

# INSTALLING SUBAQUEOUS PIPE



*18' Prestressed Concrete Pipe, installed by gantry crane and installation barge, to provide cooling seawater to power plant.*

Subaqueous installation is usually associated with open waters, such as oceans, lakes, or rivers. Access can be achieved with conventional land-based equipment utilizing temporary fill, trestles, and/or barges. For full-floating operations, a convenient staging area is required.

In some geographical locations, high water tables and certain soil conditions can make subaqueous installation the most economical solution. For example, if the soil conditions in a land-based installation can be easily dewatered, a problem can exist with the disposal/runoff of significant volumes of water. When water filtration requirements and pH additives are considered, such a project can easily become a water management issue rather than a pipeline installation issue. Installation using the subaqueous method can eliminate the water management issue and may eliminate or significantly reduce the need for sheeting and shoring due to the elimination of an unbalanced hydrostatic head. Effects on adjacent property can also be reduced or eliminated.

## INSTALLATION

Installation consists of three steps: trench excavation, pipelaying, and backfilling. While each of these processes is familiar to installers of pipe on land, there are important differences in processes and materials required for a successful underwater installation.

### Excavation

Subaqueous excavations are often performed using conventional land-based equipment such as backhoes and clam shells. If the water surface is relatively stable (i.e., no wave action) and excavation depths are not excessive, backhoes may suffice. However, clam shell cranes are typically the best land-based equipment to use. They provide the greatest horizontal reach, can excavate to depths of 150



*Clear view of attached Hydro-Pull® end cap with high-volume pump to facilitate subaqueous pipe engagement and joint testing. Concrete Pressure Pipe is ideal to resist the external compressive forces resulting from use of the Hydro-Pull®.*

feet, and are easily suited for the pipe laying operation.

Dredging may be an attractive alternative to land-based equipment. Dredging may be particularly suitable for installations of larger diameter pipe. Large-capacity barge gantry cranes with dredgers are typical marine equipment for such projects.

Since the saturated, excavated material will assume its smallest angle of repose, trench stability needs to be maintained before the pipe is installed. Certain types of clays, when initially excavated, seem firm and stable but can become “quick” (i.e., liquefy) after exposure to water and may need to be removed.

### Backfilling

The bedding material for backfilling the pipe needs to be carefully considered. Is the excavated material suitable for the bedding, or is imported material required? Since it is almost impossible (or at least cost prohibitive) to excavate the trench to form a bedding angle, additional material is almost always required.

Granular materials that flow fairly freely, such as sand or crushed stone, work well for bedding. The typical standard material is 3/4” rock (#57 stone). Potential problems with the use of fine grain materials will be discussed in the backfilling section. It must be realized that saturated soils cannot be compacted, but can be consolidated. Placing the final bedding with a backhoe, clam shell, or chute at

an elevation above the top of the pipe will allow the material to flow under the pipe until the desired minimum bedding height is reached. Care must be taken during final bedding placement to ensure that bedding is placed equally on each side of the pipe to prevent lateral displacement.

### Pipelaying

In subaqueous installations, construction divers typically function as pipe layers due to the ambient conditions. The pipe loses approximately 40% of its weight in water, allowing a further reach by the crane or backhoe. Prior to laying a pipe segment, preliminary bedding material is placed in the trench to an elevation of approximately 6 inches below the final pipe bottom elevation. After a pipe is laid, it is temporarily supported on its free end until additional bedding can be placed under the barrel of the pipe up to the required height for the minimum bedding angle. Temporary support of the pipe is accomplished using “sleepers” made of concrete, wood, or a laminate combining both materials. Placement of a sleeper is usually accomplished by divers; therefore, its submerged weight needs to be kept to a minimum for easy handling. The use of sand or gravel-filled bags can cause problems when the next joint of pipe is added, because the load the bag must support can easily double, resulting in broken or deformed bags, which may allow the pipes to settle below the required elevation.

The majority of subaqueous installations are done in waters with little to no visibility for the divers. This requires that all movements of the pipe must be directly conveyed by the diver to the equipment operator handling the pipe. Backhoes can be used for laying pipe but their hydraulics tend to bleed



*Three sections of 144” RCCP welded together are temporarily capped and floated to installation barge in Lake Mead.*



down under load and their movements cannot be as finely-tuned as a crane. There have been a few unique subaqueous projects that have been installed via remote control and without divers. In these cases, extreme physical conditions warranted the additional cost of using robotics over normal diving operations.

## PIPEJOINING

Numerous mechanical methods can be employed to make joint connections underwater. Bell-and-spigot joints require an axial, compressive force to push the pipe home. The techniques used to create this force can include draw bolts/lugs, come-alongs, in-haul winches, steel-fabricated "horses," and hydraulic rams. All methods require that the joints being connected are initially placed in relatively close axial alignment, such that the joint can be made easily and without damage. These methods may also require significant effort on the part of the diver—sometimes under adverse conditions. It must be realized that the diver is basically weightless and, therefore, cannot use his body weight to exert even light forces. For this and other reasons, additional time may be required for working underwater, causing subaqueous installation operations to incur increased costs compared to land-based operations.

Another joining system, called **Hydro-Pull®**, can minimize the time required for underwater joint assembly by taking advantage of the incompressibility of water. The process can bring a joint together in a few seconds with little effort from the divers. This system requires that the starting point (usually the land side) of the pipeline be temporarily sealed with a bulkhead or valve. Then, on the offshore laying end, the Hydro-Pull® bulkhead is placed over the end of each pipe to be connected to the pipeline. This special bulkhead contains a submersible pumping unit, usually hydraulically powered and controlled from the surface.

Under the direction of the diver, the pipe to be installed is placed close to the previously-installed joint and is axially aligned. The pumping unit in the special bulkhead is started and a relatively small amount of water is rapidly withdrawn from the pipe. This withdrawal of water creates a pressure imbalance across the bulkhead which results in an axial compressive force that moves the pipe toward the joint. As the joint closes, the pressure differential and created axial force increases until the joint is



*Two sections of 42" Prestressed Concrete Pipe, welded together for subaqueous installation.*

completely homed. Since water is considered incompressible, only a small amount of water is needed after the joint is complete, to reach the maximum dynamic pressure of the pumping unit. This maximum pressure differential can be up to 25" of mercury Hg. After sleepers or a small amount of bedding is placed under the pipe to stabilize it, the special Hydro-Pull® bulkhead is then removed and the process repeated. By monitoring this pressure drop inside the pipe when the joint is made, the integrity of that joint and all previously installed joints can be verified. Note that Hydro-Pull® will only provide about a 10–12 psi pressure test; therefore, testable joints or an overall hydrostatic test on the completed pipeline may be required to meet the requirements of the design engineer and the finished project.

Testable joints add additional cost to the pipe, but can provide an ongoing integrity test of the pipeline for the engineer and owner. The small, threaded test port for these testable joints must be left open until they are to be tested. If the ports are not left open during the underwater joint assembly, the rapid decrease in volume between the two gaskets can cause the displacement of one or both gaskets, thus rendering the testable feature unusable. The use of excessive gasket lubricant between the gaskets and test port can also prevent pressure equalization of the space between the gaskets as they are compressed.

The number of joints which must be engaged under water can be reduced by joining multiple pieces of pipe on the ground or a barge, then lowering the joined pipes as a unit. These pipes may be secured together either by welding or mechanical restraint. The length of the pre-assembled unit will depend in

part on the size of pipe and capacity of lifting/placing equipment.

## **SUBAQUEOUS DRAW BOLT JOINTS**

If subaqueous draw bolts are used for assembly, they cannot be relied on to provide restraint against unbalanced internal pressure hydrostatic forces. The nuts on the draw bolts must be backed off after the joint is assembled to provide for future settlement of the pipe. If joint restraint against unbalanced thrust forces is required, one of the restrained joint types, such as a harnessed clamp or Snap Ring®, must be used.

## **BEDDING MATERIAL**

The most economical source for bedding is the excavated material. However, this material may not be acceptable for several reasons, making imported material necessary. Whatever material is used, no object larger than 1" in any dimension should be in contact with the pipeline's exterior surface. As previously noted, saturated material cannot be compacted; it can only be consolidated. Clean granular material, such as clean sand or 3/4" stone, is easily placed under and around the pipe to the height required to achieve the necessary bedding angle. If, during the design life of a subaqueous pipeline, it will see dynamic conditions—such as seismic activity, wave action, or both—the selection of the appropriate backfill material and sufficient bury depth is critical.

Saturated fine grain material, especially 1/16" and less in size, can become fluidized or "quick" when moved by seismic activity or differential pore pressure due to surface wave dynamics. These fine grain materials can have a net buoyancy effect of

120 or greater pounds per cubic foot (pcf) on the pipeline. Since concrete pipe with water inside has a specific weight less than 120 pcf, the pipeline will be displaced upward through the quick material used for backfill.

Surface wave dynamics in a body of water can produce liquefaction several meters deep into the subsurface. Therefore, a careful analysis is required during project design. A free-draining bedding material such as 3/4" stone can prevent liquefaction in bedding and backfill in sizes up to cobbles. Even the use of a free-draining material alone may not secure the pipe over the long term if the material above or around the pipe is of a fine grain size, since the fine material can eventually migrate into the pore area of a free-draining material and affect its ability to drain freely. The use of a geotextile fabric to encapsulate a free-draining material can prevent future clogging of the pore area. Another approach to countering the effects of dynamic liquefaction is to install the pipeline at a significant depth below the surface, where liquefaction cannot occur. If the costs to bury the pipeline at a sufficiently increased depth to avoid wave liquefaction are uneconomical, the use of armor stone, of appropriate size, above the pipe to overcome buoyant forces may be economically justified. An analysis of wave dynamics and erosion on any armor stone is then required in the design of the project.

## **PIPE PROTECTION**

Concrete pressure pipe has excellent, built-in corrosion-resistant properties for most installation conditions. The high alkalinity (pH in the range of 12.5 to 13.5) passivates the embedded steel, preventing corrosion. In continuously submerged pipelines, the embedded steel does not experience damaging corrosion (even in seawater that contains 20,000 ppm chloride ion) due to the extremely slow rate of oxygen diffusion through the saturated portland cement mortar coating. As a result, supplemental protection over the mortar coating is not required for continuously submerged concrete pipe. However, a protective coating system should be applied over the exposed portions of the steel joint rings unless they will be encased in portland cement, grout, or mastic material.

## **PIPELINE TESTING**

Occasionally, it may be necessary to conduct post-construction pressure testing on the completed



*This yellow device holds four pipe sections, welded together, and also has a tank which can be filled with either air or water to provide controlled buoyancy and reduce the submerged weight of the pipe.*





*Crane used for clamshell excavation and subaqueous pipe laying.*



pipeline. Acceptable methods include an infiltration test or an internal pressure hydrostatic test.

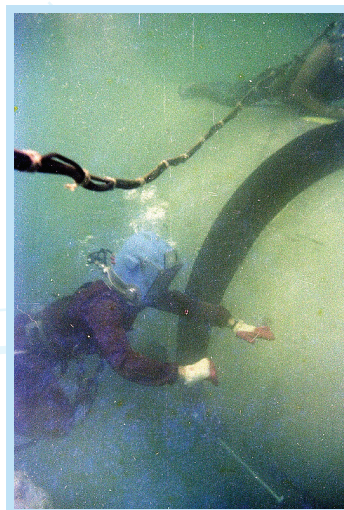
An **infiltration test** is typically conducted on pipelines installed below the water table. It is a relatively simple process that does not require restrained bulkheads, as is necessary for hydrostatic testing. Water levels inside the pipe are drawn down to the required head differential with a pump connected to an end cap or access manhole. The water level is monitored to determine if there is any infiltration. Using Hydro-Pull® as the installation method provides an “automatic” infiltration test each time a pipe segment is added to the pipeline with 10 to 20 feet of differential head pressure.

**Hydrostatic testing** requires the entire pipeline to be properly backfilled to prevent lateral and axial displacement. Bulkheads are rated for the test pressure and restrained. Once the pipeline is entirely restrained or has a sufficient number of restrained joints at the bulkheaded ends, the pipe is secure for hydrostatic testing. If restrained joints are not used, temporary concrete thrust blocks must be placed against the end bulkheads in order to prevent movement.

*ACPPA thanks Dane R. Hancock, P.E., for his assistance with this article.*



*Subaqueous joint installation lugs are clearly visible on this pipe.*



*Divers guiding pipe joining.*

# LEARN MORE

For more information about the subaqueous installation of Concrete Pressure Pipe, speak with your Concrete Pressure Pipe supplier, or contact the American Concrete Pressure Pipe Association at **714.801.0298** or **[www.accpa.org](http://www.accpa.org)**.



**ACPPA Headquarters**  
T 714.801.0298  
**email:** [support@accpa.org](mailto:support@accpa.org)  
**[www.accpa.org](http://www.accpa.org)**