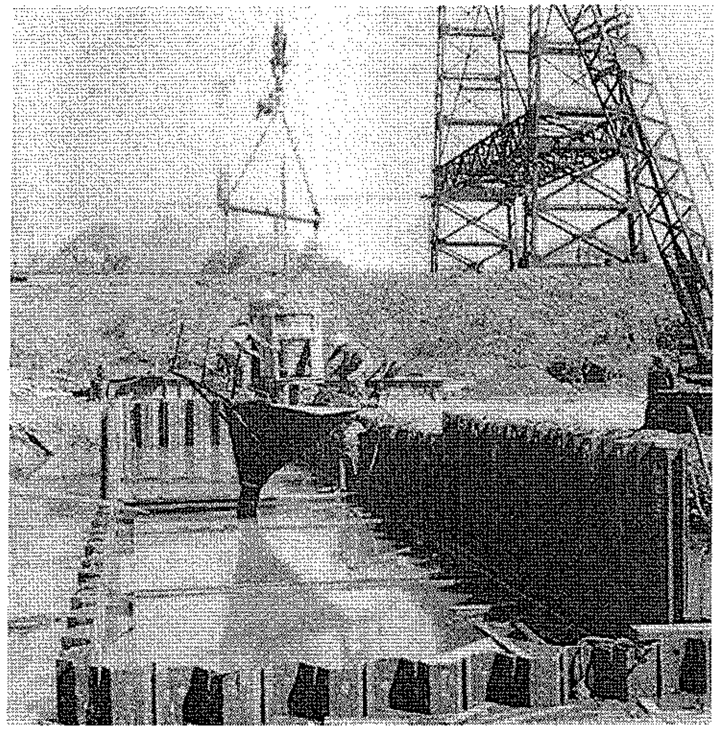
TREMIE CONCRETE

Some useful facts about the preferred technique for placing concrete under water



Placing tremie concrete for a bridge on the Connecticut Turnpike.

Concrete is often placed beneath a water surface to seal cofferdams and caissons, to weight objects such as precast tunnel sections, and to construct numerous types of subaqueous foundations. Methods of placement on such projects include lowering the concrete in burlap or tarpaulin sacks, using special buckets to transfer the mix to the underwater floor, laying aggregate and then grouting it, and pumping concrete directly into place. These techniques have proved successful in meeting certain job requirements, but the most common and expeditious way to place large volumes of concrete to considerable thickness under water is the tremie method.

The word "tremie" comes directly from the French tremie meaning "hopper." Tremie concrete refers to placement by gravity feed from a hopper through a vertical pipe extending from above the surface to the underwater floor. As concrete flows from the bottom of the pipe, more is added to the hopper so that the tremie pipe is continuously charged with fresh mix.

The tremie pipe is constructed of extra heavy steel and usually has a minimum diameter of 12 inches. Smaller pipes can be employed, but any below 10 inches in diameter carry the risk of being plugged by the concrete.

A tremie pipe is generally lowered, raised and moved laterally by a derrick or a crane. It is possible to ride a tremie pipe in a hoist tower on the edge of a barge. It is also possible to mount a pipe on a framework spanning a cofferdam and control it with a winch.

The origin of tremie concrete is uncertain. There is some evidence of its use in the mid-19th century. Later tremie concrete was employed in the construction of the Detroit River Tunnel in 1906 and to construct a dry dock at Pearl Harbor between 1909 and 1913. Utilization of tremie pipes to place reinforced structural concrete is a somewhat recent development, furthered in great part by the construction of graving docks and dry docks during World War II. Twentieth century experience plus laboratory and field tests have indicated that tremie concrete properly used offers the following advantages: relative ease in rapidly placing large volumes of concrete at great depths; curing conditions that are excellent; avoidance of the need for dewatering before placement; and freedom from voids and honeycombing in the finished product.

The major aim in underwater concreting is to place the mix in its final position with as little disturbance as possible. A mix with sufficient slump to flow easily into place is needed. Excessive laitance is likely to result if too rich a mixture or too finely ground cement are used. Since employment of construction joints is not recommended, the concrete should be placed in one continuous pour whenever possible.

Tremie concrete need not be extra rich for if the pipe is handled properly there will be little cement loss. A 5 or 6 sack mix with a slump of from 5 to 7 inches has been found to work well. Both field and laboratory tests have shown that the addition of entrained air and a chemical retarding agent improves tremie concrete considerably, resulting in a smooth flow with good cohesion and a marked reduction of laitance and internal heat over ordinary concrete. Tests on ordinary concrete placed by tremie pipes indicated a 33.5 percent reduction in strength between the center and the extremities of the flow. Air entrained concrete with a retarding agent showed only an 8 percent difference. This type of concrete in field tests reported to the American Concrete Institute developed an average 7-day strength of 2,980 psi and an average 28-day strength of 4,620 psi.

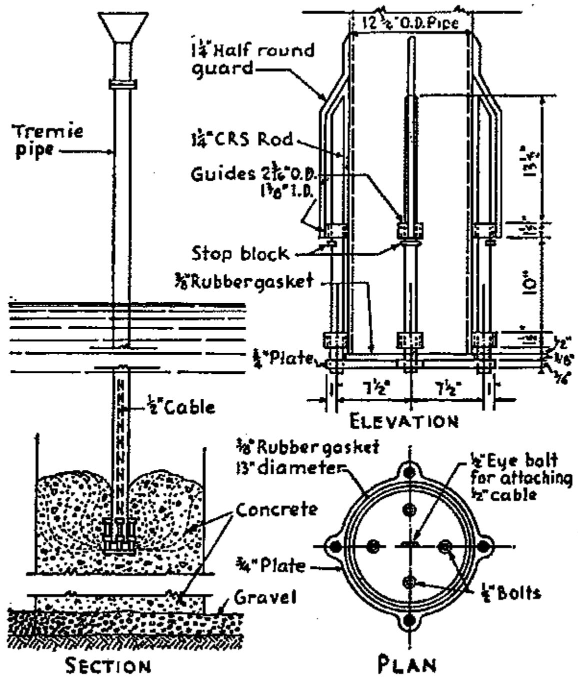
The horizontal flow of concrete under water will depend mainly on the depth at which the concrete is placed and the consistency of the mix. Concrete with sufficient head and a 5- to 7-inch slump will move as far as 100 feet from the tremie pipe. One pipe placed a third of the distance from one end and in the center transversely can make the usual bottom seal pour in a 35- by 90-foot cofferdam, leaving at the most only a few cubic yards of concrete to level off at the extreme end. One of the largest cofferdam placements of recent record occurred during the construction of the Delaware Memorial Bridge. A seal measuring 100 by 220 by 32 feet starting at a 72-foot depth was completed by 2 tremies in a continuous 172-hour casting operation. Tremie concrete of the proper consistency poured from one position will also flow around and encase steel H-piles driven in the bottom of a cofferdam, with no voids and no indication of leakage upon dewatering.

As concrete flows from the tremie pipe the end of the pipe is buried in the mass. Gradually the mix flows out toward the edges to fill the forms and as the concrete builds up, the pipe is raised sufficiently to keep its delivery end buried about 3 feet. The concrete around the end of the pipe seals it from the water and prevents aggregate segregation and washing away of cement. An important task with tremie concrete is to establish a seal before the initial pour.

Numerous devices have been used to seal the tremie pipe. They include the use of a burlap bag filled with straw, a wooden disk or plate held over the bottom of the pipe, and various kinds of mechanical valves.

A straw-filled burlap bag can be placed at the base of the hopper after the pipe has been bottomed. The weight of the concrete drives the bag down the pipe pushing water ahead. When the pipe is raised slightly to allow the concrete to flow the bag is pushed out the bottom and buried in the mix.

An objection to the use of a burlap bag as a seal maker is that it allows concrete to flow rapidly and without control down the tremie pipe and strike the underwater floor with considerable force. This action can scour and erode the floor and create turbulence. Sometimes the turbulence is great enough to damage forms. Turbulence can wash out cement, cause aggregate segregation, and damage concrete already placed should the seal need to be re-established. A burlap bag and straw also are foreign elements in concrete.



Details of tremie foot valve and section showing how valve distributes concrete under water. (Reproduced from ACI Journal by permission of copyright owner.)

Perhaps a somewhat better way to establish a tremie seal is to place a wooden disk or plate over the bottom of the pipe. The disk should be about 2 inches larger in diameter than the pipe itself and it should be fitted with a rubber gasket. As a rule a cable is attached to the disk to insure its recovery after the seal has been established.

The disk is placed against the bottom of the pipe and water pressure secures it while the pipe is lowered. The weight of the concrete introduced once the pipe is in place overcomes the water pressure and pushes the disk aside. Then the mix flows freely and forms a seal as it builds up. While an effective and fairly simple device to use, a wooden disk does carry some hazard of rapid delivery of concrete with the possibility of scouring and turbulence around the pipe opening. The use of a disk also requires complete dewatering of the tremie pipe to re-establish a seal.

A cone valve is one mechanical device that can be used to establish a tremie seal. It can be made from 1/4-inch plate with a transverse bar welded across the bottom in the vertical position and placed at the bottom of the tremie pipe. The top of the cone is cut off to create a one-inch hole through which a supporting and controlling cable is passed and fastened to the transverse bar. The cable is operated at the top of the hopper to open and close the valve.

The cone valve is closed and from 4 to 6 feet of concrete placed in the pipe before it is lowered. Once the pipe is bottomed the valve is opened to allow the mix to flow out. The use of a cone valve permits constant control of the rate of concrete flow and allows for relatively easy re-establishment of a seal whenever necessary.

Another mechanical device and one whose use requires more preparation than others is a rotary valve placed approximately midway in the pipe. A compressed air hose is connected to the pipe just below the valve. With the valve closed, the empty pipe is bottomed. Then compressed air is introduced into the lower portion of the pipe to force the water out. Once bubbles appear on the surface indicating that the pipe is free from water, sufficient concrete is allowed to flow from the hopper to slightly exceed the air pressure. The valve is then opened. The concrete forces the air ahead of it and in effect is lowered relatively gently on a cushion of compressed air.

Establishing a seal by the use of a rotary valve and compressed air offers several advantages. A gradual introduction of concrete to the floor avoids scouring and turbulence. At the same time foreign material is kept from the concrete, the need to recover a device such as a wooden disk is eliminated, and the possibility of malfunction of a device such as a cone valve is avoided. The major disadvantage is the need for special preparation of the tremie pipe.

The selection of a method to establish a seal will be influenced by job requirements and by experience. Regardless of the method chosen, the composition of tremie concrete will not usually vary.

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