Cylindrical Hollow Prestressed Concrete Piles

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Driving 200 ft. long prestressed concrete pile.

GENERAL

Lake Maracaibo in Western Venezuela covers some of the world's largest oil reservoirs. Drilling is carried out from drilling barges and platforms that support the power and rotary units and derricks. These platforms in water up to 110 ft. depth, are supported by piles. Originally steel piles and reinforced concrete piles were used. The former ones are attacked by corrosion, the latter do not always stand up to the required hard driving and become very heavy for great lengths.

Lately hollow prestressed concrete piles have entered the field. They are a natural for such deep foundations in aggressive water. A drilling platform was designed to be supported by 8 such cylindrical piles. The dimensions of these piles were, an outside diameter of 36 in., and a wall thickness 5 in. Lengths up to 200 ft. were cast in one piece. An ingenious and rapid soil investigation method measures the point and frictional resistance of the soil. This information is relayed by radio to the main office, where a soil mechanics engineer decides on the pile lengths and issues orders to the yard for dispatching the proper piles. Various lengths, ready for use are kept in stock.

FABRICATION

Before deciding on the type of pile, our firm fabricated and tested square, rectangular, hexagonal, octagonal and even H-shaped piles. The merits of post-tensioning and pretensioning systems were carefully evaluated. We finally decided on the pretensioned monolithically cast, cylindrical hollow pile with a 36 in. O. D.

In order to produce a pile of this length with uniform density and concrete strength, extensive testing and research was necessary. This testing included the location of exterior vibrators determining their direction of impulse waves plus designing the mix and the pouring.

December, 1960
General view of casting beds.

Prestressing the wires.

Wires prestressed, stirrups placed; note some field splices in the wires.
procedure. Numerous tests resulted in a mix that satisfied requirements for strength and durability. The mix contained 8½ bags of cement per cubic yard and had a slump of ¾ in. The relation between the quantities of sand and stone was 1 to 6.5, pozzolith No. 8 was also added for density. With natural curing this mix reaches a strength of 4,000 psi in 32 hours, after which the pre-stress force is transferred to the concrete and the piles are removed from the casting bed. At 7 days the concrete strength averages 6,-800 psi and at 28 days, 8,000 psi. The strength tests were conducted on standard 6 in. by 12 in. cylinders.

On casting beds, over 800 ft. long, high tensile strength steel wires were stressed in one operation by pulling an end bulkhead with two 200 ton hydraulic jacks. The wires are of heat treated alloy steel, with oval cross section and ribs to improve bond. These wires can be

Concreting operations; note the exterior vibrators.

The revolving 60—T crane lifts a pile.
The pile being placed on the stockpile; note some flat points.

The bending test on a 45 foot section of a 36 in. pile.

A 600 Ton load test.
The floating piledriver hoists a 195 ft. pile on a 2-point lift.

spliced with a Voigt machine (B.B. R.V. patent). The number of wires used per pile depends on the required prestress force, which is mainly governed by the bending moments during handling. The stress is kept at 10% over the initial design stress of 118,000 psi for 10 minutes. The yield/break-strength is 206,000/226,000 psi.

Mild steel spiral stirrups are then placed, followed by steel outside forms and an inflated rubber tube, reinforced by steel sleeves, forms the hollow circular void. Exterior vibrators are placed at staggered 5 foot intervals. This vibration combined with the compaction of the concrete produces a very dense concrete in the bottom and sides of the pile. The top, however, needs additional vibration, which is accomplished by needle vibrators and by finishing with a floating vibrator. Test cores taken from all parts of the pile section show little spread, and average 23% higher than the test cylinder.

HANDLING AND DRIVING

Piles are removed from the casting bed by an overhead gantry crane with a 4 point pickup. They are then placed on railroad cars and transported to a 60 ton revolving crane that loads them on a stockpile or on a barge. They next proceed to the floating piledriver that hoists them using a 2-point lift.

We use heavy single acting steam-hammers, with either a 16.5 or a 22 ton ram, the stroke of which can be manually controlled between 6 in. and 4 ft. We feel that the relation between weight of ram and weight of pile should be at least 0.25. The higher this relation is, the better, as the pile can be driven to greater bearing capacity with less damage.

After using a 16.5 ton ram for years, we recently acquired a steam-
200 ft. pile being moved to position.

200 ft. prestressed pile.
hammer with a 22 ton ram. It was especially designed and built for us by Messrs. Menck and Hambrock of Hamburg, Germany. This hammer is believed to be the heaviest and most powerful hammer in the world. It can deliver a 176,000 ft. lb. blow at a 4 ft. stroke. It will be used on foundation work for the bridge over Lake Maracaibo where extremely hard driving is expected.

Initially we drove the piles open-ended but abandoned this practice when it was found that longitudinal cracks appeared occasionally; we think this is caused by water hammer and internal pressure. Since then we drive closed-end, empty piles, and longitudinal cracks have not appeared any more.

Occasionally fine horizontal cracks have been detected in piles with soft driving. We believe that excessive tension during soft driving with little point resistance, but appreciable shaft friction, is mainly responsible for such cracks. These cracks do not go through the wall and do not admit water. Divers report the presence of exudate, and we believe they heal themselves. We take two steps to remedy this situation. First the stroke of the ram is controlled by hand and constantly adjusted to driving conditions. Short strokes for soft driving and long strokes for hard driving. Second the design tension in the steel is kept so low that at the moment of driving it is below 103,000 psi or 50% of the yield limit. The steel is then still able to absorb the large tension waves caused by driving, before the yield limit is reached, at which point horizontal cracks might appear. With these precautions we have driven piles continuously for over three hours with the 15 T ram and a 39 in. stroke to a final resistance of 150 blows per foot, without damage to the pile head or shaft.

TESTS

Impermeability tests on a pile section with an internal water pressure of 170 psi left the concrete on the outside face dry. A bending test was also performed on a 45 foot section. The pile failed at 1600 foot kips. The first cracks appeared at 910 foot kips. After unloading the pile the cracks closed at 660 foot kips. Even when the pile was unloaded from 96% of the failure load, the cracks still disappeared. The concrete cylinder strength at the time of the bending test was 6500 psi. With our present improved mix of 8000 psi the bending test would give even better results.

Various pile load tests have been made periodically. One pile was loaded to 600 tons and had a gross settlement including elastic shortening, of 1 inch. The net settlement after the load was removed was ½ in. Another pile loaded to 470 tons had a gross settlement of ¾ in. and a net settlement of ½ in.

CONCLUSION

With strict control of all phases of the fabrication, handling, and driving operations; prestressed concrete piles of up to 200 ft. length can be used successfully for great bearing capacities.