Choice of Safety Levels for Conventional Breakwaters

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CHOICE OF SAFETY LEVELS FOR CONVENTIONAL BREAKWATERS

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ABSTRACT

1. INTRODUCTION

Guidance on selection of breakwater types and related design safety levels for breakwaters are almost non-existent. The selection of type of breakwater is mainly based on the functional requirements and the local environmental conditions including material supply possibilities. The involved very wide range of aspects makes it almost impossible to formulate simple rules for optimum selection of breakwater type. However, when selected, it is possible to give some guidance on the optimum safety levels for the chosen type of structure.

The Spanish Recommendations for Maritime Structures, ROM 0.00, provides rational recommendations for safety levels linked to the functional and the economical importance of the structure. However, the figures given must be regarded as tentative until more systematic investigations on optimum safety levels have been performed.

The present paper contributes to such systematic investigations by presenting and discussing optimum safety levels for conventional rubble mound breakwaters and vertical wall caisson breakwaters. The optimization is based on minimization of the total costs over the service life of the structure. This includes initial and repair costs as well as downtime costs. Numerical simulation technique is used with implementation of uncertainties on wave loads and structure responses. The optimum safety levels are linked to design limit states chosen to be: ULS, ultimate limit state corresponding to very severe damage (failure), RLS, repairable limit state corresponding to moderate damage, and SLS, serviceability limit state corresponding to the limit for damage not affecting the function of the breakwater.
Breakwaters belong typically to a low safety class where consequences of a failure imply no risk of human injury but some economic and maybe environmental consequences. The presented optimum safety levels are related to this safety class.
The present paper is an extension of Burcharth et al (2005).

2. RESULTS

Some main results are given in the following.

Dependence of lifetime costs on structure safety
Fig. 1 shows a typical example of total lifetime costs as function of structure safety in terms of mass of the armour blocks in a rubble mound breakwater.

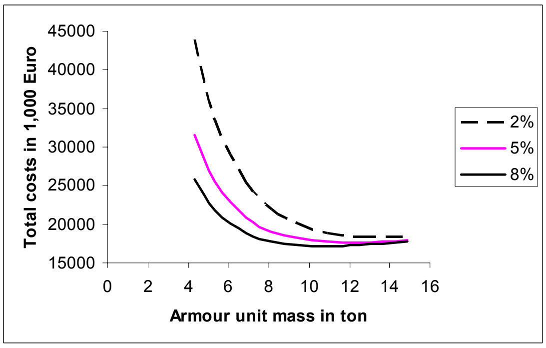

Figure 1. Example of total costs in 50 years lifetime for a rubble mound breakwater in 15 m water depth as function of real interest rates.

Figure 1 shows for real interest rates in the range 2 % - 8 % very flat minima of total costs as function of armour unit mass. Thus it is less important to identify the exact optimum safety level. As a consequence it is generally preferable to choose a conservative design in order to reduce political and financial inconveniences related to repairs.

Table 1. Optimum safety levels for a cube armoured rubble mound breakwater. 50 years service lifetime. Damage accumulation included.

Real Interest Rate (%)	Downtime costs	Deterministic design data				Optimum limit state average number of events within service lifetime			Construction costs for 1 km length (1,000 EURO)	Total lifetime costs for 1 km length (1,000 EURO)
		Optimum design return period, T (years)	H_s^T (m)	Armour unit mass W (t)	Free-board Rc (m)	SLS	RLS	ULS		
2	None	1000	6,56	14,8	5,6	0.54	0.027	0.0034	17,490	18,365
5		400	6,20	12,5	5,6	1,10	0.007	0.0014	16,683	17,609
8		200	5.92	10,9	5,6	1,81	0.015	0.0035	16,230	17,192
2	200,000 USD per day in 3 months	1000	6,56	14,8	5,6	0.54	0.027	0.0034	17,490	18,378
5		400	6,20	12,5	5,6	1,10	0.007	0.0014	16,683	17,667
8		200	5.92	10,9	5,6	1,81	0.015	0.0035	16,230	17,284

Influence of interest rate

The optimum safety levels decrease rather significantly with increasing interest rate, as illustrated in Fig. 1.

Optimum safety levels and influence of downtime costs

Table 1, which covers the same case as Fig. 1, shows that optimum safety levels correspond to exceedence of SLS in average between app. 0.46 and 1.11 times in 50 years lifetime, dependent on the interest rate. Analyses of a wider range of rubble mound breakwaters show that the typical optimum range for this type of structures corresponds to app. 0.5 – 2.5 exceedences of SLS in 50 years.

Table 1 also shows that when designing rubble mound breakwaters for the SLS safety level, the probability of occurrences of RLS and ULS are very small. A consequence of this is that downtime costs, which are related to more severe damages, have little influence on optimum safety levels, even if these costs are considerable. This is illustrated in Table 1, which shows unchanged optimum safety levels even if downtime costs of 200,000 USD per day in three month occurs when the RLS is exceeded.

Influence of damage accumulation on optimum safety levels

The simulations show that the choice of model for rubble mound armour layer damage accumulation has significant influence on optimum safety levels. This is more significant in shallow water due to the more frequent occurrence of maximum waves.

Application of the identified optimum safety levels

The optimum safety levels identified in the analyses are closely related to the applied stochastic models. Therefore, these models should be used in the design together with the identified safety levels. The models, which are conventional, will be explained in the paper.

3. ACKNOWLEDGEMENT

The authors appreciate the discussions in the PIANC Working Group 47 on Criteria for the Selection of Breakwater Types and their Optimum Design Safety Levels.

4. REFERENCES

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