REMR Technical Note GT-SE-1.6

TRADITIONAL TECHNIQUES FOR SHORELINE EROSION CONTROL IN RESERVOIRS

PURPOSE: To succinctly identify low-cost shoreline protection techniques that have been used in protected coastal waters (including the Great Lakes) and that may have application to reservoir shoreline protection.

BACKGROUND: Shoreline protection may be achieved through a variety of techniques. Familiar and well-defined techniques include (a) revetments defined as wave-protection structures placed on an existing sloping embankment, (b) bulkheads defined as vertical earth-retaining structures, (c) seawalls defined as wall-like structures placed on shore to resist wave attack, (d) breakwaters defined as structures (offshore or shore-connected) to dissipate wave energy, (e) sills defined as low, submerged walls designed to retain sediment, and (f) groins defined as walls constructed perpendicular to the shore for the purpose of trapping sand and stabilizing existing or artificially filled beaches. Other techniques include bank grading, beach nourishment, wetland vegetation, other re-vegetation, and bioengineered techniques. Bioengineered techniques use vegetation in combination with other techniques to stabilize shorelines. Bioengineered techniques are often preferred because of their environmental and aesthetic properties, but they become less effective as wave energy increases.

The intent of this document is to highlight potential shoreline protection techniques applicable to reservoir shorelines by summarizing an evaluation of structural systems published by the Corps of Engineers (Moffat and Nichol, Ref a). Moffat and Nichol provide recommendations for selecting, designing, monitoring, and evaluating the performance of low-cost shoreline protection systems. During the study, about 50 shoreline protection systems were evaluated. The performance of each system was documented, and in some cases recommendations for modified designs were given. The study, which is often called the "Section 54" study, was pursuant to Section 54 of Public Law 93-251 of the 93rd Congress approved on 7 March 1974. The public law was part of the Water Resources Development Act of 1974.

The remainder of this technical note presents the systems that were evaluated in Moffat and Nichol (Ref a) with brief mention of their performance and study recommendations. The performance of the materials used in the systems is also presented. During the study, common modes of failure of the systems were identified and are summarized herein. Manuals and other references used within the Corps of Engineers for proper selection and design of shoreline protection structures are noted as well.

SHORELINE PROTECTION STRUCTURES AND MATERIALS: Table 1 is a list of the systems studied in Moffat and Nichol (Ref a) with comments on performance as categorized by protection type. Expanded descriptions and definitions for

Table 1. Comments on performance and design for shoreline protection systems for low wave energy environment as documented in Moffat and Nichol (Ref a).

System	Comments
Bulkheads and Seawalls	
Treated timber[1]	Excellent performance; treatment extends life of timber; some construction difficulty
Steel and timber[1]	Excellent performance, but high cost; difficult to install
Concrete sheet piles[1]	Excellent performance, but high cost; needs filter and special equipment to install
Rubber tire and post	Fair performance; needs good filter; tire fill material washed out
Longard tube[2]	Tube must be away from bluff to prevent displacement by slides; sand-epoxy coating helps protect against vandals and debris damage
Earth-filled concrete pipe[2]	Fair performance; some pipes tipped over; needs stock pile of used pipe
Rubber tire stack[2]	Fair performance, but fasteners failed; system needs improvement
Untreated timber	System filed due to filter wash out; useful where logs are plentiful; boring insects could be a problem; needs good filter system
Hogwire fence & sandbags	System filed; could be improved, but short life of bag material is a problem
Concrete and timber	System failed; concrete and timber not compatible
Revetments	
Stone riprap[1]	Excellent performance; stone must be adequate size; filter is essential; recommend whenever low-cost stone is available; needs heavy handling equipment; best suited to large projects
Sand-cement-filled bags[1]	Good performance; easy to install but failed where design and installation were poor; good small project system
Concrete blocks[2]	Good performance where blocks were sized and shaped to match wave environment; easy to install, but subgrade must remain even; good small project system
Gabions[2]	Good performance, but broken basket wires may be a problem; needs proper sized stone fill; good substitute for stone riprap on small projects
Concrete rubble[2]	Good performance but failed where improperly designed; good way to dispose of large amounts of rubble; design criteria in text
Steel fuel barrels[2]	Good performance but use limited by availability of barrels
Concrete slabs	System failed; could be improved but limited to availability of salvageable building slabs; other systems less costly
Sand-filled bags	System failed; not recommended, as bag material is vulnerable
Fabric	System failed; might work with grout fill, but tests are needed
Tire and fabric	Storm waves displaced tires, and failure seemed imminent; method of stabilizing tires needed
Breakwaters and Sills	
Stone rubble[1]	Excellent performance in breakwaters, but high cost; requires special equipment
Timber sheet piles[1]	Excellent performance in low sills; requires special equipment and substrate must be suitable for driving piles

[1] Successful system
[2] Systems that could be successful with minor changes or when used in special environments or circumstances.

Table 1. (Continued)

System	Comments
Tires on piles	Good performance, but requires special equipment, more experimentation needed
Sand/cement bags[1]	Good performance, but filter-cloth encasement at one demonstration site appears vulnerable
<u>Breakwaters and Sills</u>	
Floating tires[2]	Fair performance; better interconnections needed; limited to short period wave environment
Longard tubes[2]	Good performance if tubes are not damaged; requires special equipment; vandalism of tubes made demonstrations inconclusive
Gabions[2]	Good performance, but structural failure seemed imminent at demonstration site
Concrete boxes[2]	Fair performance, but requires special equipment; covers needed to keep sandfill in boxes
Z-wall[2]	Good performance, but structure deteriorated; system not recommended until hinging of modules is improved
Sta-pods	Poor performance, but structure undamaged; system not recommended until improved to attenuate waves better
Sand-filled bags	Poor performance; small bags not stable; large bags require special equipment, tend to pull apart when filled, leaving gaps; vulnerability of bag fabric makes dependability suspect
Surgebreaker[2]	System not monitored long enough to adequately evaluate performance.

each protection technique may be found in Moffat and Nichol (Ref a) and the <u>Shore Protection Manual</u> (Ref b). If a particular shoreline protection system is of interest, the actual study report should be consulted to acquire more detailed information regarding design, installation location, environmental conditions, monitoring techniques, and recommendations for the system.

Several materials were used in the various techniques presented in Moffat and Nichols (Ref a). Abbreviated comments regarding the effectiveness of the materials are provided below. The original report should be consulted for more information.

a. <u>Quarrystone</u> worked well and withstood the environmental forces, but was expensive.

b. <u>Asphalt mastic</u> was effective. Asphalt mastic is asphalt mixed with smaller stones to create larger and stronger units.

c. Cement worked well when quality control of the material was administered.

d. <u>Concrete rubble</u> worked as a revetment when in sufficient quantity and when an appropriate filter was used. Performance increased with decreasing amounts of small pieces of rubble, elongated and flat stones, and debris.

e. Timber was easy to shape and connect and could be used in many structures. When used for bulkheads, a proper filter backing was required. Treated timber was recommended.

f. Gabions were marginally successful and required periodic refills of material.

g. Steel fuel barrels were successful when bolted together to form revetments or groins. The barrels tended to rust and were recommended only where barrels are in large supply (e.g. Alaska).

h. Longard tubes were effective as low breakwaters, bulkheads and groins. However, every Longard tube in the study was damaged by vandalism or floating debris. Longard tubes are a good material for emergency protection, but not for long-term protection.

i. Filter cloth was good for reducing settlement in soft materials. The cloth worked well as a filter for revetments, bulkheads, seawalls, and sills.

i. Rubber tires were not usually damaged, although their success varied. The damage was usually suffered by the tire connections and structure design. Tires did not work well when stacked loosely because they are too light and bulky. They must have durable interconnections.

DESIGN CONSIDERATIONS: Most shoreline protection structures fail physically because of inadequate design. Poor design often results from inadequate assessment of the environmental factors that are influencing the shoreline erosion. Poor design also results from overlooking necessary design details. The following is a list of design elements that are often neglected:

a. Filters allow drainage of the soils beneath and behind the structure, while preventing pump-out of fine-grained material. Also, filter fabrics placed beneath a structure help to distribute the weight of the structure over the substrate.

b. Drainage problems resulting from clogged filter layers or from a lack of weep holes may produce excessive water pressures on the structure causing the structure, foundation, or backfill to fail.

c. Uniform substrate is required to minimize differential settlement of a shoreline protection device. Differential settlement can damage and expose portions of the protection device to loss of foundation material.

d. Debris. vandalism, and theft damage is often an overlooked design problem, yet such damage is blamed, at least in part, for many shoreline protection failures. Every Longard tube discussed in Moffat and Nichol (Ref a) was damaged by vandalism or debris. Also, the theft of aesthetic revetments such as interlocking blocks, may expose filter or bedding to erosion, reducing the integrity of the revetment.

e. Toe protection is required at the base of structures to prevent scour and undermining. For example, toe protection at the base of a quarry-stone revetment can prevent waves from eroding sediments from the base of the structure, which could cause stones to roll forward off the revetted slope into the eroded region.

f. Overtopping can cause extensive erosion of sediments from behind a structure and result in the structure's eventual failure. Significant consideration must be given to expected design wave conditions to determine an adequate structure height that will prevent overtopping during design conditions.

h. Flank Protection is required to prevent wave energy from eroding the shoreline adjacent to the shore protection structure. Erosion occurring at the ends of the structure will begin to expose the backside of the structure to erosion as well, unless the ends of the structure are sufficiently tied into the shoreline.

i. Deterioration of materials used in a shore protection design must be considered. Generally, when the integrity of the materials used in shoreline protection is diminished, the effectiveness of the protection is also diminished. For example, decay of untreated wood used for a bulkhead may cause early loss of the structure.

i. Connections (and anchors) must be substantial enough to resist stresses due to loadings and must be made of materials that will not deteriorate rapidly.

These considerations take account of only those elements of design that affect the physical quality of the project. However, the overall success of a project sometimes depends on other subjective considerations as well. Additional design considerations include boat access, navigation, bathymetric characteristics, waves and currents, circulation (e.g. for water quality), beach access, recreational potential, aquatic and terrestrial habitat, deeper water access, aesthetics, opportunity for nature studies, project expansion, ease of repair, durability, inspection requirements, erosion control, safety, vandalism, ease of construction, and cost.

SUMMARY: The study results summarized herein indicate the many and varied shoreline protection techniques that are possible, as well as the materials available for their construction. While each technique is different in some respects from the others, the techniques often have similarities. Included in the similarities are important design considerations. The design considerations listed above should be addressed during the design of any structure to assure success.

While this technical note can be used to develop ideas for viable shoreline protection alternatives and to identify important design considerations, the lists of possible structures, materials, and important design considerations presented above are not exhaustive. Other sources should be consulted for the selection and design of shoreline protection techniques including the Shore Protection Manual (Ref b); EM 1110-2-1414 (Ref c); EM 1110-2-1614 (Ref d); EM 1110-2-2904 (Ref e); and Coastal Engineering Technical Notes (Ref f).

REFERENCES:

a. Moffat and Nichol. 1981. "Low-Cost Shore Protection: Final Report on Shoreline Erosion Control Demonstration Program (Section 54)," US Army Coastal Engineering Research Center, Fort Belvoir, VA.

b. Shore Protection Manual. 1984. 4th ed., 2 vols, US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, US Government Printing Office, Washington, DC.

c. Headquarters, Department of the Army. 1989. "Engineering and Design: Water Levels and Wave Heights for Coastal Engineering Design," EM 1110-2-1414, US Government Printing Office, Washington, DC.

d. Headquarters, Department of the Army. 1985. "Engineering and Design: Design of Coastal Revetments, Seawalls, and Bulkheads," EM 1110-2-1614, US Government Printing Office, Washington, DC.

e. Headquarters, Department of the Army. 1986. "Engineering and Design: Design of Breakwaters and Jetties," EM 1110-2-2904, US Government Printing Office, Washington, DC.

f. US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center. Section CETN-III, Vicksburg, MS.