Violent Overtopping of Waves at Seawalls (VOWS)

- Physical Model Study

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Figure 1: Heugh Breakwater, Hartlepool, UK
(Photo courtesy George Motyka, HR Wallingford)

Why is VOWS needed?

Many coastal seawalls are designed for a (tolerable) mean discharge to overtop the structure over a storm event. Prediction of mean overtopping discharge rates are based on empirical formulae fitted to laboratory measurements. These formulae mainly cover pulsating wave conditions, but studies by Besley et al (1998) have indicated configurations of vertical and composite walls for which impulsive breaking may occur, and have demonstrated that present methods may under-estimate overtopping under impact conditions.

Importantly, impulsive breaking leads to sudden overtopping where water is thrown landward at considerable velocity. Such events have overturned railway wagons on a breakwater (Dover 1942), cars / vans have been swept into the sea (Port Talbot 1985), small buildings destroyed (Seaford 1996), and people drowned (Alderney 1992). These processes show great potential to cause damage to developments close to the defence, but little generic guidance is available to predict the magnitude and effects of such events.

Analysis by Besley et al (1998) extended research by Allsop et al (1996), and previously Franco et al (1994) to develop new methods to predict peak overtopping volumes. These show that peak volumes and flow velocities are strongly influenced by the form of wave breaking, but reliable design methods are not yet available for a significant range of structures. Allsop et al (1996) showed that impulsive breaking is particularly severe for steep or vertical walls with steep beaches or rock mounds. Analysis by Besley et al, (1998) developed guidance on peak overtopping discharges or volumes, but showed that present methods may significantly under-estimate volumes under impulsive wave breaking.

VOWS objectives

This collaborative project will develop new / improved prediction formulae for mean and peak overtopping discharges where impact breaking is significant. For the first time, systematic measurements have been made of throw velocities and distances to develop predictive methods for velocities / trajectories for safety assessments. Physical model tests are complemented by numerical modelling by project partners Causon and Ingram, early results of which are reported by (Causon & Ingram, 2000).

As part of continuing research, the 2-d tests reported here will be extended to include the study of further representative structures, eg a 45^0 slope, a battered wall and a wall with recurve. Testing will then move to a 3-d wave basin in which the effect of non-uniform approach bathymetries and complex plan geometries (eg wall bends and elbows) will be investigated.

The VOWS team

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The Industrial Supporters

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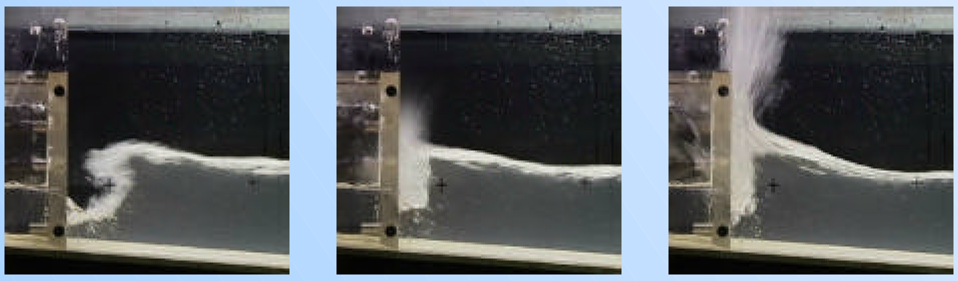
Bullen Consultants	Mark Breen Dominic Hames

Project Manager Michael Owen

Figure 2: Overtopping of seawall onto main railway - Saltcoats, Scotland (photo: Alan Brampton)



Throw velocities / energies

As part of the 2-d flume testing at Edinburgh, the velocity and the trajectory of the thrown discharge have been quantified. Velocities of up to c. 40 ms^{-1} (scaled) have been measured for impulsive events such as that illustrated in Figure 3.

Figure 3 (left): An impulsive overtopping event

Results: vertical wall

Mean overtopping discharge measurements (Figure 4) show good agreement with Besley et al's (1998) method over the range of test conditions studied.

The variation of the percentage of overtopping waves with freeboard for the plain vertical wall is shown in Figure 5. These new data are however in relatively good agreement (typically to within a factor of 2) with previous prediction methods.

Maximum individual overtopping volumes predicted using methods by Besley (1999) are compared in Figure 6 with those measured. It would appear that maxima are well predicted, typically to within a factor of 2.

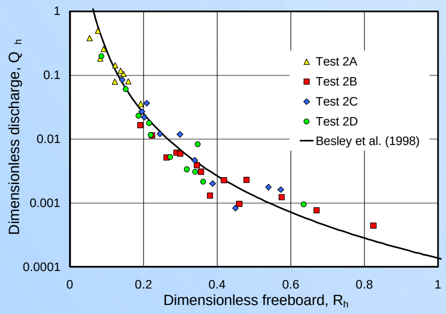


Figure 4: Comparison of mean overtopping discharge on plain vertical structures.

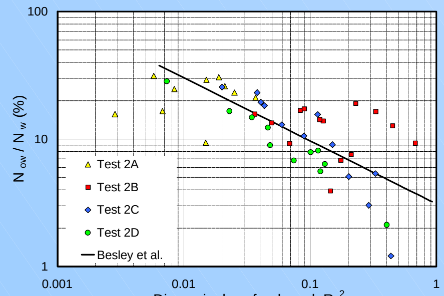


Figure 5: Number of waves overtopping on plain vertical structures

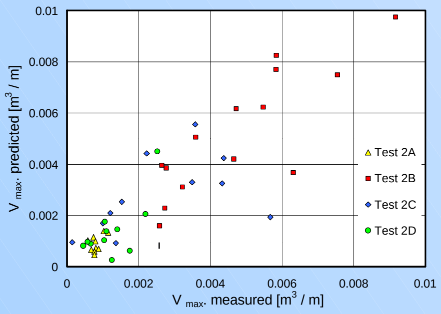


Figure 6: Correlation between predicted and maximum measured individual overtopping volume

Impulsive deck pressures

Following reports of damage to breakwater decks or seawall promenades at sites including Peterhead, St Andrews and Burnmouth, physical model study has measured pressures experienced on the horizontal deck of a breakwater under violent wave overtopping conditions.

Figure 7 shows a probabilistic representation of deck pressures measured at two locations for one particular 1000-wave sequence. Location 1 is 65mm back from the seaward edge; location 2 a further 65mm back. The data shows two populations, with pressures at the seaward location the greater by an order of magnitude.

Early conclusions are that the maximum deck pressures are of the same order of magnitude as the maxima on the front face. Maximum pressures are typically experienced within c. 1.5 H$_{si}$ of the seaward edge of the structure.

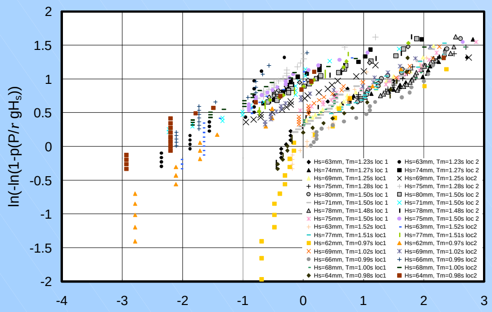


Figure 7: Pressures on deck; probabilistic analysis of raw pressure data

Conclusions

The number of overtopping waves and mean discharge are not significantly affected by the transition from impulsive to pulsating conditions, remaining well predicted (typically within a factor of 2) by Besley et al (1998).

Besley (1999) appears to be a good predictor of individual overtopping volumes under impulsive conditions.

Further work is needed to understand overtopping mechanisms over different structure types and identify the forms of waves responsible for the largest overtopping and largest throw velocities and ranges.

VOWS: next moves

3-d wave basin tests at HR Wallingford will test the effect of the plan geometry of the wall, eg, the effect of bends / elbows.

Large-scale flume tests at *WAVELAB (UPC/LIM, Barcelona)* will study scaling effects. The nature of impulsive overtopping is such that the form of discharge ranges from green water to spray. A thorough investigation of scaling effects is therefore of great importance.

Keeping in touch

www.vows.ac.uk

VOWS - thanks

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