

CHAPTER 82

FIELD MEASUREMENTS OF DUNE EROSION

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ABSTRACT

A series of field experiments was made to evaluate the use of a laboratory derived relationship between the force in the wave uprush and the erosion of beach dunes. Measurements of the wash velocity and height at the dune face were used to compute a specific force parameter. This force term was correlated with the specific erosion of the dune. A linear relationship similar to that found in the laboratory was determined with a R squared value of .87.

INTRODUCTION

The prediction of dune retreat by storms is an essential element of any beach erosion model. Most of the current models use some form of an equilibrium beach profile to determine the volume of sand eroded from the dune during a storm. These models have a common basis in the use of the Bruun Rule (Brunn 1954) which states that sea level rises a beach will try to achieve the same profile it had previously. The profile will be shifted upwards and towards the shore using the material eroded from the beach to fill the required volume.

In terms of the application of this approach to the dune, Edleman (1972) and Dean (1976) have both developed methods which seem to give useful results for extreme events. In this case the beach can be expected to reach an equilibrium profile. Vellings (1982) and Hughes and Chui (1981) have included physical model results in the application of this approach. More recently, Kriebel and Dean (1985) have improved the equilibrium profile model with the use of numerical methods and additional empirical analysis of storm eroded beaches.

An alternative method for the prediction of dune erosion was proposed by Fisher and Overton (1984) where the erosion from each

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individual swash uprush is used to determine the dune erosion. The total storm erosion is a function of the frequency and intensity of the swash. This approach does not require the development of a post-storm equilibrium profile.

Both approaches to the dune erosion problem have merit. The equilibrium profile method is particularly well suited to long-term planning and the prediction of the erosion from extreme events. The wave swash approach enables one to estimate the impacts of smaller events for which the equilibrium profile may not be achieved. In order to develop a dune erosion model using the swash characteristics, it is necessary to determine the relationship between the swash and the dune scour. A series of laboratory and field experiments as well as numerical modeling have been used in this current research. This paper presents a portion of our results dealing with the results of the field studies. Additional field results are reported by Chisholm (1986). Young (1986) presents the initial laboratory results, and the numerical work is in Overton, Fisher and Fensholt (1987).

BACKGROUND FOR FIELD EXPERIMENTS

The basic approach of this research is that the total erosion of a dune during a storm can be viewed as the summation of the erosion from the individual swash uprushes which impact the dune. The uprush is assumed to behave as a bore characterized by its leading edge velocity and a characteristic height. When the bore reaches the toe of the dune, it scours sand and is reflected down the beach. The volume of sand eroded for each swash impact is probably a function of the swash hydraulics, the sediment size, dune geometry and moisture content. The present laboratory research simplifies this problem by only considering a single sand size and a limited range of moisture contents.

In order to investigate the relationship between the swash and the dune scour, a series of laboratory experiments have been carried out, Young (1986). The experiments focused on the volume of sand eroded for individual bores in a 12 m flume. The bores were generated by releasing water from a head tank with a quick opening gate. The water then traveled up an inclined beach to the experimental dune. A number of different initial head tank elevations were used, thus generating different bore sizes at the dune.

The analysis of the results for 50 experiments with 10 different head tank levels yielded a linear relationship between the force of the uprush at the dune and the volume eroded. SVE is defined as the specific volume eroded, cu m , and SF is the specific force, N/m , exerted by the bore against the dune, defined by the mean of the product of the leading edge velocity squared and the maximum bore height while it is in contact with the dune. Figure 1 illustrates the linear correlation between SVE and SF for the laboratory tests. These data have a R squared value of .84.

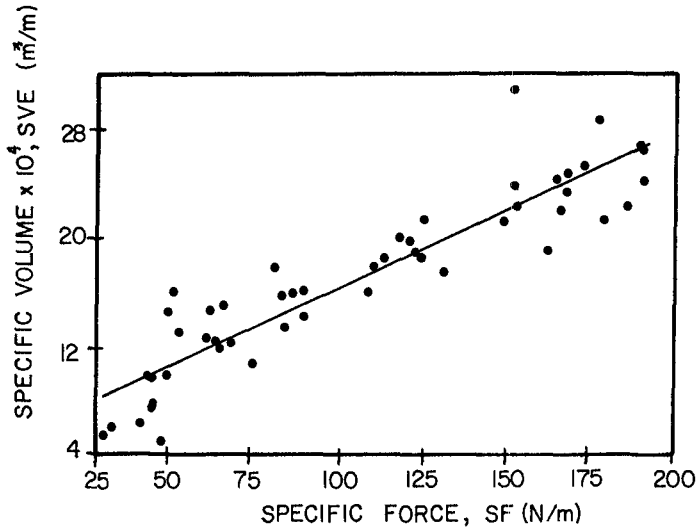


Figure 1. Linear correlation of specific force and specific volume eroded for laboratory dune.

These results are for a limited number of laboratory experiments. The dunes were all constructed with the same size sand. Moisture content was not varied significantly, and the small scale meant that the force on the dune was relatively small. A series of field experiments was therefore initiated in order to determine if this or a similar relationship could be found at scales more closely approximating prototype conditions.

DESCRIPTION OF FIELD EXPERIMENTS

The field experiments were made at the Field Research Facility of the Army Corps of Engineers, Duck, North Carolina. The experiments consisted of the construction of a dune on the beach and the measurement of the rate of erosion by the wave swash as well as the hydraulic characteristics of this swash. Figure 2 is a schematic diagram of the field setup. A detailed description of the experiment is presented in Chisholm (1986).

The test dune is constructed at low tide with its toe at about the position of the mean tide level. No attempt is made to time the dune construction with extreme wave conditions. The experiment proceeds with whatever wave swash is present. The sand for the experimental dune is collected from the local dunes at the research pier. The dune is constructed between two vertical retaining walls. One side is made of a

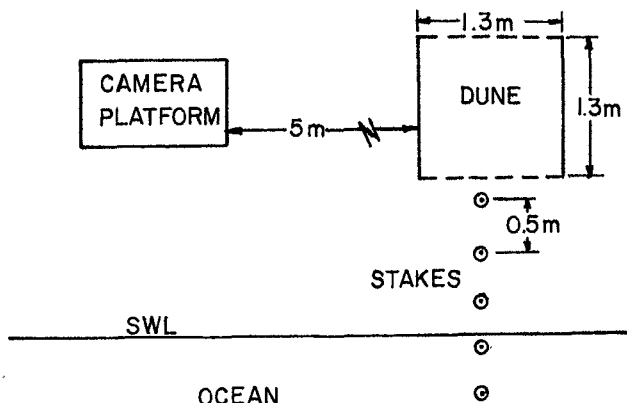


Figure 2. Schematic diagram of field setup.

clear plastic (normal to the shoreline) and the other of plywood. The former side has a grid on it, and both 35mm and video pictures are made of the dune as it erodes. The walls are 1.3 m apart, and a typical dune is built to an elevation of about 1 m. The dune is constructed in a series of discrete stages. New sand is placed between the walls, compacted and saturated by pouring water on it. This is followed by the addition of more sand, compaction and water. This process is continued until the desired elevation is reached.

As the water level rises with the incoming tide the dune begins to be scoured and eroded by the wave uprush. A video camera records both the changes in the dune (through the clear plastic wall) as well as the swash. Vertical stakes are placed in a line in front of the dune as reference points for both the depth and velocity of the swash. These data are also collected by the use of two capacitance wave gages located along this same line in front of the dune. A still camera is used to photograph the dune profile after every major impact. These photographs are then used to calculate both the erosion for each uprush as well as the total erosion for the entire experiment. Additional wave data including the significant period and height are collected as part of the routine data collection program by the Corps.

A typical experiment consists of the continuous monitoring of the erosion of the experimental dune during the time that the swash reaches the dune, or until the dune is completely destroyed. The output from the capacitance gages is collected during the experiments on a portable computer with an analog to digital conversion system. The computer is powered by a generator, and is located in a truck on the beach. The data from these gages is used to determine the height of the wave uprush just prior to the time of impact with the dune. The actual velocity recorded is that of the leading edge of the bore. The volume of erosion for any single wash is determined from a comparison of the sequential still photographs. These pictures are digitized and volumes determined with a computer.

RESULTS

The results from four experiments during June 1986 are presented here. While other experiments were completed, these were the most successful in terms of the operation of the instrumentation and the construction of the dune. Table 1 presents a summary of the conditions for each of these four tests.

TABLE 1

WAVE DATA DURING DUNE EROSION TESTS

DATE	WAVE HEIGHT (M)	WAVE PERIOD (SEC)	TIDAL RANGE (M)
6/11	.33	14.2	.85
6/12	.41	10.6	1.05
6/25	.41	8.8	1.21
6/26	.58	7.2	1.01

The field data was analyzed to see if a similar relationship exists between the specific force and erosion for the field dunes. The data shown in Figure 3 for June 12 are typical for all of the tests. As with the laboratory analysis, the specific force is calculated as the product of the square of the leading edge velocity and the maximum bore height while it is in contact with the dune. Unlike the laboratory data, there is considerable scatter, and no significant correlation between the force and the erosion. There are several factors which may contribute to this poor correlation. The field data, including both the swash heights and velocities, are very noisy. An additional factor has

to do with the difference in the nature in the erosion of the field dune and the one built in the laboratory. In the field the dune continues to erode with the rising tide. Unlike the laboratory dune, its face is not always vertical, but rather is highly irregular, continuing to change during the experiment. This irregular face means that some uprush hit a vertical wall, others a curved undercut surface, and still others a recently failed mass of sand. While data are not available to make definitive conclusions, it is probable that the same uprush will erode different volumes of dune sand depending on the nature of dune face.

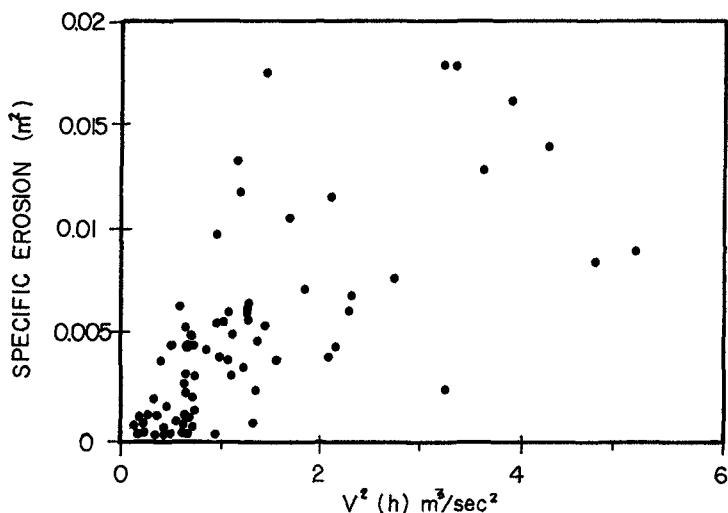


Figure 3. Specific erosion per individual swash force for June 12, 1986.

The scatter shown in Figure 3 was reduced by grouping the data according to intervals of force. Seven intervals were chosen: 0-0.5, 0.5-1, 1-1.5, 1.5-2, 2-3, 3-4, and greater than 4 N/m. For each interval, the average specific erosion was plotted against the average specific force. Figure 4 shows the linear correlation using these intervals for the combined data for three experiments, June 11, 12, and 26. (Due to a problem with the 35mm camera, the data for June 25 could not be analyzed on an individual swash basis.) There is an improved correlation (R squared equal to .75) between the specific erosion and

the specific force when these data are grouped by these intervals. The intervals obviously smooth out the scatter associated with the individual surges and the irregular dune face. When viewed this way, the field data agree with the laboratory data in that there is a linear relationship between the erosion and the force on the dune.

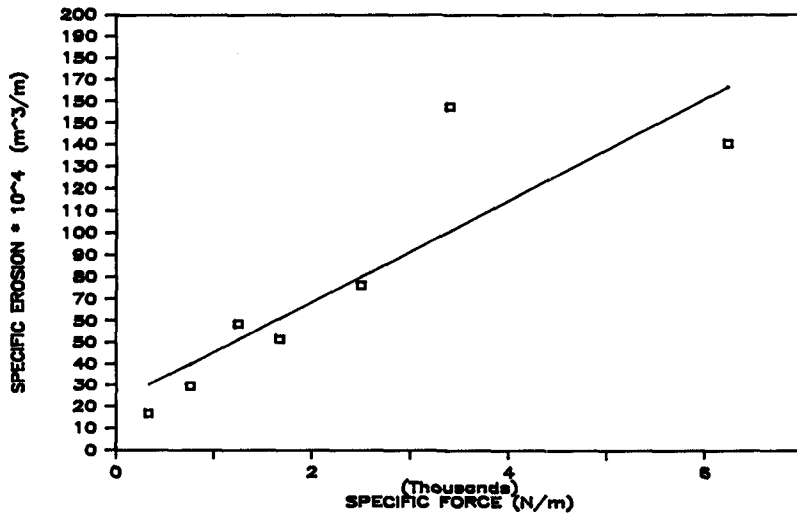


Figure 4. Specific erosion vs. specific force grouped by intervals, combination of June 11, 12, and 26.

From a practical point of view, the prediction of dune erosion based on individual swash bores is unreasonable. A method where the net dune erosion is determined from the cumulative effects of the swash would be more useful. Using the data from the four experiments, one such method was evaluated. The total specific erosion during the entire experiment was plotted against the summation of the individual specific force values, Figure 5. Only four data pairs are plotted, representing the four separate experiments. As with the data grouped by the force intervals, these data are also well correlated, R squared equal to .87.

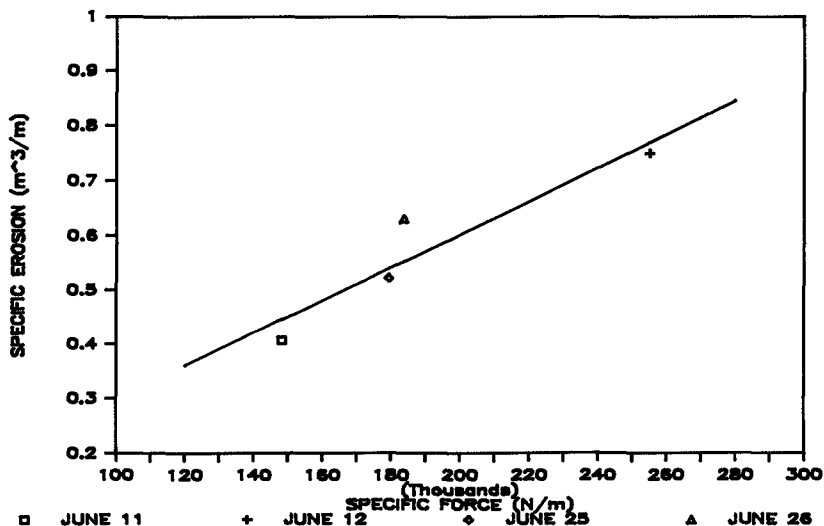


Figure 5. Total specific erosion va. summation of specific force for four experiments.

CONCLUSIONS

The primary objective of these field experiments was to determine if the relationship developed in the laboratory is valid for prototype scales. The results suggest that the general concept of relating the dune erosion to the force of the uprush is reasonable. In particular, the good correlation (R^2 equal to .87) for the net dune erosion and the summation of the swash force on the dune provides reason to think that this approach may prove useful in the prediction of dune erosion. Additional field tests are needed for larger dunes and higher levels of swash force. Further research is also needed in the mechanics of erosion, the role of moisture content, and root density from vegetation in the dune erosion process.

ACKNOWLEDGMENTS

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