Coastal Engineering Technical Note

SAND SEALING OF COASTAL STRUCTURES

PURPOSE: To describe various methods for reducing sediment infiltration of coastal structures.

DISCUSSION: Rubblemound coastal structures contain voids between individual armor units. Structure voids maximize turbulent wave energy dissipation, but also allow passage of water and sediment. The volume of sediment passing through some jetties and terminal groins can be substantial, resulting in increased channel shoaling, higher maintenance costs, and significant loss of beach material.

Most sediment infiltration problems are recognized from the resultant sediment distribution pattern. However, measuring the quantity of sediment infiltrating the structures is difficult. The extent of sand infiltration may be measured through visual observations, surveys, dredging records, aerial photographs, sediment traps, and dye tracers.

"Sand sealing" refers to techniques which make coastal structures impervious to sand infiltration. These techniques vary from the use of grout or sheetpiling, to building additional structures. Each sealing method is utilized to reduce structure permeability. However, decreasing structure permeability may increase runup and overtopping, wave reflection, and structure instability.

DESIGN CONSIDERATIONS: Good design practice dictates incorporating sand sealing techniques into the original construction. However, sealing methods may also be incorporated as part of a rehabilitation or repair effort.

A thorough site investigation, including a sediment budget and geotechnical analysis, conducted during the project planning stages, provides important field knowledge for design criteria development. Model studies may aid in predicting structure performance before and after sand tightening efforts.

Environmental parameters such as wave climate, water levels, littoral environment, and sea slope, along with structural parameters such as armor size and type, cross section, and void ratio are critical factors governing sand sealing design. Significant historical structure information including previous rehabilitations or extensions and the noteworthy effects of these modifications, not withstanding prior storm damage, can aid in evaluating a proposed sand tightening design.

Roughened rubblemound slopes increase wave energy dissipation. The need for sufficient wave energy dissipation still exists after reducing structure permeability. Wave-induced transient pressures, which would normally be transmitted through the structure, must be either contained or dissipated on the seaward structure side. In that case, energy dissipation would occur in the form of increased runup and overtopping (Seelig 1980a), wave reflection (Seelig 1980b), or toe scour (Hales 1980). Sealing may increase pore pressures within the structure, creating destructive uplift forces. As a general rule, when permeability decreases, so does stability (Bruun and Johannesson 1976). Stability may also be altered by decreased structure flexibility.

SEALING METHODS: Sand sealing may be part of an original design, rehabilitation, or repair. Sealing efforts deployed during the original construction are generally the least expensive.

Various techniques are utilized in sealing coastal structures. In this section, methods for reducing the permeability of coastal structures will be discussed.

Stone: Stone placement is the most common sealing method. Graded stone layers can be used to fill voids within the structure core. "Chinking stone" can be used to fill voids between the outer individual armor units. The rock should be sound, durable, hard, and have sufficient specific gravity to limit the volume of stone required. For stone design, e.g. 7-116 from the Shore Protection Manual (1984), commonly referred to as Hudson's Formula, is generally used, thereby incorporating a multilayer structural design.

A graded stone core or filter layer allows for turbulent wave energy dissipation on the outer armor layer. If graded layers are properly designed, the need for additional sealing may be unnecessary and post-construction alterations would be minimized. However, in some instances, the use of additional stone may lead to an increase in crest elevation, which in turn means additional cost.

Although "chinking" is a common method of sealing, the technique creates a smoother structure slope with decreased permeability, thus increasing wave runup and reflection. Additionally, "chinking stone" tends to be readily lost from the structure during storms.

Steel: Steel sheetpiling may be used as an impermeable diaphram for some coastal structures. Driven sheetpile is usually included in the original construction.

Low maintenance and durability are favorable reasons for utilization. Steel structures can be constructed quickly and deployed in many types of sediment foundations. However, steel may be expensive and is subject to rapid deterioration in the coastal environment if protective coatings are not used.

Additional steel design guidance can be obtained from ASTM Standard specifications, ASTM Standard A6.

Concrete: Sealing methods utilizing concrete vary from caps on top of the armor layer, to the installation of concrete sheetpile or a precast block core. Configurations can be tailored for site-specific use.

Concrete is durable and performs well against both water penetration and sediment infiltration. Yet, adverse chemical reactions and excessive abrasion can inhibit long-term satisfactory performance. Concrete is inflexible and prone to fracture if the structure is unstable and experiences extensive settlement after sealing. Vertical or sloped walls can reflect wave energy through the armor layer causing instability of the cover. Solid caps can trap air beneath them, creating destabilizing uplift forces. However, pressure buildup may be reduced by strategic vent placement.

Basic properties to consider in concrete design are ease of placement, consistency, strength, durability, and density. The use of additives such as polymers, aggregates, and admixtures can help tailor the design to site-specific requirements. Of course, increasing the unit weight of the concrete may affect structure cost. Additional concrete design information can be found in ASTM Concrete Design manuals.

Bitumen: Bituminous concrete contains asphalt, a durable cement that is adhesive, waterproof, flexible, and chemically inert. These qualities make bitumen a favorable choice as a sealing material.

There are three major categories of bituminous concrete: asphalt concrete, porous asphalt mixes, and asphalt mastics (asphalt grout) (CETN III-24). Mastics, bituminous grouts, are preferred for many sand sealing projects. Grout reinforces the structure, producing a firm yet flexible mass which conforms to slight differential settlements while resisting erosion. Grout mix designs are highly site-specific and may be adjusted in the field for optimum consistency. The grout should be fluid enough to flow and fill structure voids while resisting erosion from wave action during solidification. When viscosity problems occur, they may be solved by altering the mix design and/or temperature at deployment. Grout placement using pressurized injection rather than gravity flow, facilitates a wider distribution within the structure voids.

Chemical Grout: Chemical grouts consist of solutions of two or more chemicals that react to form a gel. Their cement counterparts (i.e. concrete) differ in that they consist of solid particles suspended in a fluid. Since chemical grouts are a low viscosity gel, containing no solid suspended particles, they may be injected into regions considered too small for cement grouts to be used effectively.

There are numerous types of chemical grouts, such as acrylamide, lignin, resin, and the more commonly used sodium silicate, each having unique characteristics.

Sodium silicate is used for most chemical grout sand sealing applications and is the basic chemical in the grouting process. When combined with a reactant, the grout gel forms, filling the structure voids. The grouting procedure can be a one solution process, whereby the silicate and the reactant are injected together, or a two solution process, where the sodium silicate is injected, following by the injection of the reactant.

The one solution process permits good control of the grouting radius and penetration because of controlled gel time. The two solution process allows an almost instantaneous reaction, a critical consideration when working within the surf zone. Yet, since the reaction is so rapid, the grouting radius may be limited. The two solution process also produces stronger gels.

Although more expensive than their cement counterparts, chemical grouts are durable, highly impermeable, and can be easily deployed. The use of additives such as bentonite can vary the viscosity and penetration of the grout.

Grout placement is facilitated by pressurized injection through open-end steel pipes driven into place in a predetermined grid pattern. Small grid spacing provides increased spreading continuity of the grout curtain.

Geotextile Fabrics: Geotextile fabrics, composed of synthetic fibers, are commonly used as filters in coastal construction. The design selection of these permeable fabrics should be based on the filtering, physical, mechanical, and chemical properties of the material. These properties are influenced by the three major types of fabric construction.

Woven - Manufactured by weaving, using a variety of yarns.

Nonwoven - Developed by bonding discrete fibers together using either needlepunch, spun bond, or melt bond. These fabrics are neither knitted nor woven.

Combination fabrics - Produced by combining woven and nonwoven fabrics using one of the previously mentioned bonding methods.

Woven fabrics provide maximum strength with minimum displacement. Nonwoven fabrics provide more elongation and tend to stretch and conform. Excessive elongation can enlarge or distort the fabric pores, changing the soil retention characteristics.

Manual placement of the fabric, extending vertically through the armor stone and underlayer, both above and below the waterline, provides an inexpensive sealing method. However, sealing effectiveness may be limited due to the high probability of fabric tear. Geotextile fabrics are also susceptible to deterioration from ultraviolet light.

Demolition Agents: Impact blasts from an explosive charge may be used to pulverize large inner core stone in some coastal structures. Extremely permeable structures with large core stone can thus have permeability reduced, experiencing only minor localized settlement.

This technique was used successfully at Yaguina Bay, Oregon, and may be a viable method of sealing for some unique structures. Quality control, though needed, may be difficult. Deployment personnel should be competent in the use of explosives.

SUMMARY: It is both practical and cost efficient to incorporate sealing methods within the original construction to prevent the loss of beach material and/or reduce channel shoaling. However, with older structures, sand sealing can only be accomplished through rehabilitation. As with any project, a cost/benefit analysis is necessary to determine an economically justifiable method of sealing.

Any sealing effort should be designed to minimize wave reflection, runup, toe scour, and destructive uplift forces. Additional factors to consider are sealing method durability, longevity, and ease of deployment. With proper design considerations, a high degree of sealing effectiveness can be achieved, thus reducing maintenance dredging and/or the loss of beach material.

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