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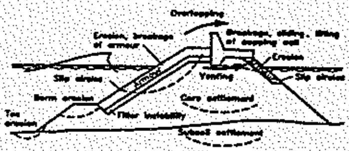


Rubble Mound Breakwater Failure Modes (Contract: MAS2-CT92-0042)

2-D model test of Dolosse Breakwater

AU Denmark
January 1994

1 Introduction

The rational design diagram for Dolos armour should incorporate both the hydraulic stability and the structural integrity.

The previous tests performed by Aalborg University (AU) made available such design diagram for the trunk of Dolos breakwater without superstructures (Burcharth et al. 1992).

To extend the design diagram to cover Dolos breakwaters with superstructure, 2-D model tests of Dolos breakwater with wave wall is included in the project *Rubble Mound Breakwater Failure Modes* sponsored by the Directorate General XII of the Commission of the European Communities under Contract MAS-CT92-0042.

Furthermore, Task IA will give the design diagram for Tetrapod breakwaters without a superstructure. The more complete research results on Dolosse can certainly give some insight into the behaviour of Tetrapods armour layer of the breakwaters with superstructure.

The main part of the experiment was on the Dolos breakwater with a high superstructure, where there was almost no overtopping. This case is believed to be the most dangerous one.

The test of the Dolos breakwater with a low superstructure was also performed.

The objective of the last part of the experiment is to investigate the influence of the method of placing and packing the blocks on the hydraulic stability. The Dolosse were more carefully put on the slope and the hydraulic stability of such slope was compared with that of the more randomly packed slope.

The whole experiment was carried out in the period of August - November 1993. The analysis on the hydraulic stability has been finished while the stresses analysis is under way.

2 Test set-up

A 1 : 1.5 slope armoured with 200 g concrete Dolosse of waist ratios 0.37 was exposed to irregular wave in a wave flume with a foreshore slope of 1 : 20. Fig. 1 shows the layout of the model and the cross section of the breakwater.

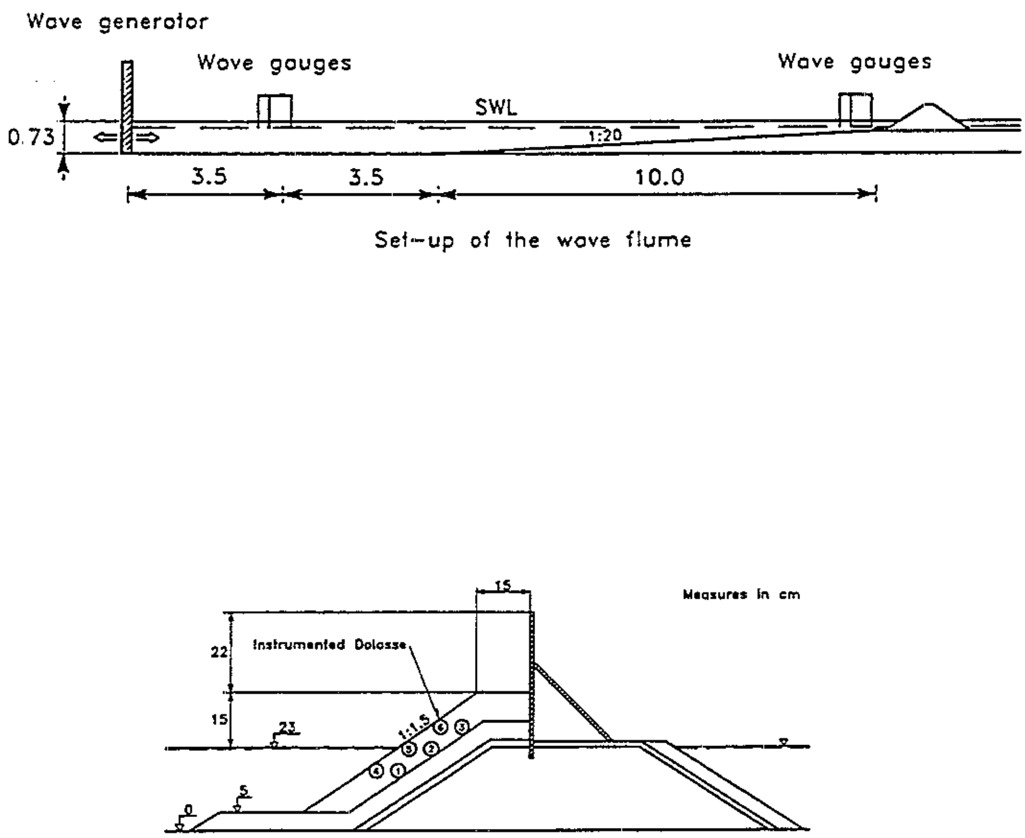


Fig. 1. Lay-out of the round head in wave basin

To compensate for reflected waves two arrays of three wave gauges were installed, both in front of the wave paddle and in front of the structure. The incident wave spectrum was calculated by the least square method presented by Mansard et al., 1980. In the following the wave height refers to the incident one.

The irregular waves were generated by a piston type paddle according to the five parameter JONSWAP spectrum. Table 1 lists the characteristics of the applied waves propagating towards the breakwater recorded at the paddle and at the toe of the breakwater. T_p is the spectral peak period, $\xi_{mo} = \left(\frac{H^t_{mo}}{L_{p0}}\right)^{-0.5} tan\alpha$, where L_{po} is the deep water wave length corresponding to T_p.

Table 1. H_{m0}, T_p and ξ_{mo}

H^p_{m0}	at the paddle	(cm)	5 - 15
H^t_{m0}	at the toe	(cm)	5.7 - 17.5
T_p	at the paddle	(sec)	1.5 - 3
ξ_{mo}			3.0 - 6.0

The experiments were performed in series in which the wave height was increased step by step. The run time for each step was 5 minutes.

For each combination of H_{m0} and T_p the number of runs was 10. Each run started with the slope rebuilt. Because there were only 3 instrumented Dolosse, the actual number of runs for the stress recording is 5.

In order to study the hydraulic stability of the Dolos armour layers a grid was put parallel to the breakwater slope before and after wave attack and photos were taken. All displacements could then be visually registered.

The load cell instrumented concrete Dolosse were calibrated for impact loaded conditions using prototype impact test data and were checked for dynamic amplification, cf. Burcharth et al. 1990. They were put in 6 positions on the slope as shown in Fig. 1.

The natural frequency of the instrumented Dolosse was found to be app. 1,500 Hz by the impact calibrations. The sampling frequency in the wave flume test was 6,000 Hz, i.e. app. 4 times of the natural frequency of the instrumented Dolosse. Theoretical investigations showed that on average the sampled peak stresses were lower than the real ones by 10% due to the limit of the sampling frequency. This one sided bias has been corrected for in the data processing.

3 Hydraulic stability of Dolos armour

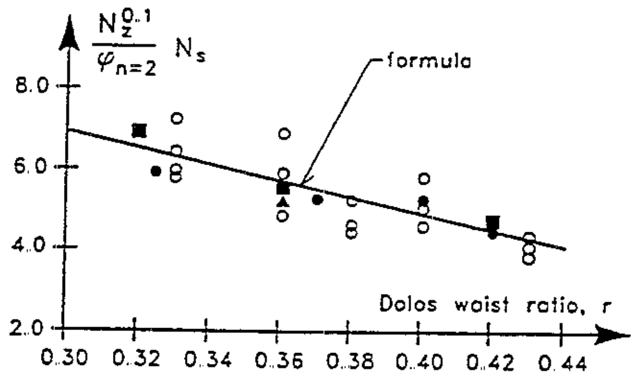
Breakwater without superstructure

The following formula for hydraulic stability of Dolos armour on slope 1 : 1.5 is based on Brorsen et al. 1974, Burcharth et al. 1986, Holtzhausen et al. 1990 and Burcharth et al. 1992 (Burcharth et al. 1992).

$$N_s = \frac{H_s}{\Delta D_n} = (47 - 72\,r)\,\varphi_{n=2} D^{1/3} N_z^{-0.1} \tag{1}$$

where	H_s	significant wave height in front of breakwater
	Δ	$(\rho_{concrete}/\rho_{water}) - 1$, ρ is the mass density
	D_n	length of cube with the same volume as Dolosse
	r	Dolos waist ratio
	$\varphi_{n=2}$	packing density
	D	relative number of units within levels SWL $\pm$ 6.5 Dn displaced one Dolos height h, or more (e.g. for 2% displacement insert $D = 0.02$)
	N_z	number of waves. For $N_z \geq 3000$ use $N_z = 3000$.

Fig. 2 shows the case corresponding to damage level of 2% displacement.



Legend:

Reference	$\varphi_{n=2}$	Repeated No	Duration (min.)	ξ_{mo}
▲ Brorsen et al. (1974)	1 (App.)	2	60	2.49–5.37
■ Burcharth et al. (1986)	0.61–0.7	5 or 15	20	3.04–4.49
○ Holtzhausen et al. (1990)	1	3 or 8	60	2.91–7.6
● Burcharth et al. (1992)	0.74	20	5	3.23–11.7

Fig. 2. Hydraulic stability of two layer randomly placed Dolos armour on a slope of 1 : 1.5. *Damage level,* $D = 2\%$ *displaced units within levels SWL* $\pm 6.5 D_n$. *Note that the data points are average of repeated tests, cf. the legend.*

The formula covers both breaking and non-breaking wave conditions, with the limits given by

$$\begin{array}{ccccc} 0.32 & < & r & < & 0.43 \\ 0.61 & < & \varphi_{n=2} & < & 1 \\ 1\% & < & D & < & 15\% \end{array}$$

The uncertainty of the formula is estimated to correspond to a variational coefficient of 0.2. If the PIANC partial coefficient system is used (Burcharth 1991) the design equation reads

$$\frac{1}{\gamma_z} \Delta D_n (47 - 72\, r) \varphi_{n=2} D^{1/3} N_z^{-0.1} \geq \gamma_{H_s} H_s^T \tag{2}$$

For the calculation of the partial coefficients γ_z and γ_{H_s} the coefficient values $k_\alpha = 0.025$ and $k_\beta = 38$ should be used

Breakwater with a high superstructure

The experiment was performed on the Dolosse with waist ratio of 0.37. In the experiment, severe damage was observed from SWL to the shoulder of the breakwater. The reason is that the up-rush, after returned by the superstructure, drops on that area with high velocity. The damage is more severe than the case of the breakwater without superstructures. In order to compare with the previous test, the test area is extended to SWL ± 6.5 *Dn* under the assumption that no displacement takes place in the extended area. The results are shown in Fig.3, where the fitted curve is written as

$$D = 0.0045 \left(\frac{H_s}{H_D}\right)^3 \qquad (3)$$

where $H_D = 0.075m$ is the Dolos height.

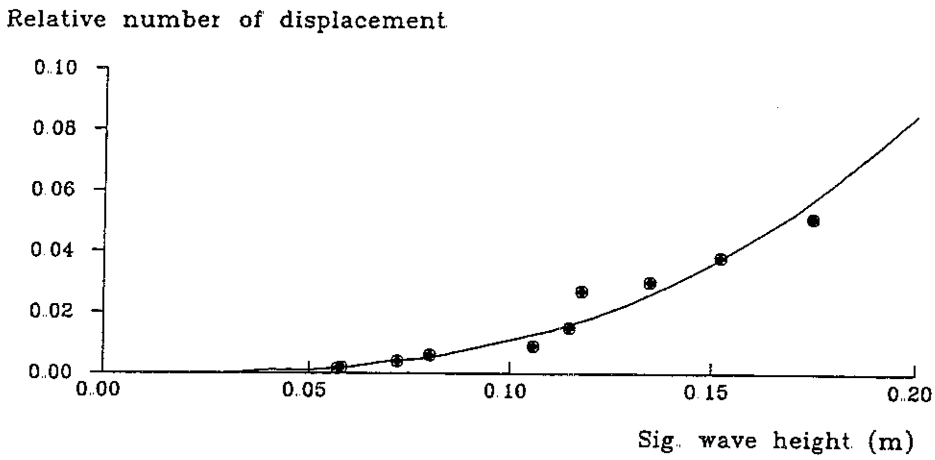


Fig. 3. D vs. H^t_{mo} of Dolosse breakwater with a high superstructure. Dolos waist ratio 0.37.

Assume the same influence of Dolos waist ratio, packing density and wave duration on the hydraulic stability as found in the breakwater without superstructure, the formula is modified as

$$N_s = \frac{H_s}{\Delta D_n} = (43 - 66\,r)\,\varphi_{n=2} D^{1/3} N_z^{-0.1} \qquad (4)$$

Breakwater with a low superstructure

The same experiment was performed on the Dolos breakwater with a low superstructure. The test parameters are the same as shown in Table 1 except that only one peak period $T_p = 1.5$ was applied. In this case, the superstructure is so low that there was significant amount of water overtopping. Consequently, the damage to the armour layer is less severe than the high breakwater without superstructure and the breakwater with a high superstructure, cf. Fig.4.

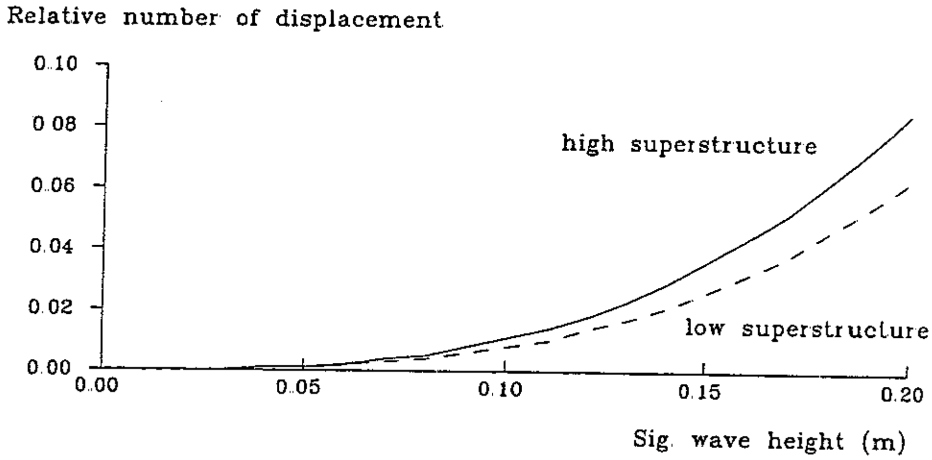


Fig. 4. Comparison of low superstructure with high superstructure

Carefully packed

Under the case of the breakwater with a low superstructure, the same experiment was carried out with a very carefully packed Dolos armour layer. First the Dolosse were put uniformly on the slope to form the bottom layer, then the other Dolosse were put carefully to fill the gap to form the top layer. Significant improvement in the hydraulic stability of the amour layer was observed, cf. Fig.5. Even though no stress recording was carried out, it is believed that the structural integrity will be enhanced because it has been found before that the Dolos breakage involves the significant stress contribution from impact actions.

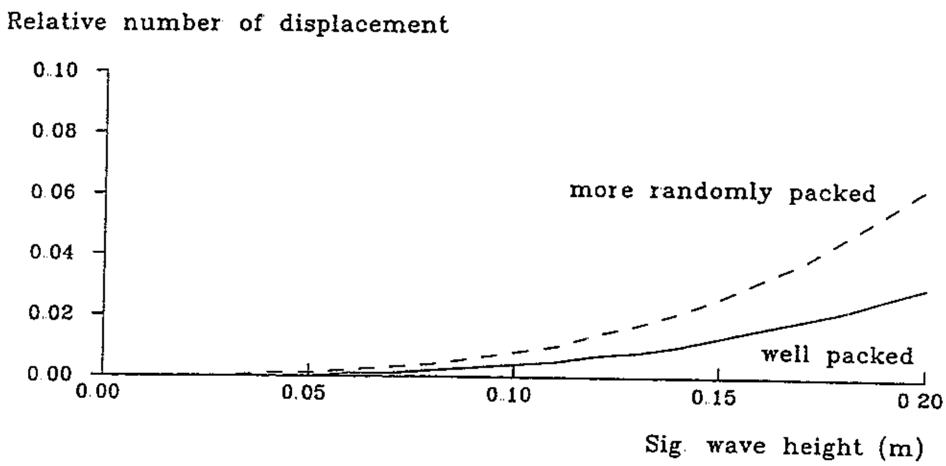


Fig. 5. Comparison of well packed slope with more randomly packed slope. Low superstructure

4 References

Burcharth, H.F., Liu, Z. , 1992. *Design formulae for hydraulic and structural stability of Dolos armour*. Proceeding of the 23th International Conference on Coastal Engineering, Venice. Italy