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Detached Breakwaters

By PETER FRÖHLE

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1. Introduction

In Germany, detached breakwaters have been constructed only at the Baltic Sea coast of Mecklenburg-Vorpommern up to now. Here, they are used for the protection of eroding sandy coastal stretches since 1978. Today, 23 detached breakwaters are installed in 8 systems along the Baltic Sea coast (Fig. 1).

Detached breakwaters for coastal protection are constructed using rubble and/or natural rocks. Their layout is nearly homogeneous with no core or filter layer. The weight of the natural rocks used for the breakwaters is in the range between 2t and 7t, depending on the local wave forces. In a construction the heaviest blocks are used for the armour layer and the crown of the construction, since there normally the loads are concentrated. A typical cross section of a detached breakwater used in Mecklenburg-Vorpommern is given in Fig. 2.



Fig. 1: Systems of detached breakwaters in Mecklenburg-Vorpommern, Baltic Sea coast

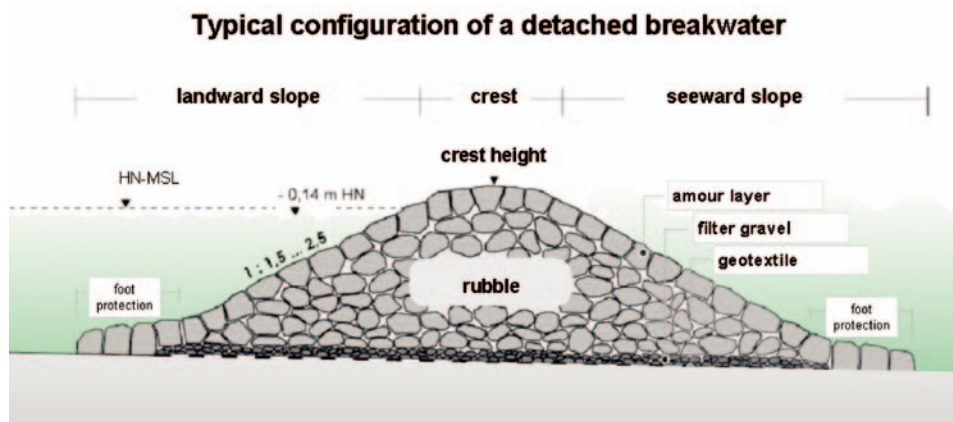


Fig. 2: General layout of detached breakwaters in Mecklenburg-Vorpommern (StAUN Rostock)

Detached breakwaters are used as single breakwaters or in systems with up to 4 units. Their length is typically between $L = 50$ m and $L = 200$ m, the distance to is between 70 m and 200 m and the crest elevation between $H_c = 0$ m and $H_c = 2$ m above mean sea level. In systems, the gap width is between $L_g = 50$ m up to $L_g = 100$ m (CARSTENSEN, FRÖHLE, JÄGER and SOMMERMEIER, 2004).

The ratio between length, distance to shore and gap width is normally selected in a way that a stable salient can be expected. The development of a complete tombolo is normally not the aim of the detached breakwaters built in Mecklenburg-Vorpommern. To support the development of stable salients in the wave-shadow of the detached breakwaters, the construc-



Fig. 3: System of detached breakwaters at Sellin/Rügen (Google Earth)

tions are normally combined with initial beach nourishments. An example for a constructed project which consists of a system of 2 detached breakwaters is given in Fig. 3.

2. Design of Detached Breakwaters

The general function and the general influence of detached breakwaters on the sediment budget and on the morphological development of a coast area are shown in Fig. 4. The principles of the physical processes dictate that all hard structures can provide local protection, only. The evolution of a coastline shows the desired accretion in the protected area behind the breakwater. However, one usually must expect downdrift-erosion on the lee-side of the detached breakwater.

The design of detached breakwaters is normally separated into a functional and a constructional part. The functional design ensures the performance, namely the development of a salient or tombolo, of the breakwaters/breakwater systems. The constructional design ensures that the designed cross section of the breakwater is statically and/or dynamically stable for the selected design parameters.

The functional design of detached breakwaters is normally based on numerical simulation of the sediment transport in the project area to determine the influence of the structure on the local and wide area sediment transport and, hence, the future morphological development of the area. The numerical simulation includes an assessment of the long term behaviour of the affected area. An example of such an assessment is given in Fig. 5.

In order to assure the results of the numerical simulations, they are double-checked based on nomograms and empirical and/or analytical solutions (Fig. 6). For details see e.g. POPE and DEAN, 1986 or SILVESTER and HSU, 1993.

The structural design of the breakwaters is often performed based on the research work on the stability of rubble mound structures by HUDSON (1954) and VAN DER MEER (1991). Since breakwaters are used to direct the morphological development of a coastal stretch, the probability of occurrence of the design parameters (wave height, etc.) is selected to be comparatively high, e.g. in the range of $p = 0.05$ to $p = 0.02$.

OFFSHORE - BREAKWATER

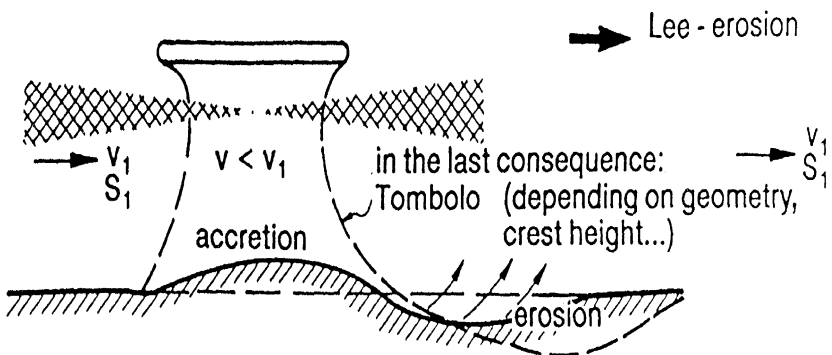


Fig. 4: Influence of a detached breakwater on sediment transport and coastline development (schematic, after KOHLHASE, 1991; KOHLHASE, 2004)



Fig. 5: Numerical modeling of shoreline evolution using Genesis (general example)

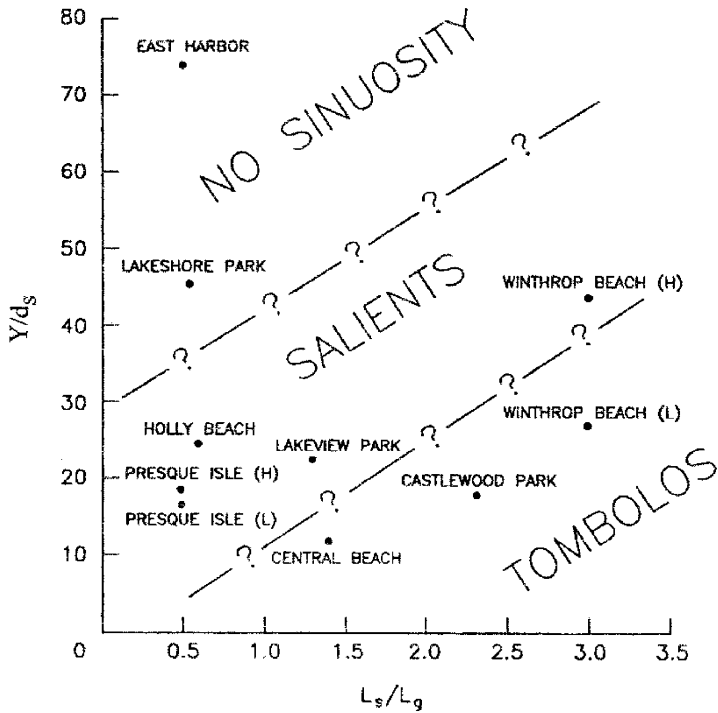


Fig. 6: Effect of breakwater layout on the morphological response of the coast (POPE and DEAN, 1986)

3. Breakwater System Streckelsberg

The Streckelsberg (Fig. 1, No. 8) is located in the middle of the NE-coast of the island of Usedom, Mecklenburg-Vorpommern. This part of the island is extremely exposed to waves. The Streckelsberg is an erosive cliff of up to 50 m height consisting of glacial sandy deposits. The length of the area in question is approximately 500 m. South of the Streckelsberg the coast is formed by active cliffs (boulder clay). North of the Streckelsberg, the coast changes from an (partly) active cliff (boulder clay) to the typical low lying sandy coasts with dunes and comparatively wide beaches. This low-lying area forms a narrow border – sometimes less than 50 m – between the open Baltic Sea and the coastal lagoon (Bodden) of the Achterwasser. Consequently it is very vulnerable to breaching caused by high water levels and strong wave attack.

This vulnerability is the main reason for the protection of the Streckelsberg cliff, being an anchor for the development of the entire surrounding coastal area. Loosing ground here would also cause retreat of the adjacent coastlines north and south of the Streckelberg and would, finally, result into a breaching of the narrow stretch coast and the separation of the island of Usedom.

For more than one century the Streckelsberg has been protected by a beach wall (Streckelsberg Wall), which was destroyed over time (Fig. 7). Due to the negative sediment budget in the area, the beach in front of the Streckelsberg Wall has eroded completely.

After a detailed investigation of the problem, one decided that a system of detached breakwaters could be seen as the only effective protection of the Streckelsberg cliff. The layout of the breakwater system was optimized using a numerical model, in which a wide



Fig. 7: Destroyed Streckelsberg Wall

variety of systems-layouts, transmission-coefficients of the structures and distances to shore have been analyzed. The assessment of the situation was based on long-term wave information covering a period of 5 years. Criteria for the layout were mainly the formation of a stable salient in front of the Streckelsberg Cliff without a tendency towards a complete tombolo and, on the other hand to minimize negative downdrift effects.

Investigations resulted in the design of a system of 3 detached shore parallel breakwaters with a length of approx. 190 m each, and a gap width of approx. 50 m. They were to be built at a maximum distance of approx. 200 m from the shoreline, considering the construction costs. In addition to the detached breakwaters, a new beach wall was built to protect the Streckelsberg Cliff against extreme high water levels. Shore perpendicular groyne systems south and north of the completed detached breakwaters system were installed to minimize negative effects. An aerial photo of the detached breakwater system is shown in Fig. 8.



Fig. 8: System of detached breakwaters at Streckelsberg/Usedom

Detached, shore parallel breakwaters have been used successfully for the protection of sandy, erosive coasts at several locations in the German Baltic Sea. At the German part of the North Sea the mainland coast is normally protected against high wave attack by the shallow areas of the Wadden Sea. Hence, a protection using detached breakwaters is normally not useful.

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