OPTIMIZED ROCK GROYNE DESIGN FOR LONG-PERIOD SHIP WAVE LOADS

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GROYNE DAMAGE AT ESTUARINE WATERWAYS

Increased severity of damage to estuarine rock structures such as groynes, training walls and revetments have been observed across the major German estuaries during the past two decades (e.g. BAW 2012). These damages are predominantly caused by long-period primary ship waves, which can result in load cases that are particularly erosive to the rock armour layer. Ship-induced loads have become the most relevant hydraulic loading in large parts of German estuaries and - with ever increasing traffic frequency and vessel size - it is expected to increase further. However, to date no practical design method exists to dimension structures for long-period ship wave loads. This study aims at (i) assessing the suitability of a groyne design optimized for resistance to ship-induced waves to provide a practical solution to the responsible authorities and (ii) collecting data which allow for the characterisation of wave-structure-interaction as well as loads and damage (resistance) parameters for the future development of validated design methods.

OPTIMIZED DESIGN

Based on the characteristic pattern of damage observed at deteriorated groynes an optimized design was developed. This design accounts for the vulnerability of the groyne root and crest areas to high-velocity overtopping flow and was investigated in BAW 2015. To allow wave energy to bypass the structure, the transition area from groyne body to revetment is fashioned as a wide recess secured with scour protection (Figure 1). In addition, the design includes shallower slope angles and a reduced crest width.

Figure 1 - Prototype recessed groyne in the estuarine waterway of the Lower Elbe, Germany.

FIELD EXPERIMENT

After testing the performance of optimized design variants in hydraulic scale-model experiments, a prototype recessed groyne was built in the estuarine waterway of the Elbe, at a location highly exposed to ship-induced waves. A monitoring programme was implemented which included recording of structural damage, wave height, overflow velocity on the crest, parameters for individual ship passages and topographic surveys of the adjacent groyne fields. After 21 months of experiment some damage was observed at the prototype. The armour layer was subsequently re-profiled using a larger rock grading and monitored for another 15 months. No further damage has been observed.

RESULTS AND CONCLUSIONS

Results indicate that the modifications to groyne geometry are effective in reducing hydrodynamic loads and increasing armour layer stability in vulnerable areas of the groyne (Melling et al., 2020). The recessed groyne showed significantly less damage compared to a reference groyne, without negatively affecting its functionality. This better performance is reflected in the measured wave heights around the groyne body which suggest that the recessed design is successful in reducing wave and overflow loads in the root and the crest area, indicating that the structure works as intended. The analysis of the comprehensive dataset reveals also that the variety of influencing factors complicate the establishment of a direct linkage between the parameters describing a ships passage (length, draught, speed, passing distance, partial blockage factor etc.) and the loading at the structure. In terms of armour layer stability, water level is shown to have a significant impact on the nature of the wave-structure-interaction and intensity of load on the structure. The development of a validated design method for dimensioning rock groynes for long-period ship wave loads is still in progress (e.g. Melling et al. 2019).

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