A N   E V A L U A T I O N   O F   I M P R O V E D

S T R U C T U R A L   M A T E R I A L S

I N

M A R I N E   P I L I N G

By

William J. Quinn
Research Coordinator

Research Section
Oregon State Highway Division

For presentation at the AASHTO Annual Meeting

November 1980

EVALUATION OF IMPROVED STRUCTURAL MATERIALS IN MARINE PILING

A study to evaluate the production and field performance of marine piling fabricated with improved structural materials is currently being performed by the Oregon State Highway Division under the sponsorship of the Federal Highway Administration. In this study, materials that were developed mainly for bridge deck protection and rehabilitation were used in fabricating precast prestressed concrete piling. During this project, 23 test piles measuring 12" x 12" x 65' long were fabricated and placed in a dolphin for pier protection in Yaquina Bay at Newport, Oregon.

The special materials incorporated into the study included polymer concrete, polymer impregnated concrete, latex modified concrete, and internally sealed concrete. Five piles were fabricated using each system. In addition, six miniature piles measuring 8" x 8" x 20' containing epoxy coated reinforcing steel bars were constructed and attached to three conventional precast prestressed concrete piles.

This project was unique in several ways. It was the first time all four of the experimental materials were tested in a single study and the first time three of the systems were used in a prestressed element in the United States. Because each of the systems had to be modified to some degree, an accelerated laboratory study was conducted to prepare specifications for construction of the piles and their installation. After a six month study, enough data was generated to write specifications and to let a contract. Due to the complexity of the project, only one prestressed concrete plant submitted a bid to fabricate the piles. That company was Morse Bros. Prestress Inc. of Harrisburg, Oregon.

Fabrication of the piles required three months of intensive coordination and planning. Since most of the work was experimental, the responsibility for the manufacture of the piles was delegated to the Quality Control manager of the prestressed concrete yard. In spite of careful planning, some disruption of the plant's normal activities occurred which led to an internal conflict between production and quality control. Once this matter was settled, the construction of the piling progressed at a relatively smooth rate.

Fabrication of the latex modified concrete piles consisted of adding Dow Chemical's latex modifier A to a conventional concrete mix during batching. The modifier was added at a rate of 3.5 gallons per sack of cement replacing an equal amount of mixing water. The first five latex modified concrete piles had to be rejected when they failed to develop the required strength. Lack of bond between the strands and concrete caused the piles to deflect noticeably as they were removed from the forms. An investigation revealed a water reducer-set retarder admixture produced an adverse reaction. When the chemical admixture was omitted from the mix, the latex modified concrete piles were cast successfully. One slight disadvantage in using the latex modifier system was the two-day cure required to produce adequate strength for strand release. A one-day turn around time for form use is normally achieved when type III cement and steam curing are used in prestressed concrete work.

The fabrication of the internally sealed concrete piles was accomplished by adding approximately 3 percent by weight of tiny wax beads to a conventional non-air entrained concrete during batching. The beads were a blend of 75 percent paraffin and 25 percent montan waxes and ranged in size from #20 to #80 mesh. The concrete was steam cured at a reduced maximum temperature of 125°F. to prevent a premature melting of the wax. After the concrete was allowed to cure and dry for 14 days, the 65 foot long piles were placed into a specially constructed oven to melt the beads. The specifications required each side of the pile to be heated uniformly to a minimum temperature of 185°F at the two-inch depth. The melting process was thorougly monitored by means of thermocouples placed within the piles at several locations. The melting of the beads was accomplished satisfactorily. After the piles had cooled, a few small shrinkage cracks were detected on the surface but the overall appearance was very good.

The fabrication of the polymer concrete piles consisted of mixing a dry, well graded aggregate with a proprietary acrylic mortar of resin and fine aggregate. In this system an acrylic resin served as the total binder. Although there were several polymer mortars available,"Crylcon" was chosen for this experimental work. The polymer concrete was mixed in a one cubic yard pan-type mixer for approximately two minutes before being discharged. Within 15 minutes, it was placed into the forms and finished. The polymer concrete had an allowable work time of 30 minutes before the resin began to gel. All consolidation and finishing had to be completed within that time. The polymer concrete had a rapid strength gain, exhibiting an ultimate compressive strength of over 3,000 psi in three hours.

The production of the polymer concrete piles proceeded without problems but after prestressing, the piles continued to shrink and creep. Measurements made over a three-week period indicated an average 25 percent loss in prestressing force had occurred due to shortening. Additional laboratory study confirmed that even though polymer concrete exhibits a high ultimate compressive strength it was still subject to high creep when loaded too soon after fabrication.

The fabrication of the polymer impregnated concrete piles required five distinct activities. First, five conventional prestressed concrete piles were cast and allowed to cure a minimum of 21 days. Then the piles were subjected to drying, cooling, impregnation, and resin polymerization steps to produce the desired result. During the drying phase each 65 foot long pile was placed into an oven and heated uniformly to a minimum temperature of 260°F for a 10-hour period. This action removed moisture from the outer shell of the pile and provided space for the resin to occupy. The pile was then allowed to cool slowly to a temperature of less than 100°F. Once the pile had cooled sufficiently it was placed into a bath of methyl methacrylate resin for a soaking period of eight hours. When the impregnation was completed, the pile was removed from the resin bath and immediately immersed into a hot water bath (170° to 185°F) for an eight-hour polymerization period. The temperature of the concrete was monitored during the entire process by means of thermocouples embedded at several locations along the piles. Cores taken from the first three piles indicated this method of impregnation could accomplish a resin penetration of between 3/4" to 1".

Due to two errors during production, only the first three piles received a satisfactory resin impregnation treatment. When the fourth pile was in the polymerization phase, the water temperature in the tank was allowed to decrease to under 155°F for several hours in violation of the specification. This allowed much of the resin in the outer shell of the pile to escape before polymerization.

The second error occurred while the fifth pile was in the resin bath during the soaking cycle. The contractor neglected to replace the roof system that protected the resin bath from the ultraviolet rays of the sun. This resulted in bulk polymerization of the bath as the top two inches of resin solidified into a solid plastic mass. A great deal of effort was then expended trying to remove the pile from the soaking tank. Since the contractor could not impregnate additional piles within a reasonable amount of time, the fourth and fifth polymer impregnated piles were purchased at the conventional concrete bid price.

After the piles were fabricated they were transported by truck to Yaquina Bay at Newport, Oregon. Here they were loaded onto a barge and brought to Pier 3 of the Yaquina Bay Bridge. Since the foundation at the site consisted of sand, the contractor was allowed to water-jet the piles into the ground approximately 15 feet. Each pile was then driven the last three feet by means of a 3,500 pound drop hammer.

During the placement of the latex modified concrete piles, the contractor's tug boat struck one of the in-place piles breaking it at the ground line. The pile was removed and a dolphin with only four piles constructed. The jetting and driving of the other five-pile groups was completed without incident.

After all of the piles were installed in their respective groups, concrete caps were poured to provide additional stability. When the construction was completed a final inspection was performed before the work was accepted. At that time the condition of the piles was rated satisfactory and initial chloride ion samples were removed from the piles for future comparison purposes. Initial active corrosion measurements by the half-cell method were also taken for future reference.

An appraisal of the different protective systems from a fabrication viewpoint finds the latex modified concrete very easy to manufacture. The disadvantages of the latex modified system were the two-day cure required before prestressing could be applied and the difficulty in finishing the surface because of a quick forming latex film. The internally sealed concrete was easy to manufacture, place, and finish. The minor disadvantage of this system was the extra time and equipment needed to monitor and melt the wax beads. The polymer concrete system was not difficult to manufacture but it required more care. The requirement of drying, cooling, and storing a large quantity of coarse aggregates before fabrication was an inconvenience. The excessive shortening due to creep after prestressing was totally unacceptable. The system may be better suited for post tensioning work. The high cost of the polymer materials was also a disadvantage.

Finally, the polymer impregnation system was somewhat complicated and required much planning and coordination. The multiple steps requiring close surveillance were time consuming and expensive. The drying and soaking equipment needed for this work makes the widespread use of the system unlikely.

The following bid prices of the experimental materials demonstrates both the high material costs and the complexity of the different systems. The prices include the additional costs for wiring, coring, and extra testing which were necessary for this experimental project. It is estimated the additional data gathering work cost approximately $325 per pile.

	Unit Bid Prices	
	Per Pile	Per Cubic Foot
Normal Concrete	$1,140	$17.54
Internally Sealed Concrete	1,440	22.15
Latex Modified Concrete	1,670	25.69
Polymer Concrete	2,620	40.30
Polymer Impregnated Concrete	5,920	91.07

For more information concerning this project contact:

William J. Quinn
Oregon State Highway Division
2950 State Street
Salem, Oregon 97310

(503) 378-2318