ANEXO 4

PRESENTACION DE CASOS DE ACUEDUCTOS
DE ESTADOS UNIDOS
The most important element in a prestressed pipe which protects it against corrosion from the environment is the mortar coating covering the wires. If the coating is uniform and there are no aggressive agents at the wire surface, no corrosion will occur. The alkaline environment provided by the hydration of portland cement creates a passivated surface on the wire such that corrosion by water and air alone does not occur.

In considering the protective quality of the coating there are a number of aspects which must be recognized:

1. In order to create a uniform environment, slurry must be placed on the concrete core ahead of the prestressed wire as well as on top of the wire after it has been prestressed.

2. Durable coatings should be placed using a low water/cement ratio. In such coatings only 50-60% of the cement becomes hydrated.

3. The most important characteristic necessary for a good coating is compaction. Consolidation is measured indirectly by the 5-hour boiling absorption ASTM Method C497. The lower the absorption the better the protective quality of the coating. Acceptable coating absorptions should not exceed 10%.

4. Proportions of cement and sand in mortar coatings must be closely controlled. Mixtures with too little cement exhibit high absorptions. When too much cement is used, the volume changes due to drying shrinkage increase and the coating tends to develop cracks. Ratios of cement to sand between 1:2.75 and 1:2.0 as measured on the pipe after application are recommended for satisfactory coatings. These proportions will change on different sizes of pipe when the same mixture is applied by counter rotating brushes due to rebound of the coarser particles.

5. The corrosion of the prestressing steel in mortar coating is under cathodic control. Unless an adequate supply of oxygen is present, polarization will occur and no corrosion will take place. For this reason, pipes installed below the water table generally undergo little if any corrosion even with inferior coatings.
6. In the absence of oxygen, steel in mortar or concrete will not corrode even when relatively high concentrations of chlorides are present. The threshold of corrosion depends on the ratio of chloride to hydroxyl ion.

7. High rates of corrosion can take place at the interface where steel is partially embedded in concrete or mortar and partially exposed to a moist environment, i.e. at a crack or separation in the coating. The rate of corrosion will be a function of the ratio of the area embedded in concrete to the area exposed.

8. It is hypothesized that in regions of a limited oxygen supply polarizion effects can produce atomic hydrogen in cathodica areas resulting in the embrittlement of high strength steels with time. An example is the brittle fracture of prestress wires under apparently sound coating adjacent to cracks or spalls.

North American Case Histories

Literally thousands of miles of prestressed concrete cylinder pipe have been installed throughout North America since World War II. Most of these pipelines have been successfully operated without major maintenance for many years. At the same time there have been several hundred failures usually involving only individual sections of pipe. In some cases, however, subsequent investigations have revealed general corrosion in significant portions or in the entire length of the line. A few lines have been abandoned entirely.

Some of the notable cases with which we have been involved or which we have studied are:

- Pinellas County Florida

This line is a 60-inch diameter prestressed concrete embedded cylinder transmission main approximately 13 miles in length installed in 1978. The pipe is rated at 150 psi and is currently operating at 80-90 psi. The soil is fine sand with no chlorides or sulfates present.

Two failures have occurred. The first was at normal operating pressure. Corrosion in the burst area was general and could have been caused by a cylinder leak. The second failure occurred at 150 psi during a pressure test and was attributed to corrosion under a separated coating.

Excavation of a number of additional pipe sections revealed varying degrees of corrosion of the prestressed wires. Investigations have revealed deficiencies in the design, materials used and fabrication procedures. In particular the aggregates used in the concrete and mortar did not meet the specification requirements of the AWWA standard for prestressed cylinder pipe.
Cobb County—Marietta, Georgia

This line is situated just north of Atlanta and was installed in 1968 through 1972. It is approximately 69 miles in length mainly 36 inches in diameter operating at pressures of between 150 and 250 psi. A total of 77 failures have occurred in this line since installation. Although both lined and embedded cylinder pipe are involved, the failures have been principally in the 200 to 250 psi embedded cylinder pipe. In our opinion, cause of the failure has been due to the design and manufacturing defects.

The embedded cylinder pipe was designed with a D/16 wall having a total thickness of 2 1/4 inches (57 mm) fabricated by vertical casting in 16 ft. length. The presence of the embedded cylinder in the wall resulted in very thin concrete sections on either side necessitating the use of high slump concrete. In addition a fine sand was employed which did not meet the AWWA specification requirements leading to a high water requirement. Significant bleeding at the top (spigot end) of the pipe as cast produced a weak concrete at the spigot. Excessive contraction of the core due to shrinkage and creep after prestressing caused the coating to separate from the pipe. A vast majority of the failures occurred by virtue of separated coatings starting at the spigot ends.

Washington Suburban Sanitary Commission

A number of failures have occurred recently in the Washington, DC, suburban area. These failures have involved 84, 72 and 60 inch pipes. Three of four of the most recent have taken place adjacent to private residences involving considerable damage including flooding of Route 95, the main north-south highway along the east coast.

Perhaps the most notable case was the burst of a class 150 psi 72-inch pipe installed in 1974 in the backyard of a home. Initial cause of the break was found to be corrosion caused by leakage due to a cracked weld in the cylinder. Further investigation revealed the adjacent sections of pipe to be in poor condition. A series of manufacturing defects were found. The mortar coating was of inferior quality, soft and carbonated throughout. In all a total of 19 20-foot long sections had to be removed and replaced. By contrast, a parallel 54-inch line on the other side of the highway was inspected and found to be in excellent condition. It had been installed 10 years before the 72-inch pipe.

A surface potential survey was conducted over the balance of the line and several additional anodic areas located. One suspect location was excavated revealing several pipe with damaged coating, corroded and broken wires. The line is currently out of service.
El Paso, Texas

A 10 year old 60-inch diameter 150 psi line running on the river side of the levee along the Rio Grande suffered several failures. After repairing the first break, the line was repressurized and immediately a second break occurred. It was repaired and the line again repressurized. At this point a third break occurred. The line was taken out of service.

Investigation showed approximately 30% of a 10,000 foot reach of the line was severely corroded in local areas at the top of the pipe. The bottom of the pipe is about one foot below the ground water level which contains a significant concentration of chlorides and sulfates. Cover over the pipe in the affected area is only 1 1/2 to 2 feet.

Cause of the failure was attributed to capillary action of the ground water through the coating which then evaporated from the top of the pipe concentrating chlorides at that point resulting in corrosion of the prestressed wires.

Comments

As a general rule, provision was usually made for cathodic protection in pipes installed in the eastern USA. It was thought sufficient to rely upon the protective qualities of the mortar coating. Recently, however, pipelines are being fabricated with shorting straps and bonded joints so that cathodic protection can be applied if found necessary. An attempt had been made to bond the joints of the El Paso line when it was installed but by using contact only rather than welded or brazed connections. Tests showed that the contact connections were inadequate and the line was not continuous.