CHAPTER 70

Dune erosion during storm conditions

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Abstract

Starting from a provisional hypothesis, presented by the author at the 11th Conference on Coastal Engineering, this paper deals with the further development of our knowledge about dune erosion during storm conditions. Results of measurements in the prototype are mentioned. Some speculations about the occuring processes during storms are given. However, the problem has not yet been solved. Further measurements in the prototype will be necessary.

Introduction

During the eleventh Conference on Coastal Engineering (London, September 1968) the author presented a first paper about dune erosion during storm conditions (Proceedings Volume I, chapter 46, page 719) in which he assumed, as a first approach, that after a storm the profile on the beach in cross-section was a straight line under a slope with an average value 1 in 50. This hypothesis was based on the assumption that during a storm an equilibrium slope would establish itself, comparable with the slope between highwater- and lowwater-level, as measured on the dutch beaches during normal weather conditions. It may be, that such an equilibrium slope does exist in nature, but soon it became evident, that a storm never lasts long enough to produce such a slope.

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Measurements

Since 1968 researches have been made into a large number of after-storm profiles. These investigations have revealed, that after a storm the profile of the beach is not a straight line, but a curve with a general shape as can be seen in figure 1. Only the part AC could be measured; the part lower than point C is unknown until now.

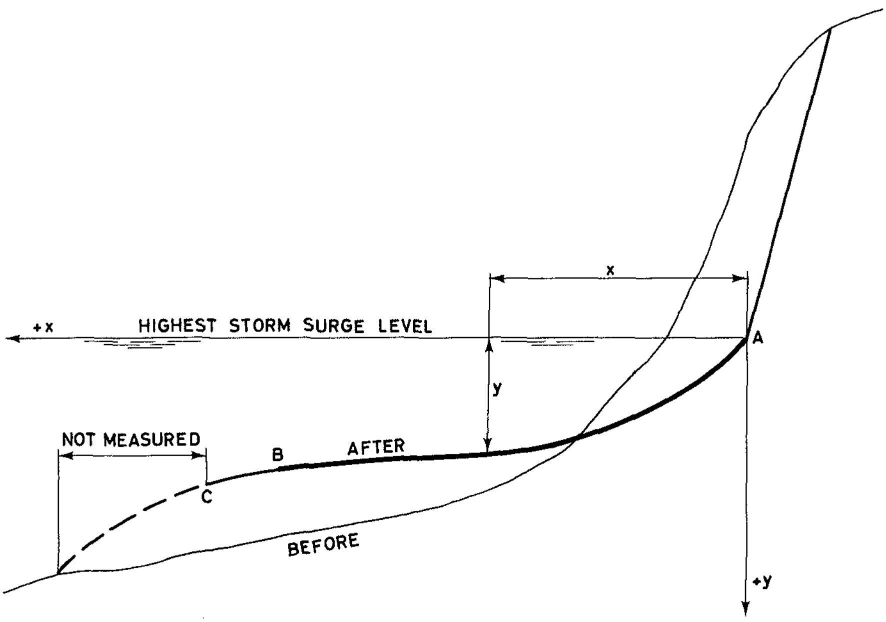

Fig. 1

The highest part of such a curve, indicated by the heavy line AB , can be represented by the formula :

$$y + 0{,}90 = 0{,}415\sqrt{x + 4{,}70} \qquad (1)$$

in which y = the depth below the highest storm surge level and x = the distance from the waterline A.

When $x = 0$ is $y = 0$ (point A) and when $x = 100$ meter is $y = 3{,}35$ meter (point B).

The remarkable fact has been observed, that, with regard to the maximum stormflood level the above parts of these curves are almost identical. Its shape appears to be almost independent of the height of this level and the formula (1) holds good for every stormflood level, that causes dune erosion. We can therefore speak of „the" after-storm profile.

Extrapolations

From figure 1 it can be seen that the slope decreases from A towards B, but that further seaward the slope increases again. It is, therefore, impossible that (1) describes the complete curve; the formula must at least be of the third degree.

We tried the simple formula:

$$y = ax^3 - bx^2 + cx \text{ ------------------------------} (2)$$

in which a, b and c are parameters.

If we want $y = 3{,}35$ when $x = 100$ (thus causing the curve to go through the points A and B), we find a relation between the parameters a, b and c :

$$3{,}35 = 10^6\ a - 10^4\ b + 10^2\ c \text{ --------------------} (3)$$

It has been found that, if we vary the values of a, b and c within wide ranges, but stick to the relation (3), we find very small variations in the part AB of the curve. The differences with (1) remain within the range of the measurement inaccuracies. This proves that it is impossible to make a seaward extrapolation starting from part AB of the curve.

This is a pity, as we must, for the present, make use of an extrapolation, because hitherto we were not able to measure the lower part of an after-storm profile in the prototype.

Apart from the fact, that it is rather dangerous to measure this part of the profile just after a storm, we still have another difficulty. It is of little value to measure the profile only after the storm, as we must also know the profile just before the storm, in order to be able to calculate the quantity of sand sedimented upon beach and fore-shore.

Since storms never announce themselves beforehand, we have to lie in wait for a storm with our manned measuring boat during the whole winter season, measuring the excisting profiles every week and hoping for a neat, heavy storm to come within the next week. Since 1968, however, such a storm did not occur.

Moreover, even if we should have good luck during next winter, we are not satisfied. For obvious reasons, we should like to obtain data of several storms, with different levels and different time-height graphs.

It seems, therefore, that for the present we are at a dead-lock. But, perhaps, there is another way-out.

Steady shape of the profile

We have seen, that the shape of the above part of the profile is almost independent of the height of the maximum storm surge level. As a first supposition we may assume that this holds good for the complete profile.

The next assumption is, that this „storm profile" excists at any moment during the rise of the water-level. During the whole period, in which large quantities of dune sand are sliding down into the boiling sea, the under-water profile may move upward and landward, preserving its own characteristic shape. Obviously, this characteristic shape must come into existence during the preceding period and has to establish itself at the moment, that the large dune erosion begins.

Further we have to assume, that the sliding sand is spread out over the whole profile within a very short time.

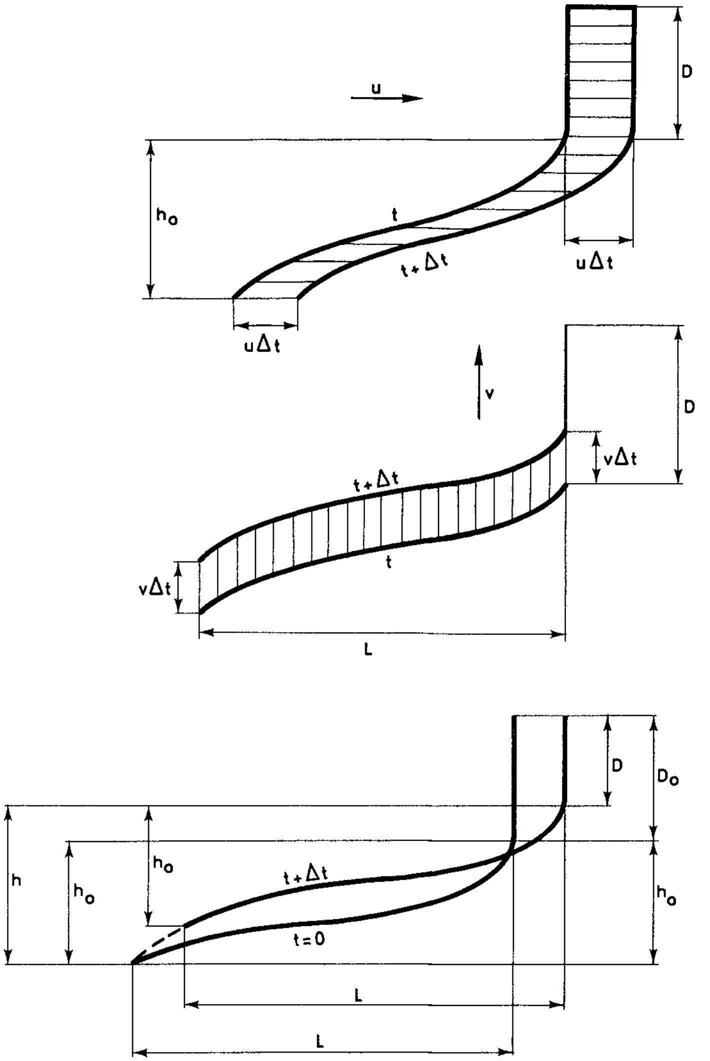

Fig. 2

If at the moment t each point of such a „storm profile" moves in horizontal direction with a velocity u and in vertical direction with a velocity v, we can derive that (see figure 2) during a time-interval Δt the horizontal movement causes a loss of material : $(h_o + D)\ u\ \Delta t$, and the vertical movement brings a gain : $L\ v\ \Delta t$. If no sand disappears from the profile, both quantities have to be equal, from which we obtain : $(h_o + D)\ u\ \Delta t = L\ v\ \Delta t$

$$\text{or} \quad u = \frac{L}{h_o + D}\ v$$

During the storm the dune-foot moves landward over a distance

$$A = \int_{t=o}^{t=t_m} u\ d\ t$$

Since $v = \frac{dh}{dt}$ and (with a horizontal dune-surface)

$$h_o + D = D_o + 2\ h_o - h$$

we find

$$A = L \ln \frac{D_o + h_o}{(D_o + h_o) - (h_m - h_o)}$$

We are able to calculate A from this formula if we can establish the values of h_o and L, the height and the length of the „storm profile".

Most investigators assume, that L is the length of the breakerzone and that h_o is the breaker-depht :

$h_o = \gamma H_s$ in which H_s is the significant wave height and γ is a constant, often assumed to be 1,3.

From this value of h_o the value of L can be found from the profile excisting before the storm.

However, if we put these values into our formula, we mostly find a value of A which seems to be too large and which is certainly not in accordance with the average dune-erosion we measure in the prototype. Probably the length of the storm profile is smaller than the length of the breakerzone, and $h_o < \gamma \cdot H_{sign}$.

At present, we do not understand the mechanism of the sand transport on beach and fore-shore very well. During normal weather-conditions the waves are supposed to induce a landward transport over the whole breakerzone. The much larger seaward transport of the sand from the eroding dunes during storms, however, may mainly be caused by gravity. This gravity transport could be a kind of turbidity current.

There is, however, no reason why we should assume, that this turbidity current should proceed as far as the end of the breakerzone. It is more likely, that on the landward part of the breakerzone gravity preponderates and that on the outer seaward part of the breakerzone the sand is still moving landward.

Conclusions

As pointed out before, we do not know exactly what happens in the breakerzone. Once more we see, that measurements in the prototype are necessary, with all the difficulties involved.

From the considerations and reflections pointed out here, it may be seen and understood, that it will probably take several years before a reliable answer can be given to the simple question: „How far will a dune row erode during a severe storm".