CHAPTER 46

DUNE EROSION DURING STORM CONDITIONS

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INTRODUCTION

Since in the Netherlands large areas of low lands are protected against the sea by coastal dunes only, it is very important to know how far, during a storm surge, the erosion of these dunes will proceed. In order to obtain an answer to this question, the cross-section of the coast has been studied.

The shape of the cross-section of a sandy coast is mainly caused by displacements of sand perpendicular to the coast-line. Obviously this transport is mainly caused by waves. Since our knowledge of the very intricate physical processes, governing the sand transport by waves is, even now, still very incomplete, we can, perhaps, obtain an insight into the behaviour of a sandy coast, if we start from some rather simplified basic assumptions which are roughly in accordance with observations in nature.

SIMPLIFYING ASSUMPTIONS

a) The quantity of sand: q_w, transported by waves may be:

$$q_w = - K \left(\frac{2\pi h}{L}\right)^2 \frac{1}{\left(\text{Sinh}\,\frac{2\pi z}{L}\right)^2}$$

in which K is a constant, depending on the nature of the transported material only, h is the wave-height, L is the wave-length and z is the water-depth. In the neighbourhood of the coast the value of the quotient $\frac{2\pi z}{L}$ will mostly be rather small; thus it is allowed to replace Sinh $\frac{2\pi z}{L}$ by: $\frac{2\pi z}{L}$, from which the formula takes the simple form:

$$q_w = - K \frac{h^2}{z^2} \qquad \ldots\ldots\ldots\ldots\ (1)$$

b) It is further assumed, that h and L are independent of z and that q_w does not include the sand transported in suspension; the latter will be neglected in this paper.

c) The waves try to bring the sand up against the slope of the shore; gravity tries to move it slope-downward. This counteracting influence of the slope is put into account as a slope-transport: q_s that is assumed to be proportional to the steepness of the slope:

$$q_s = \gamma \frac{dz}{dx} \quad \ldots\ldots\ldots\ldots (2)$$

d) Within the breaker-zone the wave-height will never surpass the value: 0,78 z; thus $h_b \leq 0{,}78\ x$ . . . . (3)

OBSERVATIONS IN NATURE UNDER NORMAL WEATHER CONDITIONS

a) Along the dutch coast it has been observed, that under normal weather conditions the cross-section of the beach is a straight line from the highwater-level to some distance below the lowwater-level. Nearly always the slope of this straight line has the same main value, depending, as it seems, only on the nature of the sand. This steepness varies along the dutch coast from 1:40 in the South, to 1:60 in the North-East.

b) Under normal weather conditions the waves within the breaker-zone are propagating through this zone in the shape of a spilling breaker. The breaker comes into being at a depth z = 1,3 h and runs as a foaming wall through the whole breaker-zone towards the water-line, decreasing gradually in height.

If we assume, that in a spilling breaker everywhere $h_b = 0{,}78\ z$, it follows from equation (1), that in the breaker-zone q_w has everywhere the same value. The straight line indicates, that also $\frac{dz}{dx}$ is a constant; thus q_s has, everywhere in this part of the breaker-zone, the same value. Therefore, this straight line must be an equilibrium profile. The length of this straight line depends on the wave height; its steepness is undependent of the wave height off-shore.

OBSERVATIONS DURING AND AFTER STORMS

a) During a heavy storm we observe that the breaker-zone is much broader than under normal weather conditions. At the seaward end of the breaker-zone we observe plunging breakers, while in the region nearer to the beach spilling breakers are dominant.

b) If the storm surge level is higher than the existing dune-foot, we observe that the outer parts of the dunes erode and that whole quantities of sand disappear into the boiling sea.

c) After the storm, we see that a new dune-foot has established itself on a level, which lies a little bit lower than the highest level reached by the sea. Between this new dune-foot and the normal lowwater-line the cross-section of the beach is a straight line under the same slope as originates under normal weather conditions on the wet beach (equilibrium profile).

CONCLUSIONS

If we consider the fact, that at the seaward end of the breaker-zone the quantity of sand, transported by the waves from off-shore reaches its maximum, and that in this region the transport capacity of the waves will strongly decrease in the, even there occurring plunging breakers, (which means that the greater part of the landward transported sand will precipitate here) it seems to be obvious, that a seaward transport of the eroded dune-sand beyond the breaker-zone is not likely to occur. We may assume, therefore, that the whole quantity of sand, eroded from the dunes, will precipitate within the breaker-zone proper. If we assume, further, that this sand is spread-out equally over the whole breaker-zone, we are able to estimate rather exactly the spot where the new dune-foot after a storm will come into existence. We have to know, however: 1) the profile of beach and dunes before the storm; 2) the equilibrium slope of the wet beach in the considered coastal area; 3) the highest storm-surge-level; 4) the wave height during the storm. A determination of the place of the new dune foot is very easily done by a graphical construction (fig. 1); we have only to shift the straight line AB so long till both the hatched surfaces are equal.

However, if we want to investigate in a more general way the influence of the height of the dunes (H), or the influence of the wave height (h), on the erosion of the dunes (the distance "d" in fig. 1), we can better start from a simplified original profile (fig. 2) and make a real calculation. The results of such a calculation have been plotted in fig. 3 which shows how "d" depends on H in the case that the storm-surge-level lies 5.20 m above mean sea level, the original dune-foot lies 3.80 m above mean sea level, the waveheight off-shore h = 10 m and the equilibrium slope is 1:50. In fig. 4 has been plotted how the dune erosion depends on the height p of the storm-surge-level and the dune height H, assuming that the wave height h = 1.5 p.

It can easily be seen, that high dunes give a certain amount of safety; this trend has been found in nature as well as in laboratory tests. It must be pointed out, however, that such a prediction holds good only if we are dealing with a "normal" beach. If, for instance, a channel exists in the fore-shore, that can swallow up the whole quantity of sand eroded from the dunes, a high dune produces no extra safety at all.

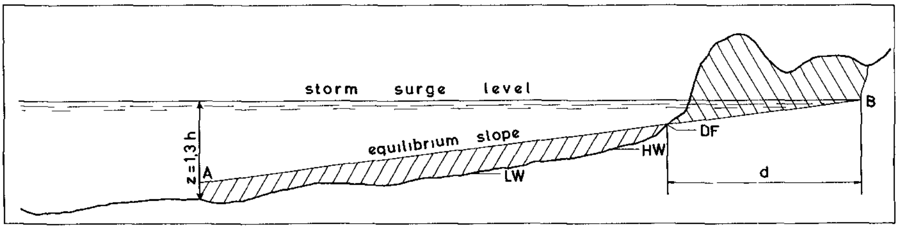

Fig. 1 Graphical construction

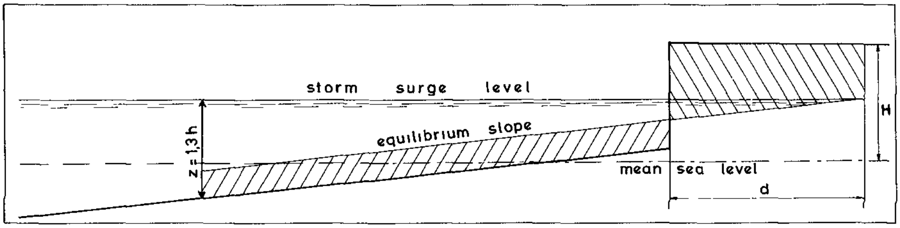

Fig. 2 Simplified profile for general calculation

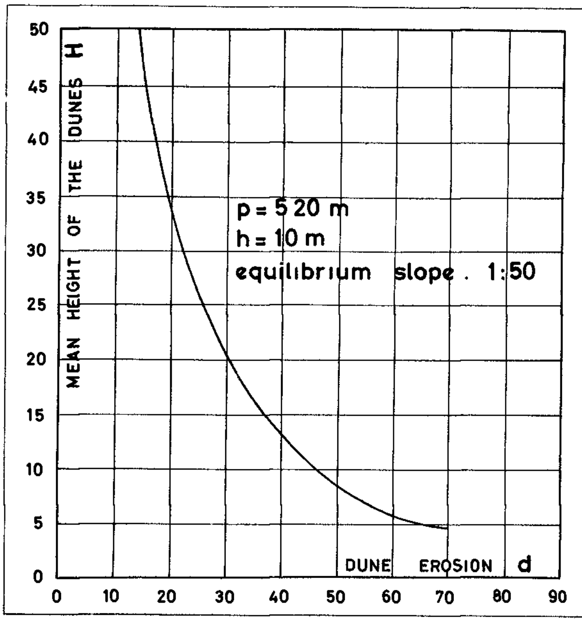

Fig. 3 Dune erosion with different dune height

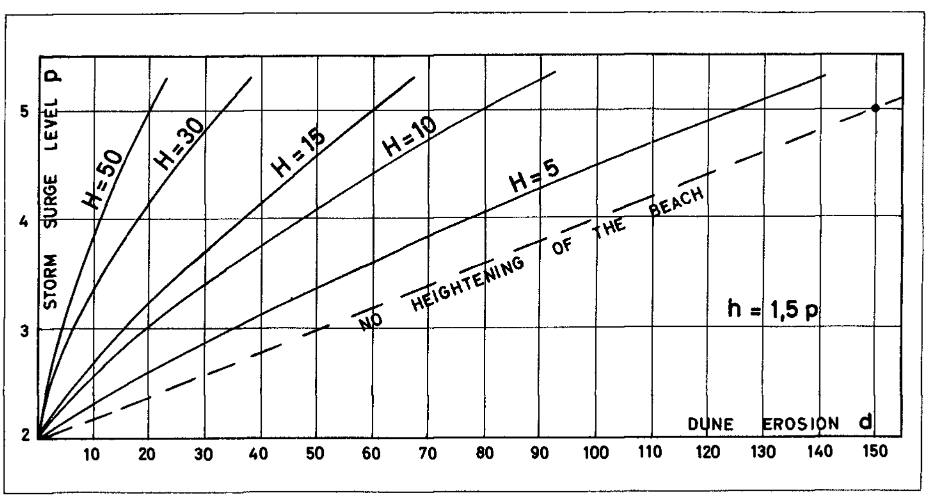

Fig. 4 Dune erosion depending on storm surge level and dune height