THE "CROSSOVER" PROJECT: WAVE OVERTOPPING UNDER DIRECTIONALLY BIMODAL WAVE ATTACK

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SUMMARY
It is common for the local sea state in coastal waters to be a complex combination of waves due to local and recent wind (the "sea") and long period waves resulting from earlier weather systems, which have travelled many 100s of km with little attenuation of these very long waves (the "swell"). Sea and swell may have very different directions and periods (Fig. 1).

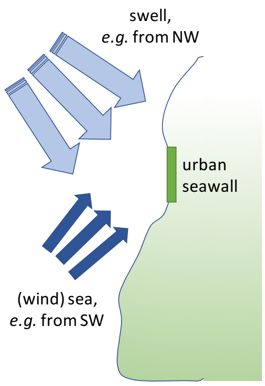

Figure 1: Seawall exposed to crossing sea and swell.

The *CrossOver* project was born out of the recognition that there is an absence of guidance on the influence of directionally bimodal (or bidirectional, or 'crossing') seas on wave overtopping at a coastal defence. Through a physical model study carried out in the Delta Basin, the "CrossOver" project is beginning to fill this gap in the knowledge.

BIDIRECTIONAL ('CROSSING') SEAS NEAR THE COAST

Bidirectional seas are well-reported in the oceanographic literature, but few studies in coastal waters are found. Alves & Melo (1999) report reconstructed bidirectional seas at the coast at Santa Catarina state, Brazil - a study being revisited by researchers at Univ. Cantabria (Figure 2) at the time of writing. Also in a coastal setting, Long & Resio (2007) report measured bidirectional spectra off the North Carolina coast, USA. More recently, investigation into damage at the Civitavecchia breakwater has included bidirectional seas (Artelia, 2012).

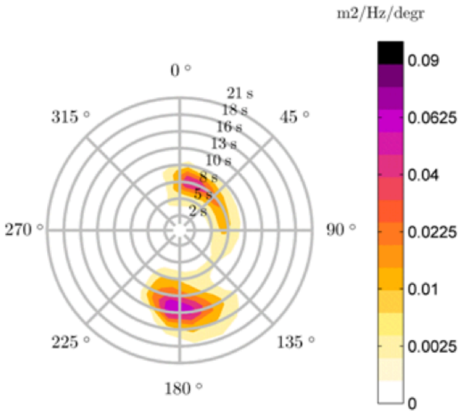

Figure 2: Bidirectional spectrum simulated from weather records, southern Brazilian coast.

OVERTOPPING KNOWLEDGE "WHITE SPOTS"

Defences whose geometry is simple can be analysed by using formulae from *e.g.* EurOtop (2016). For more complex structures, the CLASH Artificial Neural Network (ANN) (Van Gent *et al.*, 2007) is a key tool. The ANN is based upon the CLASH database of *c.*10500 laboratory measurements of overtopping (Van der Meer *et al.*, 2009) but these are not distributed uniformly across the range of conditions found at real coastlines (Table 1).

Table 1: Indicative numbers of overtopping tests in the CLASH database according to sea conditions. The highlighted cells correspond to the most common situations in nature.

	long-crested seas	short-crested seas	bidirectional
2-d	9200	n/a	n/a
3-d	1300	40	0

The paucity of testing under the more realistic conditions is due to the fact that their reproduction in wave basins has hitherto been limited to a very few facilities, and has been almost impossible for very large angle differences between swell and wind seas. The Delta Basin at Deltares with its two banks of wavemakers set at 90 degrees to each other is ideally suited to enabling the filling of this gap in the knowledge. Prior to this project, the basin had been used to explore overtopping with crossing sea and swell at $\pm 45^{\circ}$ obliquities (Van der Werf & Van Gent, 2018), with a prediction method proposed tentatively.

THE "CROSSOVER" PROJECT

Awarded access to the Delta Basin by the EC *Hydralab+* project, "CrossOver" has, at the time of writing, completed around 80 of 160 tests measuring mean and wave-by-wave overtopping at a 1:3 slope. The tests explore conditions with just the swell sea oblique, and with both wind and swell seas oblique and crossing at variable angles ranging from 15° to 75°. This paper will be the first description of this international project and its initial findings.

TEST SET-UP

The layout of the sloping structure in the Delta Basin is sketched in Figure 3. The structure is set at a 30° angle across that basin rather than at 45° in order that head on (zero obliquity) seas and swells could be generated. The structure is a 40m long 1:3 simple slope, in a water depth of 0.95m, and with a crest freeboard of 0.2m. The large 100-paddle bank of wave makers is used to generate bidirectional sea and swell for all but the most extreme obliquities. The older 80-paddle bank of wave makers is used to generate sea and swell from -60° and -75°. For all other tests, this paddle bank is nevertheless active in absorption mode.

Six overtopping collection tanks are arranged along the central 10m run of the structure, equispaced at 2m (centre to centre) intervals. Mean discharge is measured using elevation probes in each collection tank. In addition, one tank has an additional probe mounted at the crest as an overtopping event detector

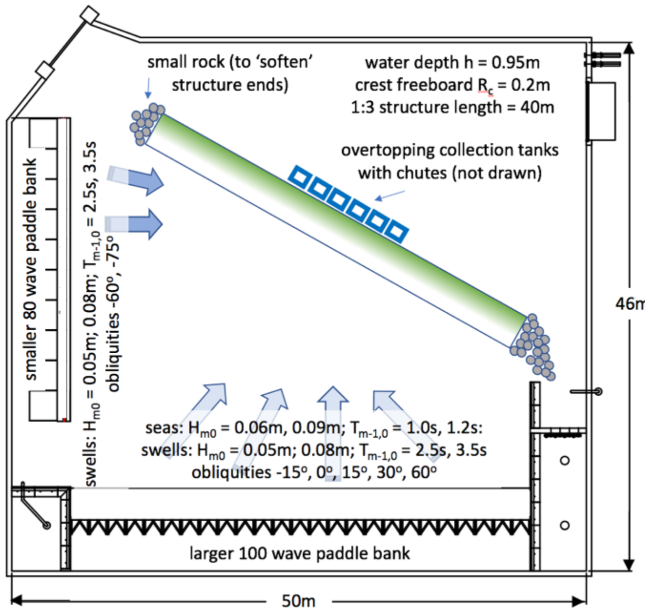

Figure 3: Sketch of the layout of the structure in the Delta Basin. Not to scale.

Figure 4: 1:3 smooth slope, with last author (1.8m high).

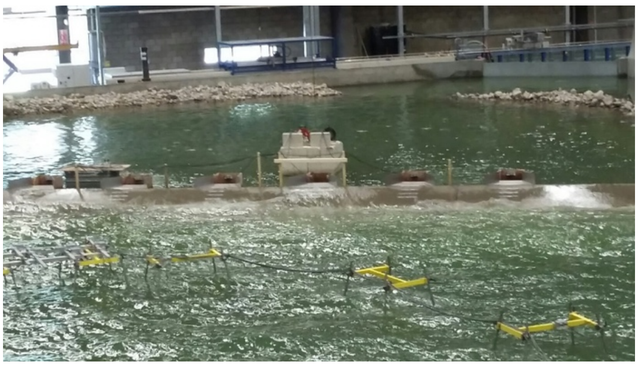

Figure 5: Photograph of testing, showing the six overtopping collection tanks.

METHODOLOGY AND TEST MATRIX

The seas and swells are calibrated separately using three directional wave gauges, one each in front of each paddle bank and 4m offshore of the toe of the centre of the structure. After calibration tests, a set of 44 tests was carried out:

- sea and swell from same direction (12 tests)
- sea normal, swell oblique (8)
- swell normal, sea oblique (8)
- crossing; sea and swell oblique and opposed (16)

All seas and swells were short-crested, with spreading of 30^{o} and 10^{o} respectively.

RESULTS

The data is being gathered at the time of writing. Figure 6 shows an example of the overtopping gathered at the six collection tanks during a typical test with crossing seas. The action of the submerged pump during the test is clear.

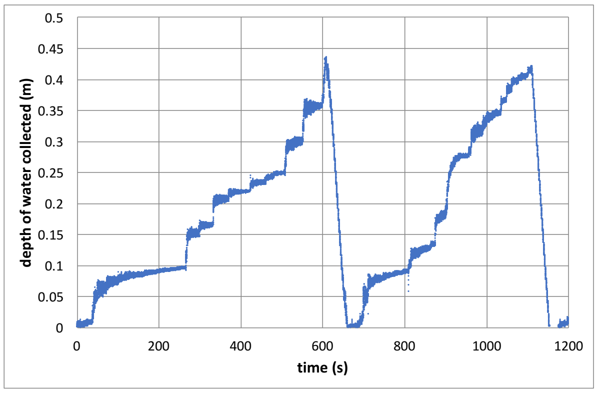

Figure 5: Example overtopping collection tank depth vs. time data. Test 5.6; swell normal; sea obliquity = 60^{o}.

The paper will present early findings of the data analysis, including a tentative formulation for the influence factor for bidirectional seas, γ_x.

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