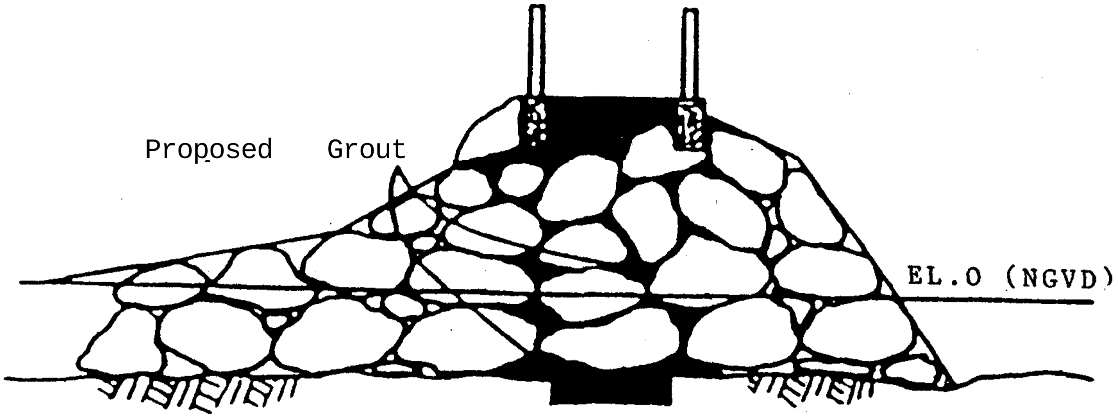
Coastal Engineering Technical Note

EXPERIENCE WITH SAND-TIGHTENED COASTAL STRUCTURES



PURPOSE:

To evaluate the effectiveness of various sand-sealing methods used on permeable coastal structures, as evidenced by site-specific performance and other available information.

GENERAL:

Rubble-mound coastal structures contain voids between individual armor units. These voids result in maximum wave energy dissipation, but also may result in the passage of water and sediment. The volume of sediment passing through breakwaters, jetties, and groins can be substantial, and result in increased channel shoaling, higher maintenance dredging costs, and significant loss of beach material.

"Sand tightening" or "sand sealing" of coastal structures entails techniques which make them impervious to sand infiltration. Sealing techniques include the placement of stone, steel, concrete, bitumen, chemical grout, geotextile fabrics, and/or demolition agents in coastal structures (CETN-111-28). Each sand tightening method is utilized to reduce structure permeability. Care must be exercised, however, since decreasing structure permeability may increase runup, overtopping, wave reflection, and uplifting forces which can create structural instability.

It is good design practice and usually cost effective to incorporate sealing methods into the original construction of coastal structures. However, with older structures, sand tightening can only be accomplished through rehabilitation.

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Traditional methods for "sand-tightening" rubble structures include dismantling the structure to rebuild core sections, chinking stone in voids along surfaces, adding additional stone layers, etc. A cost effective alternative to traditional practices has been determined to be drilling and grouting (sealing) of the structure (Simpson 1989).

FIELD EXPERIENCES:

Several existing permeable coastal structures have been sealed by cement-sand mixtures, chemical grouts, and asphaltic compounds, stone, and steel sheet-pile. These cases are discussed below with the intention of sharing on-the-job experiences (lessons learned) in an area where little guidance exists outside a few specific Corps Districts. Additional information on void-sealing may be obtained from Simpson, et al 1990.

Mission Bav, California, Jetty Sealinq:

Located adjacent to the San Diego River mouth on the coast of southern California, Mission Bay entrance is protected by jetties. A common jetty (middle jetty) separates river discharge from small-boat navigation and tidal flows of the bay. The project also has another structure that forms the north jetty of the bay channel, as well as a third jetty comprising the south jetty of the river channel. Shoaling of the Mission Bay channel was attributed to sand passing through both the north and middle jetties.

In 1955, a total of 3,000 tons of sealing stone was placed on the seaward slope of the north jetty within the limits of the littoral zone. It was anticipated that waves would drive the stones into the interstices of the structure. The seal stone ranged from 1 l/2-in to 6-in diameter. This measure retarded the movement of sand, but sediment continued to move through the jetty. It was decided that the jetties must be sealed in a manner that would produce a permanent and complete impermeable barrier.

A cement-sand material with admixtures was used to seal the jetties in 1959. The material was pressure injected through holes. drilled through the jetty crests. The sealant mix included sand, cement, clay, calcium chloride, and water. It was injected through a 1 l/2-in diameter hose, and sealant holes were drilled roughly 6.5 ft apart.

After rehabilitation, sand accumulations on the channel sides of the jetties disappeared, indicating the sealing was successful (Loudon 1959). Since that time, however, the structures have been battered by a series of intense winter storms causing extensive armor stone displacement, and probably internal core and sealant damage. Additional armor stones have been placed on the cover layer with no repairs to the barrier curtain created by the sealing process. Recent observations reveal that most of the 1959 sealing material has disappeared, and longshore sediments -appear to be again passing through the jetties into the navigation channel.

Buhne Point, California, Groin Sealing:

Situated in Humboldt Bay, California, two rock groins were constructed as part of the Buhne Point Shoreline Erosion Demonstration Project. One was shore-connected and the other was an extension of a groin built in an earlier phase of construction. Each groin was permeable to sand transport.

In 1985 the groins were sealed by the injection of concrete through holes drilled through the jetty crests. The sealant mix entailed fine and coarse aggregate, cement, clay, calcium chloride, water, and air. It was injected through a 3-in diameter hose through sealant holes drilled about 2 1/2 ft apart along the groin centerline.

After completion of the work, inspection revealed 25 to 30 small areas in the total 1,200 ft cumulative length of the sealed groins where possible sand transport could occur. No leaks are known to exist below the +5 ft mlw elevation, or to cause a problem of sand transport in significant quantities. The groins are performing their design function to this point.

Other California Harbor Jetty Sealing Experiences:

Jetty sealing, using cementitious materials and injection techniques similar to those used at Mission Bay and Buhne Point, has been accomplished over the years in California at Oceanside Harbor north and south jetties, San Luis Rey River jetties, groins in the vicinity of Newport Beach, Marina Del Rey jetties, and the Santa Cruz west breakwater. Of all these sealed structures, only the Santa Cruz project resulted in slightly less than expected effectiveness. Insufficient sealant spread is expected to be the reason for incomplete filling of the voids in the Santa Cruz breakwater which allows minimal passage of sediments through the structure.

Palm Beach Harbor. Florida, South Jetty Sealing:

Between 1978 and 1985, a shoal occurred every year at Palm Beach Harbor on the channel side of the south jetty. The shoal, caused by the passage of sand through the jetty, was very restrictive to deep-draft vessels using the harbor.

In 1985 the jetty was sealed by the injection of sealant through l-in diameter pipe inserted in holes drilled on 5-ft centers along the crest. Landward portions of the jetty where the voids were filled with sand were sealed with chemical grout consisting of a mixture of sodium silicate, reactants, and accelerators. Cement-sand mixtures were initially attempted to seal voids in the remaining portions of the jetty, but it appeared that only about 10 percent effectiveness was being achieved. A mixture of only cement and sodium silicate was developed, that proved successful, and the structure was sealed with this sealant mixture. Samples, taken from exploratory holes after sealing was completed,- indicated that the intent of the design had been achieved. Hydrographic surveys of the inlet taken since completion of the project also indicate that the sealing techniques were successful in prevention of sediment movement through the jetty.

Port Everalades. Florida, South Jettv Sealinq:

The Port Everglades south jetty is a l,OOO-ft-long rubble-mound structure. The jetty was very porous, and it was estimated that about 5,000 cu yd of sediment passed through the structure annually. Rehabilitation plans entailed sealing the shoreward 700 ft of the jetty and restoring the beach south of the jetty.

During the period September-November 1988, the structure was sealed. Sodium silicate-cement sealant was used for filling the void cavities, and sodium silicate chemical sealant along with appropriate reactants and accelerators were used to stabilize the sand layer beneath the jetty and the sand-filled voids on the shoreward portion of the jetty.- Sealant holes were drilled on 3-ft centers, and solutions were injected through a 2-in hose. The sodium silicate-cement mixture used to fill the voids in the structure consisted of the following ratio: 3 gal sodium silicate plus 4.5 gal water mixed with 0.3 cu ft water plus 0.1 cu ft cement. The sand-filled voids in the jetty were sealed with a sealant which entailed a mixture of sodium silicate and diacetin.

A monitoring program was initiated to evaluate the effectiveness of the sealing operations (Rosati and Denes 1990). Dye transmission tests and current meters placed in the structure both before and after sealing procedures indicated that the project significantly reduced structure permeability. Preliminary results have indicated that the replenished sand beach has remained in place and the project, appears to be successful.

Ashburv Park, New Jersey, Groin Sealinq:

Deal Lake groin, near Ashbury Park, New Jersey, was rehabilitated with asphaltic sealant in 1963. The outer 75-ft section was rebuilt by incorporating an asphaltic hot-mix. A foundation of rock, extending seaward from the existing groin tip, was first laid. Next, a hot asphalt-aggregate mixture was placed over the stone for a length of about 20 ft and for the width of the groin. Five ton stones then were specially placed on the asphalt. The next layer of asphalt covered those stones on all sides, and the process was repeated until the design crest elevation had been achieved. The asphalt acted as a binder to hold the structure together as a monolithic mass.

Since completion of construction, no repair work has been necessary. Current observations reveal that two stones have been dislodged from the end of the Deal Lake groin. This is a successful record of service and depicts possible benefits to be gained from using a properly designed and placed asphaltic mixture for sealing.

Manasquan Inlet. New Jersey, Jettv Rehabilitation:

Jetties at Manasguan Inlet, originally completed in 1931, were constructed with stone and steel sheet-pile cores. The jetties had crest elevations of +14 ft mlw, were capped with 2-ton stone, and extended to the -14 ft contour. Steel sheet-pile cores (el +8 ft), which extended the entire lengths.of the jetties, were very effective in preventing sediment movement through the structures and into the navigation channel. The jetties, however, were repeatedly damaged by storms through the mid 1970's. As the structures deteriorated, the inner sheet-pile cores developed large holes and severe corrosion, and became a less effective sand barrier. Sediment began moving through the jetty trunks directly into the navigation channel.

Rehabilitation of the jetties was accomplished between 1980 and 1982. The jetties were disassembled with the sand and dislodged stone being excavated. The original sheet-pile core was left in place, and 300-lb to three-ton core stone was placed to an el of +8 ft. The core stone was overlaid with armor stone ranging from 5 to 12 tons, except for the outer ends of the jetties, where a two layer system of randomly placed 16-ton reinforced dolosse was used as primary armoring.

The rehabilitated core has provided an effective barrier with respect to sand movement through the structures. Prior to rehabilitation, the channel was dredged every 1 1/2 years on the average, and since project improvements (1982), no dredging has been required (Gebert and Hemsley 1991).

Saco River, Maine, North Jettv Raising and Sealinq:

Jetty construction was initiated at the mouth of the Saco River in 1866. The original structures were loosely built, low-crested (+5.5 ft el mlw), and very porous. Sand readily migrated through the north jetty into the navigation channel after construction. In 1989 the north jetty was widened and raised to +15 ft. It was noted, that during storms, sediment continued to penetrate the structure, resulting in sand in the navigation channel. In 1968, the shoreward 850 ft of the north jetty was raised to +17 ft. A sealing blanket of 1 to 150-lb stone was first placed on the seaward slope of the jetty and capped with a 0.5 to l-ton cover stone, which was placed very tightly and resulted in a relatively smooth surface.

The 1968 jetty modification was very effective in preventing the movement of sediment through the structure into the navigation channel. The jetty, however, is more reflective and while it appears that it might be contributing to erosion of the adjacent shoreline north of the structure, the extent of its contribution to erosion has not been 'quantified. A study of the erosion problem at Saco River is currently underway, and historical trends indicate recession of the shoreline after raising and widening the jetty in 1898.

<u>SUMMARY:</u>

Sand-tightening of coastal structures using conventional methods of rehabilitation by removing armor stone and placing stone cores of low permeability, steel sheet-piling, and/or concrete cores is very effective. The low permeability, stone core was appropriate at Manasguan Inlet since the existing jetties had deteriorated and the armor stone had to be moved prior to reconstruction. The cost of this procedure is very high, however, for permeable structures that are not in a deteriorated state, particularly those constructed in relatively deep water. Sand-tightening structures by placing sealing stone and a relatively smooth surfaced armor over the existing structure has also been effective, but as illustrated at Saco River, may induce undesirable wave reflection characteristics and result in erosion of adjacent shorelines.

Sealing coastal structures with chemical gels and/or cementitious materials may be significant in returning high economic benefits, as opposed to the more conventional sealing methods. The development of sealant mixtures and injection methods has significantly advanced in recent years, and many coastal projects could benefit from the application of these technologies. In addition to site specific performance of chemical gels and concrete sealants, large-scale model tests have been conducted along with long-term field exposure tests (Simpson, et al 1990). The data provide insight into the effectiveness and durability of sand tightening materials and techniques. Based on field experience, cement-sand sealants injected into structure voids appear to be very effective. The Mission Bay Jetty cement-sand sealant curtain was effective for some 30 years before deterioratation. It was never repaired even though the structure was battered with intense storms that caused extensive armor stone displacement. Other West Coast structures that have been sealed over the years with cementitious sealants appear to have remained effective. Preliminary field experience with chemical gels (sodium silicates) injected into structure voids in Florida appear to show promise, however, the gels have not been in place long enough to evaluate their durability/longevity.

Large-scale physical model tests have been conducted to evaluate materials and methods of sealing voids in rubblemound structures. Sealants that had shown potential for success in field applications were selected for evaluation. Test results revealed that cementitious material containing aggregate achieved a more satisfactory final product for sealing a section than did a sodium silicate-cement sealant, provided the aggregate was small enough not to impede pumping, and did not seal off the openings between the voids. Sodium silicate-cement sealants flowed readily from the injection pipe, but formed only a weak gel on the floor of the test basin. A sodium silicate-diocetin used to stabilize voids filled with sand did not completely solidify (harden) the sediment.

Long-term field exposure tests have been conducted to determine how various sealants endured under actual field conditions when exposed to the effects of waves, currents, freezing and thawing cycles, wetting and drying cycles, abrasion, biological influences, and chemical reactions. Three locations (Treat Island, ME, Duck, NC, and Miami, FL), representing cold, moderate, and warm water environments, were selected. The ongoing tests are providing data to ascertain the strength, durability, and longevity of various cementitious sealants. Sodium silicate-cement and sodium silicate-diacetin specimens, however, experienced significant erosion and deterioration, particularly at the mean water line where wave effects are greatest. This situation may be more extreme than that existing within a rubble-mound structure, however, and may not be truly representative of actual conditions to which placed sealants would be subjected. Considering the low compressive strengths of the sodium silicate chemical gels and the observed rapid erosion and deterioration rate in the field, their durability and longevity are questioned, and long-term monitoring of the sand-tightened Florida jetties should be undertaken to evaluate the actual useful life of these sealing efforts.

Asphaltic sealants are durable, waterproof, flexible, and chemically inert, which make bitumen a favorable choice as a sealing material. Asphaltic sealants set hard and bond well, although no means of placing it in production quantities have been developed. Voids in coastal structures are currently filled with asphaltic sealants by gravity flow and the use of vibrators. Experience with these stabilization/sealing materials appear promising, but methods to achieve deep penetration within a coastal structure have not been developed. Abundant literature is available on successful marine applications of asphalt, but there are no known cases of an asphaltic mixture being injected into jetty voids. When equipment and placement techniques for pressure-injecting hot sand-asphaltic concrete are developed, then tests should be conducted in the field to evaluate its durability and effectiveness.

ADDITIONAL INFORMATION:

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