Coastal Engineering Technical Note

USE OF SEGMENTED OFFSHORE BREAKWATERS FOR BEACH EROSION CONTROL

PURPOSE: To provide information on the functional application of and general design considerations for using offshore breakwaters to control beach erosion. This note also presents a brief description of the U. S. Army Engineer District, Buffalo, offshore breakwater projects on Lake Erie (Figure 1).

GENERAL: Offshore breakwaters function by locally reducing the amount of nearshore wave energy thereby creating a "shadow zone" where longshore

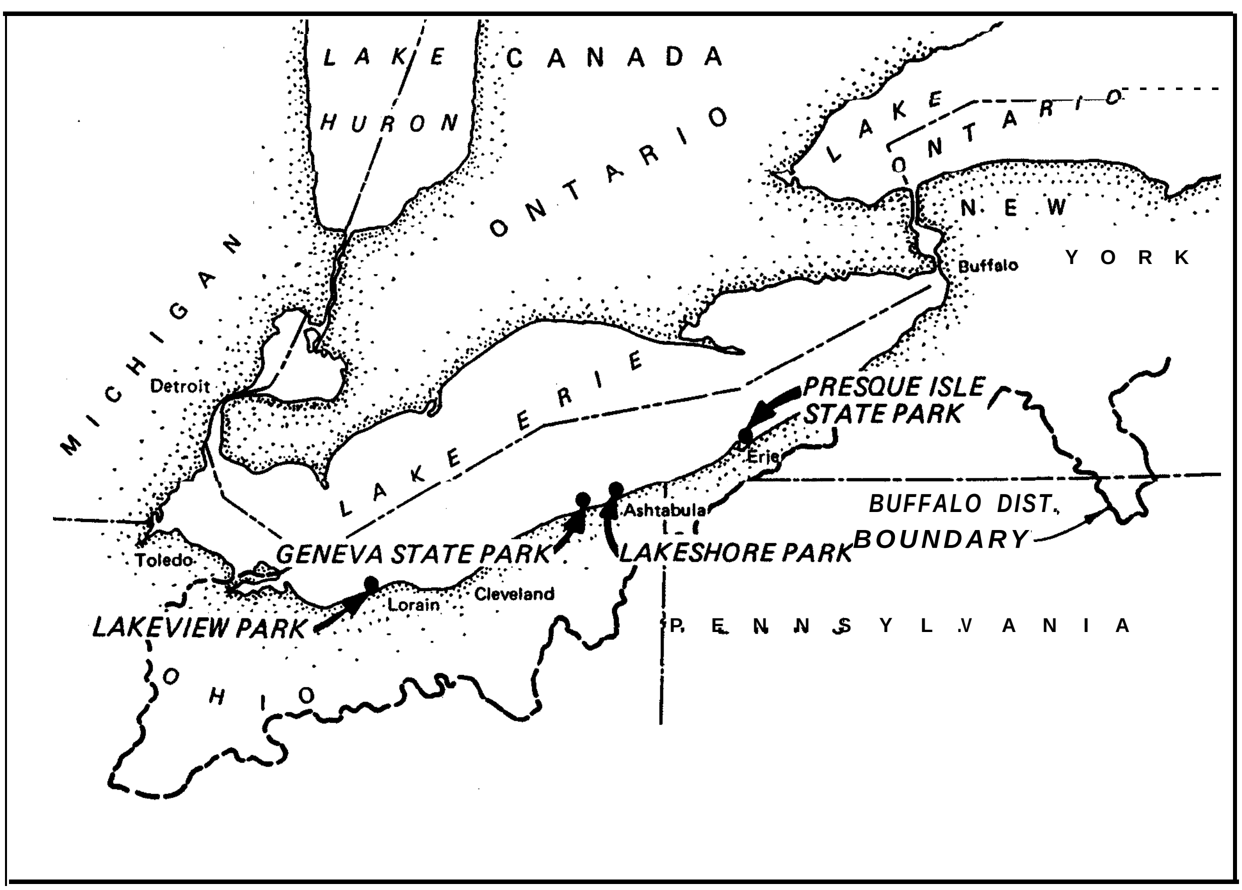

Figure 1. Location of Buffalo District Offshore Breakwater Projects

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transported sediments accumulate. The breakwater reflects or dissipates the incident wave energy and alters the wave direction and height by diffraction, thereby modifying the local longshore transport. Depending on the length and spacing of the breakwaters in combination with several other parameters, sediments will accumulate landward of the structure and sometimes a bar or spit that connects the structure to the shore (tombolo) will form.

Offshore breakwaters are generally designed to be one of two types: shore connected (tombolo formation) and detached. A shore-connected breakwater is generally long enough and/or close enough to shore that incoming littoral material or beach fill will be reshaped by waves in the form of a tombolo. Detached breakwaters, on the other hand, are usually shorter and farther from shore; wave conditions in the lees of these breakwaters are therefore too severe to permit tombolo formation, yet reduced enough to cause some sediment accumulation. Shore-connected breakwaters offer the advantage that inspection and maintenance are performed more easily. Detached breakwaters are usually preferred, however, since they do not create a total barrier to littoral transport and have a lesser impact on neighboring shorelines. The resulting beach is more suitable for bathing and other water sports. Swimmers are also less likely to climb--and possibly injure themselves-- on detached breakwaters.

DESIGN CONSIDERATIONS: The design of an offshore breakwater, especially a series of segmented offshore breakwaters, is a complex problem involving a number of design parameters (Figure 2). These are discussed in detail in the Shore Protection Manual (Coastal Engineering Research Center 1984). Some parameters are more important than others, and often one can be tailored at the expense of another without jeopardizing design success. A thorough understanding of littoral processes, bathymetry, and wave conditions is necessary in order to achieve a workable design.

Generally, the most important parameters are length of the structure relative to the distance offshore and, in the case of a segmented breakwater, spacing between breakwaters. Breakwater orientation should usually be parallel to the shoreline. A breakwater that is placed too close to shore in an area of abundant sand supply will likely create a tombolo where it may not be desired. On the other hand, if a breakwater is too far offshore or if several segmented breakwaters are too far apart, they may not provide the desired degree of protection.

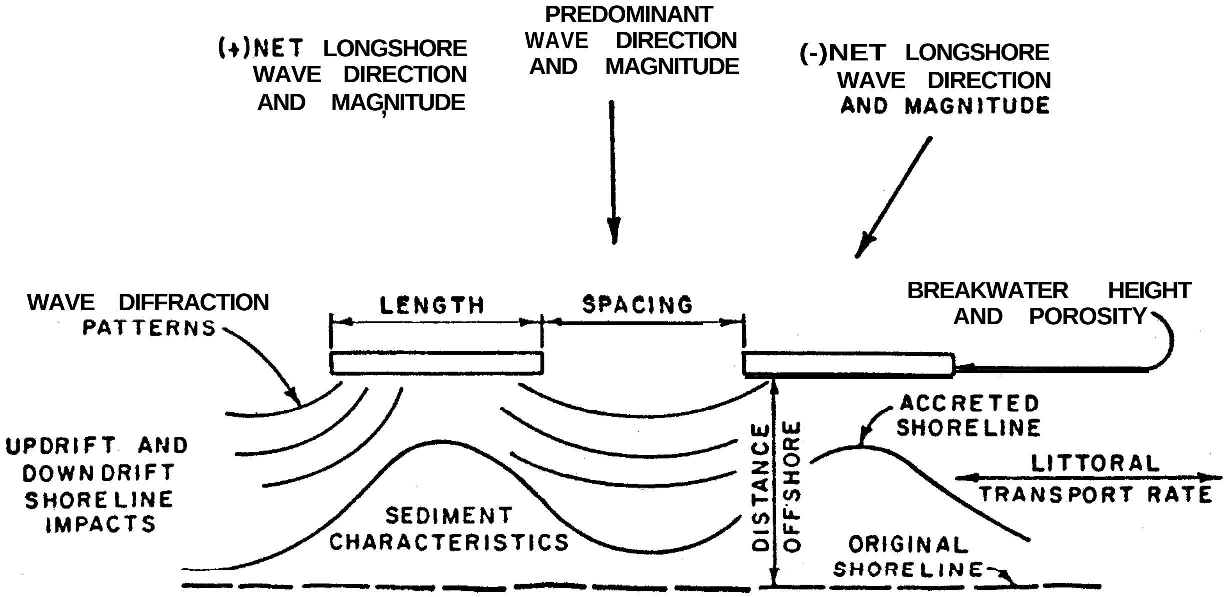

Figure 2. Offshore Breakwater Design Considerations

The magnitude and direction of the predominant incoming waves also play important roles. For instance, large, long-period waves tend to diffract more into the.lee of a breakwater than do smaller waves, resulting in a more pointed shoreline. Smaller, short-period waves diffract less, resulting in a mo're rounded shoreline. Highly oblique, predominant waves induce strong longshore currents which restrict the amount of accretion in the lee of a breakwater; in this case, breakwaters can be orientated normal to the dominant incident wave direction. Sites with a broad spectrum of wave approach will require more general protection to the shore.

Breakwater height and porosity, which are generally less important considerations, should be designed to reduce the transmitted wave energy enough to prevent the protective beach from being stripped away and back beach features endangered. The degree of transmitted wave energy which the structures allow will influence the future shoreline configuration. Where tidal energy is significant, the potential effect of the breakwater system on nearshore currents should also be considered.

The protective beach itself is an important part of the offshore breakwater system design. If the structures are to be placed in a high littoral transport rate zone and damage to downdrift beaches due to longshore trapping is a concern, beach fill should be incorporated into the project plan. The functional design of protective beaches is discussed in CETN-III-11 (March 1981).

OFFSHORE BREAKWATER PROJECTS ON LAKE ERIE: The scarcity of adequate recreational beaches on the Great Lakes combined with severe erosion problems has created a great deal of interest in the use of offshore breakwaters as beach stabilization and restoration devices. They are appealing since they can be designed as a single unit or as a series of units (segmented) and are adaptable to many coastal environments. As of 1983, the Buffalo District had constructed (1) three permanent segmented offshore breakwater projects and (2) a temporary project in which three different types of low-cost single offshore breakwaters were constructed and monitored at Geneva State Park, Geneva, Ohio. The permanent projects are located at Lakeview Park, Lorain, Ohio; Lakeshore Park, Ashtabula, Ohio; and at Presque Isle State Park, Erie, Pennsylvania (Figure 1); each includes three segmented rubble-mound breakwaters that were constructed for beach restoration and erosion control. The four projects are described below.

Geneva State Park, Geneva, Ohio. As part of a nationwide program to construct and monitor various types of low-cost shore protection devices, three different types of offshore breakwaters, each 100 ft long, were installed at Geneva State Park. They included a gabion breakwater (rock-filled wire baskets), a sta-pod breakwater (26 freestanding precast concrete units, each weighing 2 tons, placed in a single row), and a Z-Wall (14 precast concrete wall panels, weighing 6.5 tons each, connected in a zigzag pattern). The breakwaters were constructed in 1978 and were placed approximately 75 ft offshore and 500 ft apart to ensure their independent functioning. The structures performed with different degrees of success, and much information was gained on structural stability, porosity effects, and foundation design (OCE 1981).

Lakeview Park, Lorain, Ohio. In 1977, a series of three segmented offshore breakwaters were constructed at Lakeview Park to protect a sand beachfill that was placed to create a 1250-ft-long recreational beach. The park was initially void of any useable beach and was suffering severe erosion when the project was implemented. The design called for three 250-ft-long rubble-mound breakwaters spaced 160 ft apart and placed 400 to 500 ft from the original shoreline. 100,000 cu yd of beach fill material was placed. The beach is terminated by a short 130-ft concrete groin on the updrift (west) side and a 300-ft rubble-mound groin on the downdrift side. The project has been very successful and has been monitored closely through ground surveys and aerial photographs. Even though the project has experienced a net gain in sand volume, a small amount of shoreline recession has occurred at the westerly end of the project (Pope and Rowen 1983).

Presque Isle State Park, Erie, Pennsylvania. Presque Isle is a -I-mile-long recurved sand spit. As part of a study leading toward a permanent project to stabilize approximately 6 miles of the spit, three experimental rubble-mound breakwaters were constructed in 1978 near the easterly end. The breakwaters are each 125 ft long and are separated by gaps of 300 ft and 200 ft. They are located at about the -l.O-ft (LWD) contour. Approximately 5,000 cu yd of beach fill was placed in their lee. This project has also been highly successful, although the shoreline configuration undergoes significant changes during seasonal storms. A monitoring program, including aerial photographs taken three times a year and ground surveys performed two times a year, helps document the effects of different gap widths on shoreline response (U. S. Army Engineer District, Buffalo, 1980).

Lakeshore Park, Ashtabula, Ohio. This project, completed in the fall of 1982, consists of three segmented rubble-mound breakwaters. The breakwaters are 125 ft long and 200 ft apart and are placed in approximately 5.0 ft of water which is about 400 ft from the original shoreline. The breakwaters are placed in a slightly arched configuration to provide better protection to an 800-ft-long and 150-ft-wide beach fill (34,500 cu yd). Essentially, no natural littoral material can enter the project due to the presence of Ashtabula Harbor to the west and a large water intake structure to the east. The beach fill is still adjusting to the incident wave climate, and aerial photography and ground surveys are being taken to monitor the beach changes (U. S. Army Engineer District, Buffalo, 1982).

SUMMARY: Currently, there are no simple explicit techniques for designing highly effective and efficient offshore breakwater systems, due to the complexity of the problem and to the scarcity of data and field experience. Many of the physical processes involved are not thoroughly understood, and it will probably be some time before a comprehensive understanding of these complex processes is realized. Subjective judgements are required to estimate shoreline response as a function of wave climatology, project design, and sediment characteristics. An understanding of the nearshore sediment transport regime and preproject sediment budget is essential. Such a qualitative design is improved if it can be supported by field data and experience collected from existing projects in similar wave, currents, and sediment regimes.

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