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Coastal Engineering Technical Note

CASE HISTORY OF BREAKWATER/JETTY REPAIR: CHEMICAL GROUT SEALING OF PALM BEACH HARBOR SOUTH JETTY, FLORIDA

PURPOSE: To describe the most recent Corps of Engineers experience in sealing void in a permeable jetty (Palm Beach Harbor South Jetty, Florida), and to discuss the implications of this on-the-job learning process in the absence of definitive design guidance at present for the placement of chemical grouts under wave conditions.

BACKGROUND: Placement equipment and material compositions exist for sealing voids in rubble-mound breakwaters and jetties by application of chemical mixes through pressure grouting systems; however, experience in performing such operations is practically nonexistent. Only two cases of record have been documented where chemical grouting of rubble-mound jetties was conducted. In 1958, the Corps' Los Angeles District sealed portions of the north and middle jetties at Mission Bay, California, with a cement-sand grout containing stabilizing admixtures. Recent observations of these structures indicate that all such sealing materials are no longer visible. In 1985, Jacksonville District, sealed the voids in a portion of the south jetty at Palm Beach Harbor, Florida, by using various mixtures of cement, sodium silicate, bentonite, and calcium chloride. The application at Palm Beach Harbor is the state of the art at present.

PRESSURE CHEMICAL GROUTING: Pressure grouting involves the injection under pressure of a liquid or suspension into the voids of a soil or rock mass or into voids between these materials and an existing structure (Engineer Manual 1110-2-3506). The injected grout must eventually form either a gel or a solid within the treated voids. The primary purposes of pressure grouting a soil or rock mass are to improve the strength and durability of the mass, and to reduce the permeability. No guidance presently exists for application of chemical grouts under wave conditions where voids such as those found in rubble-mound structures exist. Chemical grouts for application to soil and rock conditions are discussed in EM 1110-2-3504. Under those conditions, it has been found that chemical grout is often more expensive than portland-cement grout; thus, foundations containing large voids should first be grouted with a cement grout. In a coastal environment, however, a cement grout may not have time to harden prior to being dispersed by wave action. Under such conditions, a chemical grout may offer the only possibility for successful placement.

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PROJECT DESCRIPTION: A major concern regarding the Palm Beach Harbor Jetties in 1984 was the passage of sand through the south jetty into the navigation channel. Since 1978, a shoal had build up each year inside the south jetty. The shoal was relatively small in quantity (about 25,000 cu yd), but was very restrictive to the deep-draft vessels using the harbor. Usually each year, the shoal build up to a depth of about -30 ft mean low water (mlw), which is about 5 ft less than the authorized -35 ft mlw depth. This development forced some harbor users to light-load vessels with resulting increased costs. Because of the relatively small volume of dredging involved, the cost of removing the shoal each year was relatively high, about $13.60 per cu yd. The recommended plan provided for making 1300 ft of the south jetty impervious to the movement of sand, and for restoring structural stability to a damaged section of the jetty in the vicinity of Station 55+00. The seaward limit of the work would extend to the vicinity of the toe of the active beach profile in the vicinity of Station 44+50. The landward limit would extend to Station 57+50, which is just west of the section of jetty where settling had occurred. Two alternatives were evaluated for sealing the jetty to prevent the passage of sand.

a. This alternative provided for a rubble filter protected with armor stone. Because of the shallower depths and slower velocities, the work would be accomplished on the south side of the structure. The section would be comprised of blanket stone adjacent to the existing structure, a filter layer overlain with another layer of blanket stone, then a single layer of armor stone. The work would require placement of about 7400 tons of filter stone, 14,300 tons of blanket stone, and 13,000 tons of armor stone. The initial cost of the work would be about $3.1 million.

b. This alternative provided for injecting the jetty with silicate grout between Stations 57+50 and 47+00, and construction of the previously mentioned rubble section seaward of Station 47+00 to Station 44+50. For purposes of evaluating the cost-effectiveness of this alternative, two types of grout were selected, and a ratio of 43.2 lb of sodium silicate to 10.2 lb of sodium aluminate per cubic foot of sand-filled voids was used. (Variation of the percent of silicate and catalyst to achieve a desired result does not significantly affect cost of the grout).

The Type 1 grout was a mixture of sodium silicate and sodium aluminate; the Type 2 grout was a mixture of sodium silicate, sodium aluminate, water, and cement. The grout would be mixed with or injected into the sand. It was not proposed to inject the outer 300 ft of the structure with grout because the deeper water in that area permits higher waves to act on the structure. The method of operation would be to bore through the center of the structure to depths as great as -25 ft mlw to allow the placing of a 2.5-in. casing. To ensure formation of a barrier of grout, the holes would be bored a maximum of 3 ft apart. The grout would be pumped into the structure by one of two methods:

a. Method A. A 1-in. pipe would be placed in the casing. Then, as a sand-water solution was pumped in to fill all voids prior to injection of the silicate, the casing would be pulled out. The silicate grout would then be injected into the jetty via the 1-in. pipe.

b. Method B. Existing sand would be washed from the jetty by water pumped through the casings. If the Type 1 grout was used, a water-sand mixture would be pumped into the jetty where it would be mixed with the silicate grout. As the jetty filled, the casing would be removed. If the Type 2 grout option was used, the silicate grout-water-cement mixture would be pumped into the jetty, and the casing removed as the jetty filled.

Since the jetty landward of Station 53+50 was at that time mostly filled with sand, Method A would be applied for grouting this reach of the jetty. Seaward of Station 53+50, Method B would be applied. In the contract quantity estimations, 40 percent voids was assumed for the sand which filled the voids of the jetty. The estimated cost of Method B was either $1.8 million or $1.9 million, depending on whether Type 2 grout or Type 1 grout was used, respectively.

RECOMMENDED PLAN: The most economically efficient method of sealing the jetty would be to inject the structure with a chemical grout. However, there were no known instances of using grouts in this type of environment and application. Previously, at Mission Bay, California, the jetties were made sand-tight using similar procedures; however, in that work the jetties were injected with grout only to about mean lower low water (mllw), a distance of about 14 ft. Consequently, the success of the grouting of the outer reach of the south jetty at Palm Beach Harbor, which is exposed to significant wave action and must be injected to elevations down to -20 ft mlw, could not be ensured. Similarly, it was reasonable to expect that the shoreward section of the jetty, which is exposed to relatively minor wave action and must be injected to elevation of only -10 ft mlw or less, could be made sand-tight by the use of chemical grouts.

Accordingly, based on the lack of performance data, the recommended plan provided for injecting the jetty with chemical grout from Station 57+50 to Station 49+50, and for provision of a rubble filter on the south side of the structure from Station 49+50 to Station 44+50. Injection of grout in the 350-ft section of the jetty seaward of Station 53+00 would provide experience in use of the procedure in a moderate wave environment with minimal risk. The estimated cost of the recommended plan would be about $2.2 million. This was an increase of $300,000 over the plan using chemical grouting for all aspects of the rehabilitation.

The estimated chemical grout quantities reflected a 6-ft-wide barrier of grout extending from about mlw to depths down to -10 ft mlw. However, it is important to note that, to make the structure impervious to the movement of sand, only a relatively narrow barrier need be provided. By using holes drilled every 3 ft along the center line of the considered section of the structure, such a barrier would be ensured. To ensure success, this type of work must be performed by experienced personnel (Ref d).

CONTRACT SPECIFICATIONS: After formulation of the recommended plan, but prior to award of the construction contract, certain modifications were developed regarding actual placement of the grouting materials. Preliminary investigations revealed that many of the void areas between the rubble stone comprising the jetty had filled with sand, and indeed, this sand was continually passing through the jetty into the navigation channel. Thus, the non-stone regions of the jetty below the sand-filled elevation, but above the design bottom grade elevation of the jetty, were not actually voids but were previous voids which had filled with sand. Therefore, it would be necessary to stabilize the sand presently filling many of the voids, and to both fill and stabilize those portions of the jetty which were actually void of all materials.

A contract for sealing the permeable south jetty at Palm Beach Harbor was awarded to Clarmac Marine Construction Company, Clearwater, Florida, on 5 March 1985. The subcontractor for Clarmac Marine was W. G. Jaques Company, Des Moines, Iowa, who actually performed the drilling and grouting requirements of the contract for : (a) filling the actual void areas of the jetty with cement-sand grout; and (b) chemically grouting the sand which was filling portions of the non-void areas. The cement-sand grout would consist of cement, sand, water, bentonite, and calcium chloride. The chemical grout would consist of water, sodium silicate, appropriate reactants, and accelerators. The intent of the design was to stabilize a 6-ft-wide zone through the jetty. extending to prescribed depths down to as far as -10 ft mlw below the upper surface of the jetty.

The contract specifications required drilling 3-1/2-in.-diameter holes vertically, in a single line, at 5-ft centers, until sand was encountered below the bottom elevation of the structure. Approximate elevations for drilling varied from 12- to 20-ft-deep holes. All voids encountered prior to reaching the bottom of the structure were to be filled with cement-sand grout. An injection pipe was to be inserted into the lower limits of the voids and withdrawn in 1-ft increments as the cement-sand grout was injected. The estimated amount of grout, in order to achieve a 6-ft-wide curtain, was 18 cu ft for each rise of 1 ft in the pipe. It was understood that this estimated quantity per linear foot would vary due to various sized of voids expected to be encountered. The capability to adjust the mixture proportions to achieve a quicker set and less flowability would be necessary to construct the 6-ft-wide curtain in certain areas.

After cement-sand grouting of the void areas had been completed and the grout had stabilized, chemical grouting of the sands which filled the remaining previously void areas of the jetty would be performed. Redrilling holes through previous cement-sand grout placement would be performed until sand was encountered below the bottom design elevation of the jetty. An injection pipe would be lowered to the specified bottom limits of the hole, and the chemical grout would be placed. The estimated quantity of chemical grout to be injected was 12 cu ft for each linear foot of sand-filled region surrounding the grout hole. When the chemical grouting had been completed, the drilled holes would be backfilled with cement-sand grout to the top elevation of the south jetty.

CONSTRUCTION OPERATIONS: The contractor initiated construction operations by applying the contract-specified cement-sand grout mixture in the voids. After pumping 18 cu ft of grout in three holes, apparently no grout remained in place, as the water on the inlet side of the jetty was clouded with a plume from grout material dispersion. The amount of bentonite in the cement-sand grout was varied to produce a thicker mixture that would have less flowability. After 2044 cu ft of grout had been pumped, it appeared perhaps only 10 percent effectiveness was being achieved.

At this time the contractor suggested a mixture using cement and silicate only, which he claimed from his experience would accomplish the desired results. Three holes were tried and very Effective results were achieved. A contract modification was issued, after successful negotiations, which changed the mixture from a cement-sand grout to a cement-silicate mixture.

During the grouting work, it was found that in some areas the grout that was being placed would not build up. Investigation of this condition revealed that grout was actually flowing into voids which were not shown during drilling, even with variations in the mixture. Probing of holes on each side of the apparent unfillable holes revealed that the grout was flowing in both directions with a small build up in the adjacent holes. Therefore, in order to meet the required criteria of the design, grout was placed in an alternate hole spacing sequence until the entire area formed a grout curtain sufficient to meet the requirements without filling entire unseen and unknown voids. These areas required more grout than expected; however, this unexpected over quantity was balanced by the need for less grout than estimated in other and being lost, the apparent overrun in estimated quantity was not being wasted, but was building up in adjacent areas which then required lower quantities than expected.

CONCLUSIONS: Details of the drilling and grouting procedures used at Palm Beach Harbor have been documented by the on-site construction inspector for the Jacksonville District (Ref a). His conclusion includes the fact that identifying voids by drilling may not be the most effective method for establishing their location. Other methods would be developed for discovering such voids; otherwise, considerations of large overruns in grout should be addressed in future contracts. Since it is fair and reasonable that this type of contract be awarded as "unit prices items," some imprudent contractors could take financial advantage by gaining excessive profits from material and placements. However, it should be noted that the contract modification issued to change the cement-sand grout mixture basically did not increase the original amount of the contract significantly, since the change deleted the need for bentonite and a portion of estimated quantity of sand. It also decreased the placement cost for cement-sand grout for the holes involved. This grouting activity was completed without further problems, and extracted samples from drilled exploratory holes showed the intent of the design had been achieved.

ENVIRONMENTAL CONSIDERATIONS: Reasonable caution should guide the preparation, repair, and cleanup phases of concrete or mortar repair activities involving potentially hazardous and toxic chemical substances. Manufacturer's recommendations to protect occupational health and environmental quality should be carefully followed. Material safety data sheets should be obtained from the manufacturers of such materials. In cases where the effects of a chemical substance on occupational health or environmental quality are unknown, chemical substances should be trated as potentially hazardous toxic materials.

ADDITIONAL INFORMATION: For further information contact Lyndell Z. Hales of the U.S. Army Engineer Waterways Experiment Station (601)634-3207, Lyndell.Z.Hales@erdc.usace.army.mil.

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