CHAPTER 212

BREACH GROWTH: EXPERIMENTS AND MODELLING

by

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ABSTRACT

Since 1989 research has been contucted in the Netherlands on the issue of breach growth. This contribution describes the set-up and results of wave basin experiments which had the aim to obtain insight into the process of growth of the width of a breach. From analysis of the recorded data (flow characteristics in the breach and the development of the breach) an empirical relation for breach width growth has been derived. This relation has been implemented into a (conceptual) numerical model which is briefly described in this document also.

1. INTRODUCTION

The Dutch Technical Advisory Committee on Water Defences (TAW) is aiming for a design method for water defences in which the optimal safety level of these defences is related to the risk of flooding. Risk is defined as the product of the probability of failure and the expected damage costs in case of failure. One of the key factors in the damage costs assessment is the speed and rate of inundation

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of a polder. The latter is predominantly determined by the discharge rate through the breach [Kraak et al., 1994].

Research regarding breach growth in a sandy dike-like structure started in 1989 with an exploratory field experiment. Further, flume experiments have been carried out for the initial phases of the breach erosion process (lowering of the dike crest) [Steetzel & Visser, 1992]. More recently wave basin experiments were done to investigate the breach widening process. Finally a large scale field experiment has been carried out in order to investigate the three-dimensional aspects of breach growth i.e. widening of the breach in combination with the development of a scour hole [Visser et al., 1995].

One of the main instruments to predict inundation and damage costs assessment is a theoretical model for breach growth and inundation. Recently, as a first step towards that model, a conceptual numerical model for breach growth prediction in a sanddike has been developed.

The present contribution is focused on the wave basin experiments regarding the widening of the breach and the conceptual numerical model of the breach growth process.

2. WAVE BASIN EXPERIMENTS

2.1 Set-up of the experiments

The set-up of the experiments is similar to the experiments which have been carried out to investigate the initial phases of breach growth (lowering of the crest) as is described in [Steetzel & Visser, 1992]. The cross-sections of the dike-stucture are identical in both experiments. The only difference is the use of a wave basin instead of a wave flume, with the purpose of investigating the widening of the breach.

All model tests have been carried out at DELFT HYDRAULICS and started with a sandy dike-like structure situated transversely across the wave basin. Because a breach develops symmetrically to the centre of the breach, it was sufficient to investigate only one side of the breach. The breach development, originated from minor initial overflow through a small pilot channel in the crown of the dike, was recorded using three simultaneously operating video camera's and a large number of precise instruments to obtain time series of both the water levels and the velocities in the area next to the breach. By using a recirculating system with an optional pump capacity up to 1.0 m^3/s, the upstream water level was kept as constant as possible. In this way the widening of the breach could be studied in detail until the major part of the dam was eroded.

In order to complete this description of the experiment set-up, in figure 1 a planview of the wave basin lay-out is shown.

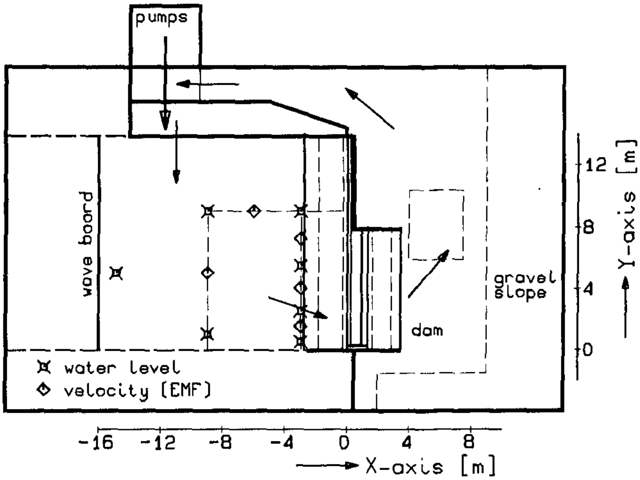

Figure 1: Planview of the wave basin lay-out

2.2. Description of the tests

The influence of several parameters on the breach erosion process has been investigated, viz. the width and height of the dike, the level of the foundation, the seaward bottom slope and the additional effect of (perpendicular) wave attack.

A total of 8 experiments have been performed in which the above mentioned parameters have been varied. Figure 2 gives an overview of the typical cross-sections used for the experiments. The focus lies here on the widening of the breach; in order to avoid effects of depth-growth, a treshold construction has been used for the experiments T1 .. T7 (as can be seen in figure 2). In the test T8 the treshold construction was absent; the only depth limitation is the floor of the basin. In this latter situation, a full three-dimensional experiment was conducted also.

In short the description of the experiments:

<u>T4 = reference case</u>
T1 = as T4, level of treshold is 0.1 m higher;
T2 = as T4, smaller crest width (0.7 m vs. 1.3 m);
T3 = as T4, lower (0.19 m) crest level
T5 = as T4, higher (0.2m) crest level
T6 = as T5, with wave attack (all other tests were without wave attack);
T7 = as T4, with a milder outer slope
T8 = as T7, treshold equals basin floor.

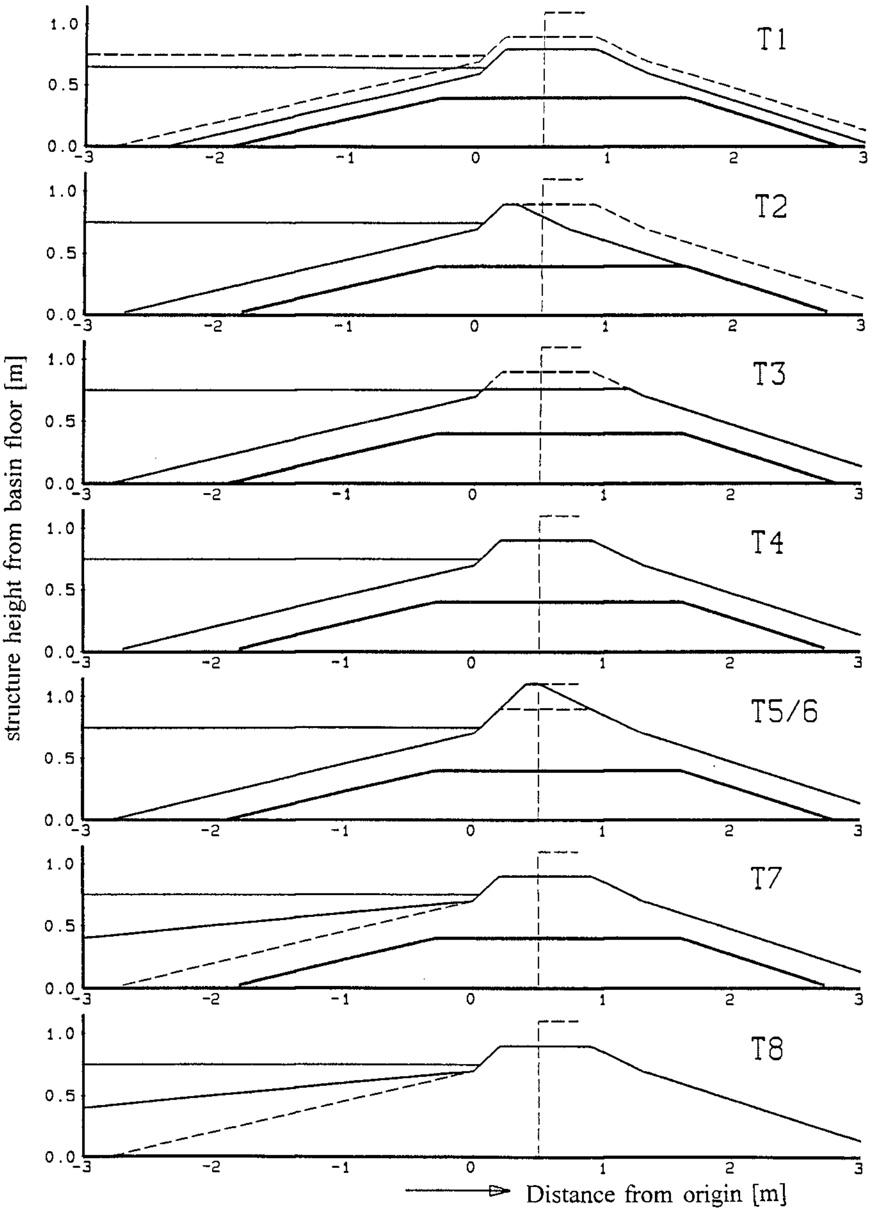

Figure 2: Overview of the cross-sections used for the tests T1 .. T8

2.3 Results of the experiments

The observed breach width development in time (B(t)) is presented in figure 3. It shows that the erosion of a dam having a narrow (T2) or low (T3) crest is more rapid than in case of a wider (T4) or a higher (T4, T5) crown. Relative to the case T5, additional wave attack (T6) yielded a larger breach width, whereas the opposite effect was present in the case of a less steep foreshore (T7, relative to reference case T4). The case without a treshold (T8) shows the slowest development of the breach width of all the tests due to the fact that a lot more sand has to be eroded in order to create the same breach width as for the other tests.

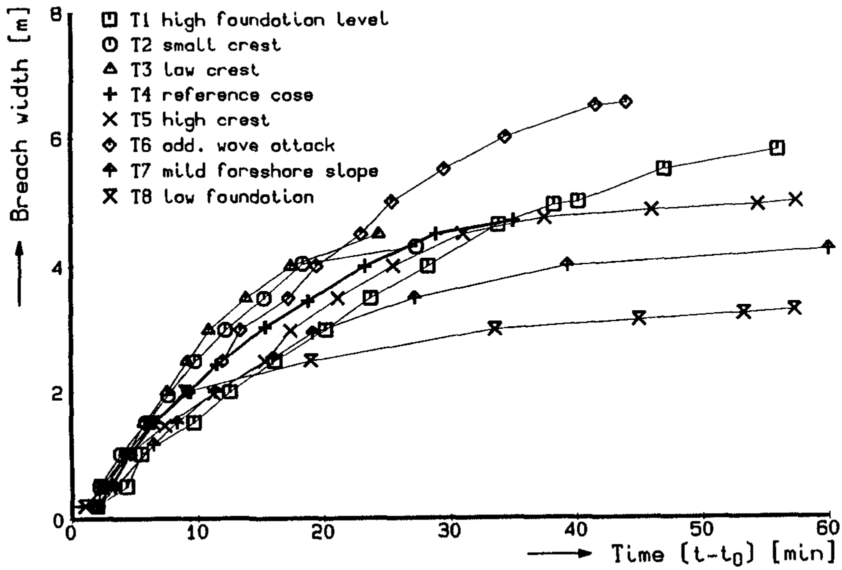

Figure 3: Overview of observed breach growth for all tests performed.

For modelling reasons a new parameter, the breach growth velocity, has been defined as:

$$ß(t) = dB(t)/dt \quad [m/min] \tag{1}$$

To get an impression of this parameter, figure 4 gives its development as a function of time. It shows that a milder outer slope (case T7) yields a smaller breach growth velocity in respect to the reference case (T4).

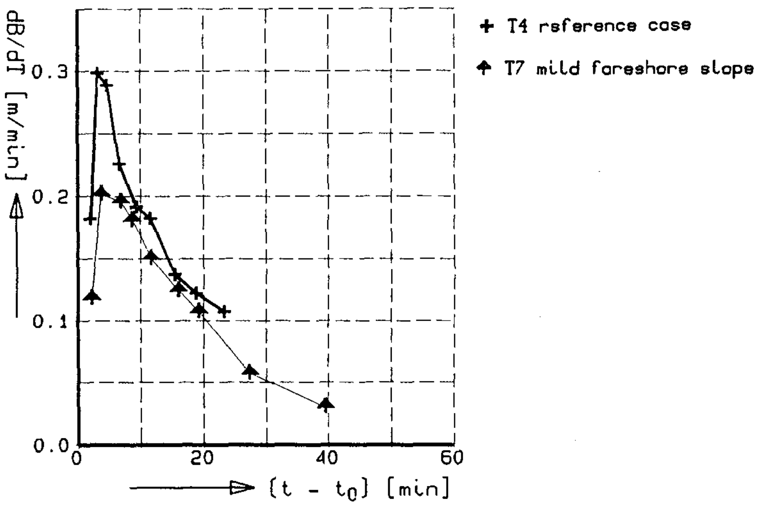

figure 4: development of the breach growth velocity as a function of time; shown is the effect of a mild foreshore slope

To get additional physical insight into the background of the breach growth velocity, this parameter is linked to the recorded flow characteristics in the breach.

Firstly, the relation with a characteristic water velocity in the breach ($v_{breach}(t)$), has been investigated. Figure 5 shows for the reference case (T4) and for the case T7 (milder outer slope) the breach growth velocity as a function of the water velocity in the breach. It can be seen that in order to obtain the same breach erosion velocity (dB/dt) as for the reference case, a higher water velocity in the breach (v_b) is required for case T7 (milder outer slope).

One of the conclusions is that breach width growth stops (and starts) when a certain critical water velocity in the breach is reached. From the experiments (laboratory and field) a critical value of 1.0 m/s can be derived

Secondly, the erodable volume is important. Therefore the volumetric breach growth velocity has been defined as:

$$dV/dt = \beta(t)*A_d \quad [m^3/min] \tag{2}$$

in which A_d = eroded cross-section of the dam as is illustrated in figure 6.

Figure 7 shows the volumetric breach growth velocity as a function of the water discharge through the breach. In this figure all the tests performed are present, exept for T6 (waves) and T8 (3D). A more or less linear relation can be derived.

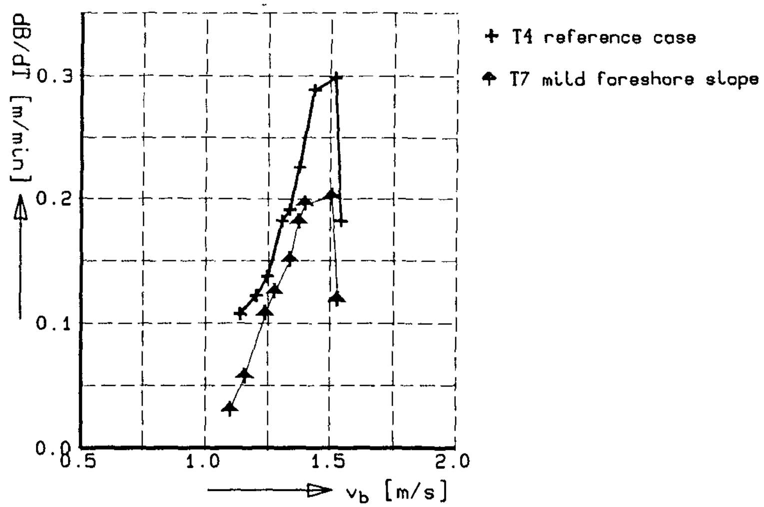

figure 5: development of the breach growth velocity as a function of the water velocity in the breach, shown is the effect of a mild foreshore slope

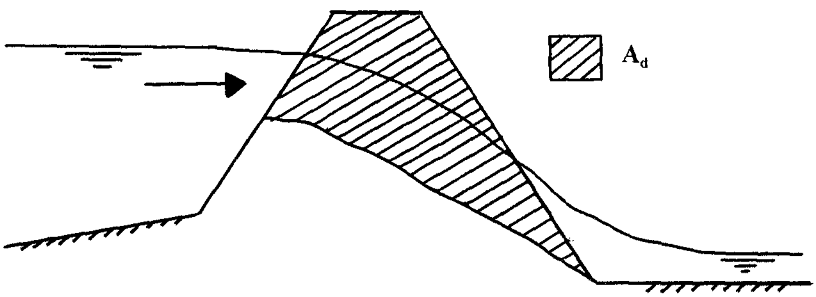

figure 6: definition of the eroded cross-section A_d

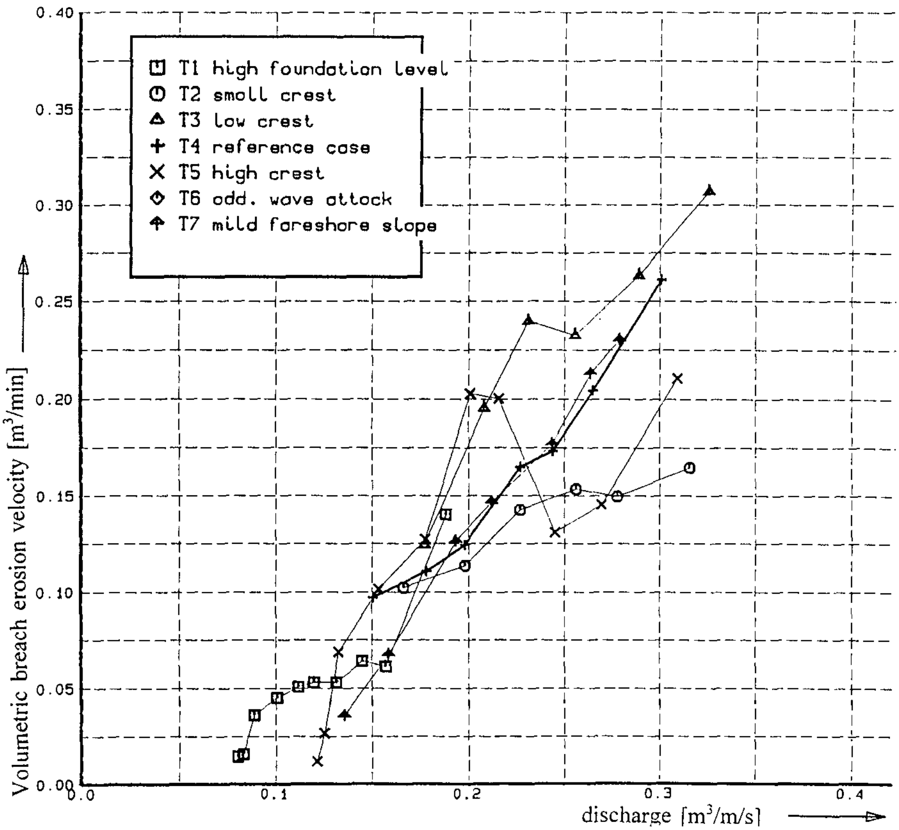

figure 7: volumetric breach erosion velocity as a function of the water discharge in the breach

3. NUMERICAL MODEL FOR BREACH GROWTH

The breach erosion process is characterized by a complex three dimensional behaviour in which low as well as very high velocities and thus erosion rates occur. The Froude number varies typically in the range of 0.03 to 3 and the Shields parameter varies from 0.03 - 50 [Visser et al., 1995]. In order to describe this complex process in a numerical model, five different phases in the breach erosion process have been distinguished [Visser, 1994]:

Phase 1: steepening of the inner slope;
Phase 2: narrowing of the dike crest;
Phase 3: erosion of the dike crest;
Phase 4: breach widening under super-critical flow and development of a scour hole;
Phase 5: breach widening under sub-critical flow until velocities are under a critical value.

In every phase a characteristic set of discharge and transport formulae is used to calculate the development of the breach during each time step. In the first three phases the rate of erosion is described by a Visser-Bagnold equation in which the erosion rate is proportional to the kinetic energy of the flow. The modelling of the first three phases has been described in [Visser, 1994]. For the modelling of the phases 4 and 5, the results of the wave basin experiments have been used. With the parameters and relations mentioned in chapter 3 the following empirical relation for the breach width growth velocity has been derived.

$$\beta = C_b*(d_b*q_b)/A_d \quad [m/s] \tag{3}$$

where: q_b is the water discharge rate per unit breach width $[m^3/m/s]$; q_b is described by a weir formula.
A_d is the eroded cross-section of the dam as defined in figure 6
d_b is the water depth in the breach
C_b is a coefficient, related to the sediment concentration near the edges of the breach

$$C_b = \bar{c}*b_r/d_b \quad [-] \tag{4}$$

where: $\bar{c}$ = depth averaged sediment concentration near the edges of the breach
b_r = width of the zone near the edges for which $\bar{c}$ is defined

At present there is a test-version of the numerical model available. This model covers all the above mentioned phases of the breach growth process. The main input parameters of the model are:

* cross-section of the sand-dike (array of (x,z) values):
  - erodable cross-section
  - cross-section with initial breach
  - ir-erodable cross-section (sill)
  - breach and material characteristics:
    - initial breach width
    - mean grain size diameter D_{50}
    - sediment fall velocity w

- porosity n
- bottom roughness r

* outside boundary:
- waterlevel as function of time (array of (z,t) values)
- optional: in case of e.g. a lake: areas/volume of the outer basin
- optional: in case of river: external input discharge

* inside boundary (in the polder):
- initial waterlevel
- area of the polder that will be inundated

During 1996 and the first half of 1997 this model will be completed. The results of the large-scale field experiments (1989 and 1994) and findings of the 1953 and earlier flood disasters will be used to calibrate and verify the model.

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