LARGE-SCALE EXPERIMENTS ON THE SWASH ZONE RESPONSE UNDER GROUPING STORM CONDITIONS

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The modelling of swash zone sediment transport and the resulting morphodynamics has been an area of very active research over the last decade. However, many details are still to be understood, whose knowledge will be greatly advanced by the collection of high quality data under controlled large-scale laboratory conditions. The paper describes tests carried out in the large wave flume of the Maritime Engineering Laboratory (LIM) at the Catalonia University of Technology (UPC). The main aim was to investigate beach response under grouping storm conditions. Preliminary results discussed here derive from analysis conducted using only a part of the whole data set.

1. INTRODUCTION

The swash zone (SZ hereinafter) is that part of the beach alternately covered by water and exposed to air by uprush and backwash action. The time scale of the swash motion is highly variable and ranges from seconds on calm, steep and reflective beaches, to minutes on energetic, low-gradient and dissipative beaches. The SZ is characterised by strong and unsteady flows, high turbulence levels, large sediment transport rates and rapid morphological change and represents the most dynamic region of the nearshore (Masselink and Puleo, 2006).

Modelling of the hydrodynamics in the SZ has seen many advances in recent years. It is now fairly well established that swash motion is driven by both low frequency infra-gravity motions and short-period bores which collapse at the shoreline and then propagate up the beach face. The two mechanisms do not appear to be exclusive, but rather, one dominates over the other one, depending on the incident waves and foreshore slope. There have also been several observations and attempts to describe the interactions between subsequent swash waves within the SZ. Holland and Puleo (2001) recently showed that the presence or lack of swash collisions might describe whether foreshores accrete or erode (this was also suggested by Kemp, 1975). On foreshore slopes where swash excursion times are of longer duration than the incident wave period, steepening is expected to occur. In contrast, on beaches where the swash is of shorter duration than the incoming bores, erosion is expected to occur and the foreshore will be flattened. Low Frequency Wave motion (LFW) is able to affect the sediment transport as it follows: phase relationship between LFW and short waves; undulation of the water surface will cause the short waves to vary in amplitude and, therefore, also to break at different positions over the beach profile; LFW velocities will advect sediment in suspension and will also alter the bed shear stress which entrains the sediment; LFW motion will include a second order mass transport if a partial standing wave motion is set up by the reflected LFW (this will only be applicable if the motion is steady and has a narrow band spectrum); LFW are also powerful agents for removing sediment put in suspensions by breaking wind waves around Low Crested Structures, thus contributing significantly to their erosion and failure.

Regarding the influence of long/short waves, Goda (1975) suggested that this is an important phenomenon that leads to de-saturation of the surf zone at short wave frequencies. In contrast, short waves may influence free long waves in several ways such us dissipation of long wave energy by short wave turbulence, phase changes due to variations in wave set-up and changes in the reflectivity of the moving shoreline. Consequently, since long waves may strongly influence sediment transport, the influence of long wave-short wave interactions may be of significant importance for the modelling of coastal processes and the development of morphological features such as bars.

Baldock et al. (1997) measured surface elevations in the inner surf zone and swash oscillations on a steep beach of 1:10 using regular waves, bichromatic wave groups and irregular waves. They found for bichromatic wave groups that much of the incident wave grouping remains both at the still water shoreline (SWS) and within the swash and that the shoreline motion is modulated at the incident wave group frequency. They also found that the swash oscillation driven by the bichromatic wave groups on the 1:10 slope is largely dominated by low-frequency motions.

Both bichromatic and random (JONSWAP) waves were used by Brocchini and Bellotti (2002) to evaluate and simplify a theoretical model of Shoreline Boundary Conditions to be used as SZ boundary in wave-averaged nearshore circulation models.

This paper will describe large scale model tests conducted at the Maritime Engineering Laboratory (LIM) at the Catalonia University of Technology (UPC). During the tests the shoreline response and the SZ hydrodynamics was carefully monitored when grouping waves, able to generate free waves and energy in the high frequency part of the spectra, impact on the controlled area.

2. EXPERIMENTAL SET UP

The model tests were carried out at the Catalonia University of Technology (UPC). The large-scale wave flume has a length of 100 m, a width of 3 m and a depth of 5 m. Controlled wave generation is achieved by a wedge type wave paddle, particularly suited for intermediate-depth waves. The control software allows the generation of regular and irregular waves.

The bathymetry in the flume was formed by moulding sand over fill in the channel to the required shape. From deep water near the paddle, the seabed was flat for about 20 m than it sloped initially at 1:10 for 10 m to change for a more gentle slope of 1:15. The used sediment consisted of a medium sand having a measured d_{50} equal to 246µm (measured fall velocity of 34 mm/s). The water depth at the toe of the paddle was fixed to about 2.5 m. Fourteen wave conditions (regular monochromatic, combination of free standing long waves plus monochromatic short waves, bichromatic waves, random waves with different Groupiness Factor) were run (Tab. 1).

Tab. 1: Wave Characteristics

Erosive Conditions				Accretive conditions			
Test number	H (m)	T (s)	Wave type	Test number	H (m)	T (s)	Wave type
M1	0.37	3.7	monochromatic	M2	0.226	6	monochromatic
C2	0.37 0.038	3.7 30	combination	C9	0.226 0.038	6 30	combination
C4	0.37 0.038	3.7 15	combination	C10	0.226 0.038	6 15	combination
B3	0.26 0.26	3.9 3.5	Bi-chromatic	B11	0.16 0.16	6.6 5.4	Bi-chromatic
B5	0.26 0.26	4.2 3.3	Bi-chromatic	B13	0.16 0.16	7.1 4.9	Bi-chromatic
R1GF1	0.53	4.1	Random GF=1	R2GF1	0.319	6.7	Random GF=0.96
R1GF2	0.53	4.1	Random GF=1.1	R2GF2	0.319	6.7	Random GF=1.08

Several "reshaping tests" were performed to reshape the beach at the end of each test. Tests were composed by four steps with different duration: step one and two of 30 minutes duration while three and four of 1 hour duration.

The following instruments have been installed/used in the controlled SZ: 1 beach profiler, 6 Acoustic Doppler Velocimeter, 10 Resistant Wave Gauges, 8 Micro Acoustic Wave Gauges, 4 Acoustic Wave Gauges, 8 Optical Backscatter Sensor, 6 Electromagnetic Current Meters, 6 Pressure Sensors. ADV were sampled at 100 Hz and all the other instruments were sampled at 20 Hz.

The detailed flume set up, instrumentation and complete tests description is reported in Vicinanza et al (2009).

3. PRELIMINARY RESULTS

Beach profiles were analyzed and preliminary results for erosive conditions can be summarised as it follows:

The comparison between initial (B3_0, B5_0) and final profile (B3_4, B5_4) for Bi-chromatic waves (B3, B5) give much more erosion and offshore transport than the equivalent monochromatic erosive case (M1) (Fig. 1 and Fig. 2). Bi-chromatic waves with smaller differences between frequencies of components (B3) give much more offshore transport than the Bi-chromatic waves with larger differences between the frequencies of the components (B5). Furthermore, B3 conditions gives a large erosion in the offshore portion of the domain (bar); B5 gives much more erosion on the beach portion above the bar but creates a sand accumulation in the emerged beach.

The comparison between the combination cases C4 and the equivalent monochromatic M1 (Fig. 3) suggests that the long wave widens the region where sediment transport takes place, but does not change the pattern much. The random wave R1GF1 gives a transport pattern similar to that of the Bi-chromatic wave groups B5 (Fig. 4). The good consistency between Bi-chromatic experiments and random wave experiments gives confidence in the data.

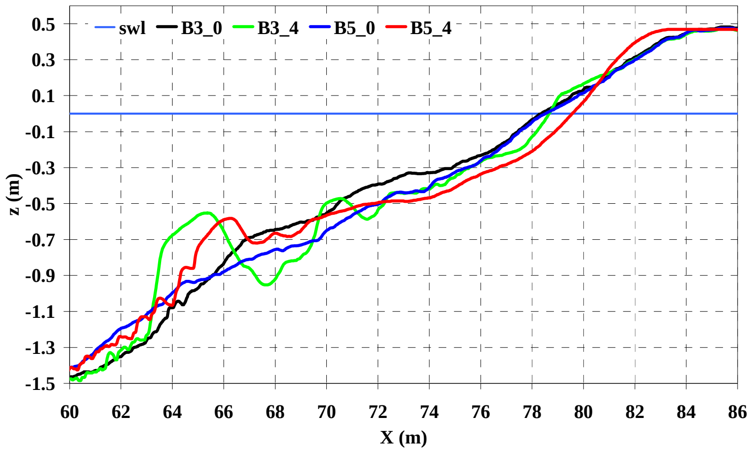

Fig. 1: Beach profile comparison for test B3 and B5

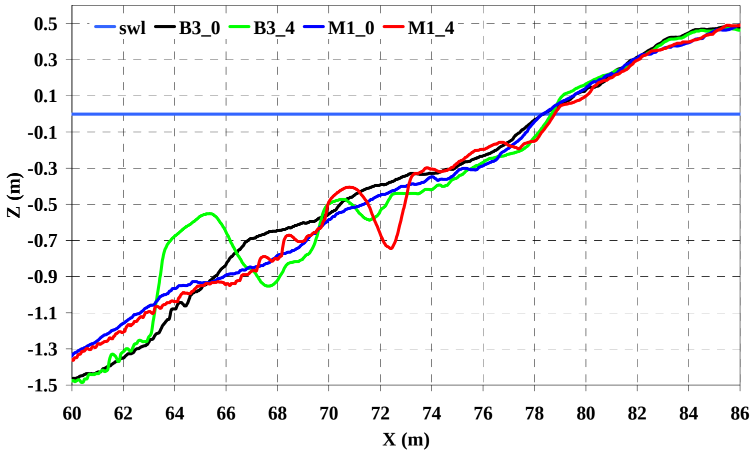

Fig. 2: Beach profile comparison for test B3 and M1

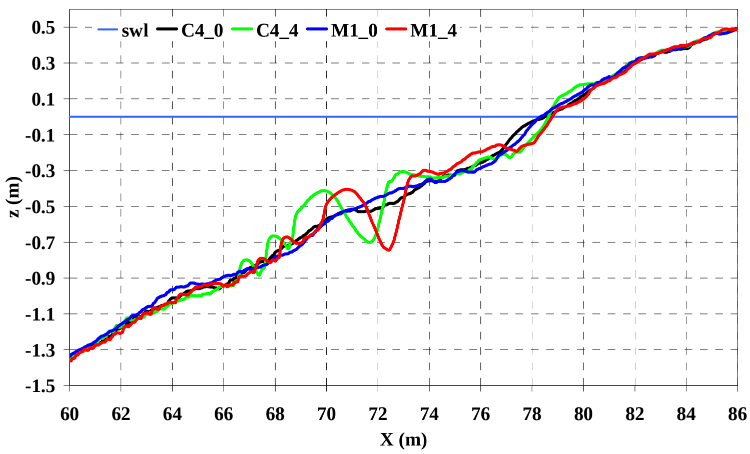

Fig. 3: Beach profile comparison for test C4 and M1

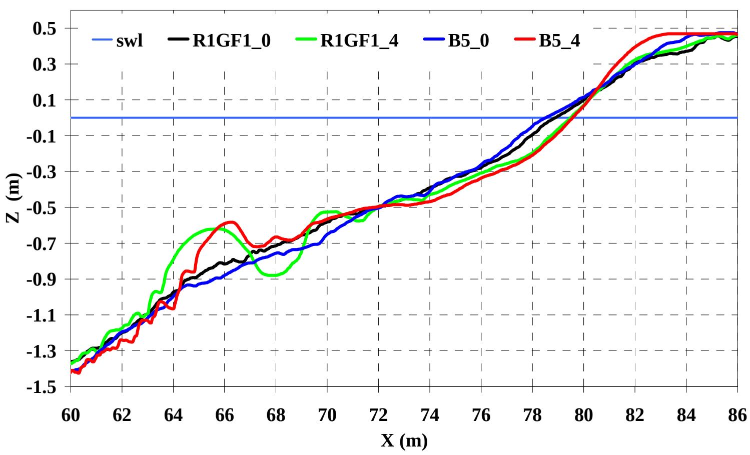

Fig. 4: Beach profile comparison for test R1GF1 and B5

ACKNOWLEDGEMENT

This work has been supported by European Community's Sixth Framework Programme through the grant to the budget of the Integrated Infrastructure Initiative HYDRALAB III within the Transnational Access Activities, Contract no. 022441.

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