ESDODDS: EXPERIMENTS ON SEDIMENT DEPTH OF DISTURBANCE FOR BEACHES UNDER THE INFLUENCE OF DRAINAGE SYSTEMS

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The paper describes experiments undertaken the Large Wave Channel (Grosser Wellen Kanal, GWK) in Hannover on sediment mixing on a beachface exposed to the action of a buried drainage system. The general aim of the project was to understand the role of swash infiltration processes inside the sediment column. Preliminary results indicate that under High Energy wave conditions (Hs=0.8 m, Tp=6.5 s) the beach reached a quasi-equilibrium profile shape after 120 minutes of wave attacks. Thereafter the action of two adjacent drains did not stop shoreface erosion, except for the area immediately over the drains. Sediment mixing was small (approx 2-4% of wave height) and seemed to increase under drained conditions.

1. INTRODUCTION

The calculation of the degree of sediment disturbance through wave action in the surf and swash zone has been studied at various levels in recent years, with a number of empirical techniques. Quantifying “Depth Of Disturbance” (also known as sediment mixing depth) enables a better understanding of nearshore processes, like the prediction of the fall in beach levels during storms and the design of beach replenishments.

Attempts at estimating sediment disturbance to date have resolved their measurements only after a complete tidal cycle and therefore have been unable to measure processes during the actual perturbations caused by wave action within the tidal event, an essential period of activity to understand bed elevation patterns (e.g. Ciavola et al. 1997, Ferreira et al. 2000, etc). In a recent paper Ciavola et al. (2006) evaluated the robustness of the relationships developed in the field using a large-scale wave flume, proving the advantages of laboratory modelling over fieldwork. In a wider context, surf zone morphodynamic research has dealt with the effect of varying water level in wave action (i.e. initiation and modes of sediment transport and induced morphodynamics). Current thinking in this field comes from a variety of studies that demonstrate the importance of wave height sensitivity and the control that water depth exerts on sediment disturbance.

However, no work has been done in order to relate sediment depth of disturbance with beach drainage systems, which has been considered an effective method of coastal protection, even if it is still to be proved to what extent they are effective in stabilizing the beach or generate accretion. We believe that the understanding of the role of water infiltration, exfiltration, fluidisation in the swash zone and sediment transport processes is one of the main questions that current research on coastal processes has to answer. It is still to be proved if a “dry” beach responds to a peculiar way to wave action, in particular if there is a relationship between the degree of saturation and the thickness of sediment mixing.

This project used the Hydralab III facility at GWK to quantify the sediment Depth of Disturbance (DoD) on a sloping beach under the effect of a beach drainage system (in controlled environments and without scaling issues).

Due to the fact that there were two proposals submitted to GWK dealing with beach dewatering and proposing similar model’s set-up and obtaining the same rating for support, the access was shared between these two teams to avoid any double effort from Hydralab (see Damiani et al., 2010 in this volume).
2. EXPERIMENTAL SET UP

Details of the 2-d movable bed can be found in the paper of Damiani et al. (2010) in this volume. According to analysis undertaken using a settling column at the University of Ferrara, the sand in the flume had a $d_{50}$ of 0.36 mm which corresponds to medium sand in the Udden-Wentworth scale. The sand in the flume was reasonably well sorted and no mud fraction was present. Notable that over 20% of the sample consisted of fine and very fine sand fractions. Damiani et al. (2010-this volume) calculated experimentally for the sand a permeability of around $3.2 \times 10^{-2}$ cm/s.

Moving away from the wave generator, the bottom of the model was unerodible and flat for about 100 m. The movable bed sloped initially at 1:20 for the following 20 m to change to 1:50 for the next 50 m. A 50 m long flat part was then shaped before reaching the beach face. The swash zone slope was 1:10 for 50 m. The drainage system consisted of four PVC drain pipes parallel to the shoreline, with a diameter of 200mm and covered by a geotextile drape: the drains (Fig. 1) are located below the emerged beach with their axis at 40 cm under the still water level and at a distance from the shoreline variable between 3 and 13 m.

![Fig. 1 GWK longitudinal cross-section. For further details see Damiani et al.-this volume](image)

Depth of Disturbance was studied installing 60 metal rods with washers along four lines spacing from the lower swash zone to the berm (Fig. 2). Readings of the depth of the washer and bed elevation were undertaken at the end of each run of waves using a graduated pin with millimetre precision. While the bed elevation was always referred to the top of the rod, the depth of the washer was measured by inserting the pin into the sand, till it was felt that the washer had been hit. The definition of the measured DoD parameters can be seen in Fig. 3.

![Fig. 2 View of the area studied for DoD](image)
Fig. 3 Definition of DoD parameters used in this paper

Beach profiles at the end of each were surveyed using a profiler mounted on a carriage that moved along the flume. The wave tests were run with irregular waves imposing to the paddle a JONSWAP spectrum (Table 1) and using variable drain configuration, eg. switching on/off one or more drains at the same time. The wave characteristics can be seen in Table 1. Still Water Level in the flume was 4.0 m. Only results from the HE (High Energy) test are discussed here.

Table 1. Wave Characteristics in deep water conditions

<table>
<thead>
<tr>
<th>Test</th>
<th>Still Water Level in the channel [m]</th>
<th>Hs [m]</th>
<th>Tp [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1-High Energy</td>
<td>4.00</td>
<td>0.8</td>
<td>6.5</td>
</tr>
<tr>
<td>A2</td>
<td>4.00</td>
<td>0.4</td>
<td>8</td>
</tr>
<tr>
<td>A3</td>
<td>4.00</td>
<td>0.6</td>
<td>8</td>
</tr>
</tbody>
</table>

3. TEST RESULTS AND DISCUSSION

Three HE tests are discussed here, respectively the beach profile configuration after 180 minutes of wave attacks with no drain (test HE_P3), after 60 minutes with 1 drain operative (test HE_1D1) and after 120 minutes with the same configuration (test HE_1D2). The water position (see Damiani et al. 2009-this volume), beach profile and sediment mixing patterns are presented in Fig. 4.

After 180 minutes the profile has eroded into a quasi-equilibrium exponential shape. The following 60 minutes of wave attack with the drain opened continues to reshape the profile with erosion of the upper beach. After 120 minutes of wave action the erosion continues in the same way and the drain seems to have a limited effect only in the area of the cone of depression of the groundwater table. It is noticeable how the hinge of rotation of the beach profile becomes located exactly in the same position where the drain is located. This is reflected on the changes in beach slope during the tests. After the wave attacks with no drain the slope of the beachface around the drain is steep (tanβ=0.10), while after the first test with the drain it becomes 0.08, decreasing further to 0.07 after the second test.

The mixing depth after the tests with no drain is rather uniform across the whole profile, with higher values around the area where the drain is located, with an average value around the drain of 18 mm. Likewise for the beach slope, the first test with the drain shows a large drop around the drain, with average of 23 mm. It is interesting to see the two maxima at the edges of the cone of depression. Finally, as time passes during the third test, a steady increase in seen (34 mm the average), possible related to the gradient of the water table between the upper beach and the drained area as the upper beach increases its saturation. Mixing depth varies from 2.2% of deepwater wave height in undrained conditions to 4.2% in drained ones (HE1_D2).
Fig. 4: a) Values of thickness of sediment mixing; b) Beach profile and water table. N.B: only line B of rods was used. P0 is the initial beach profile. The box delimits the area of action of the drain.

5. CONCLUSIONS
Preliminary analyses of the data show a role in the drainage in controlling slight beach stabilization around the drain and in increasing the thickness of sand mixing. The test examined here only considered one drain and further work will concentrate on the role of multiple drains in controlling hydraulic gradients between the upper beach and the lower swash zone.

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REFERENCES