails. Difficulties in edge detection arise from the chaotic nature of runup on a structure, with water that is highly aerated such that it is unclear what is considered solid water and what is spray. When spray becomes detached from the runup it is easily identifiable in the video and in the timestack (Figure 2). Often the spray is not detached and requires manual editing, which leads to subjectivity in this analysis technique. However, with operator training and careful observation of the video during

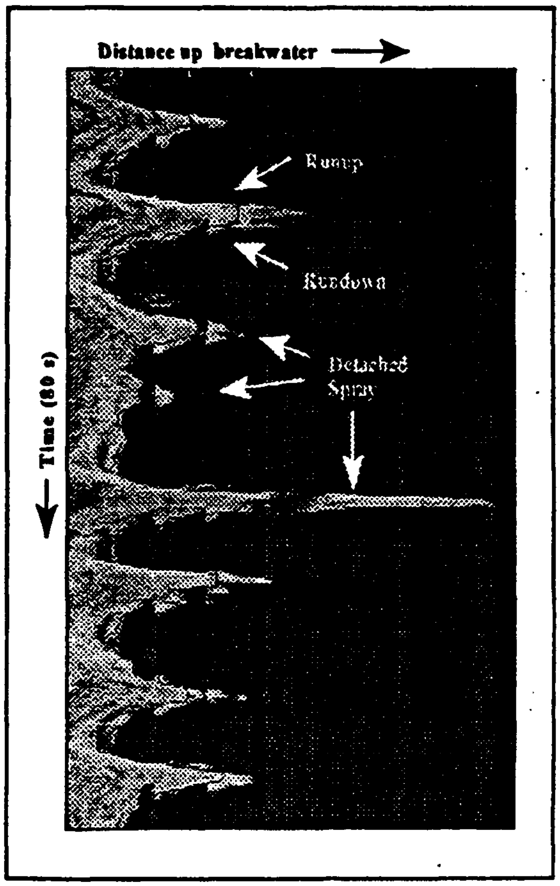

Figure 2. Example segment of a runup timestack

processing, the interpretation of runup position can be reasonably accurate. This subjectivity is usually not a problem in the analysis of typical runup timestacks from beaches, where the swash line is well-defined and continuous.

After edge detection is completed, image coordinates of the runup edge are transformed to a time series of vertical runup elevations (Figure 3). Standard wave analysis techniques are used to compute vertical runup spectra, wave height (H_{mo}), and peak period. Total record lengths were approximately 28 min, processed in 512-point (256-s) segments that overlapped 50 percent. A comparison between profiles separated by approximately 25 m showed that H_{mo} differences were roughly 10 percent and that excellent agreement existed for peak periods. Spectral comparisons were nearly identical and typically exhibited narrow frequency-banded swell (Figure 3).

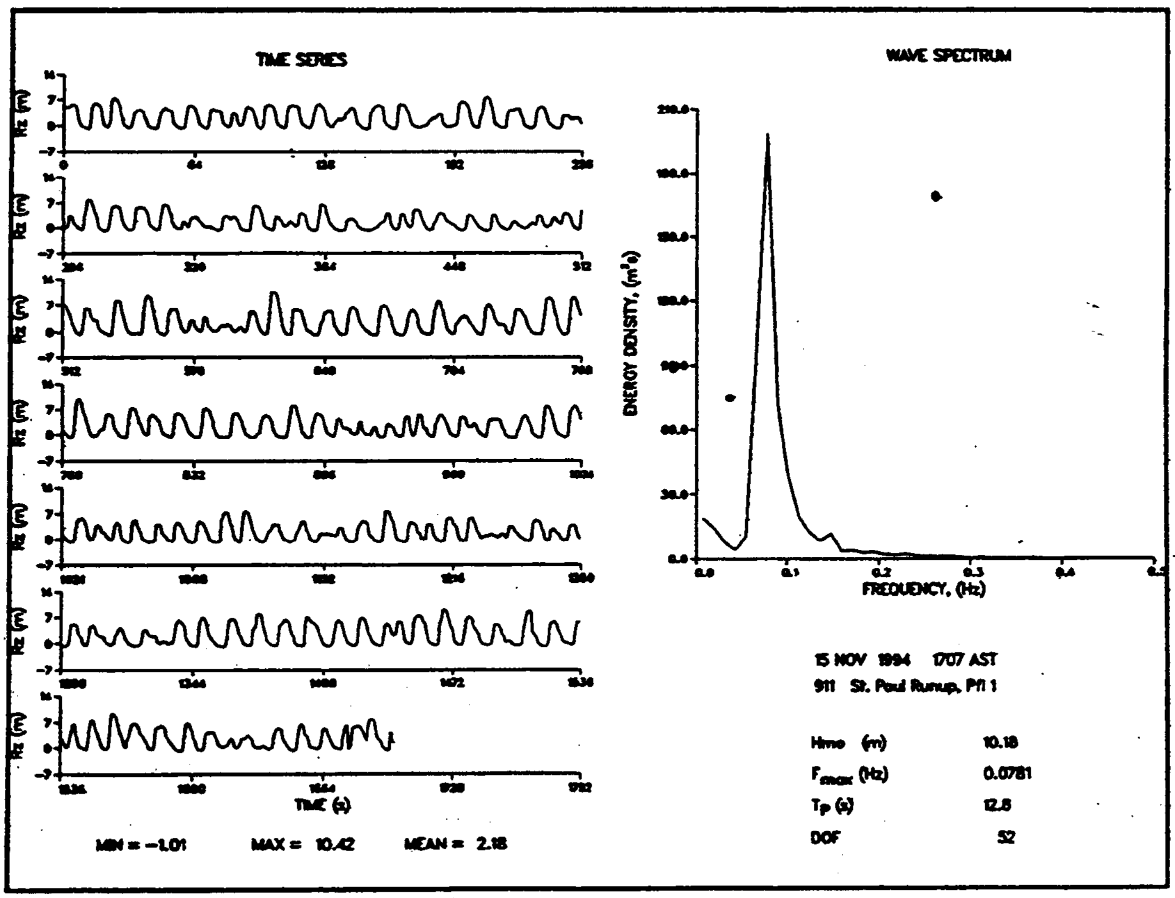

Figure 3. Example runup time series and energy spectrum

SUMMARY

The videotape methodology used to obtain wave runup data along the face of the St. Paul Harbor breakwater appeared to be very successful, except during periods of low visibility. The technique is relatively low cost, logistically simple, and provides relatively accurate results. It may be used at other coastal structure sites.

ADDITIONAL INFORMATION

For more information on wave runup methodology described herein, contact Mr. Kent K. Hathaway, Field Research Facility, Engineering Development Division, USACE Coastal and Hydraulics Laboratory (CHL) at 919-261-3511, or email k.hathaway@cerc. wes.army.mil. Information concerning the monitoring of St. Paul Harbor, in general, may be obtained from Mr. Robert R. Bottin, Jr., Wave Processes Branch, Wave Dynamics Division, CHL, at 601-634-3827, or email r.bottin@cerc.wes.army.mil.

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