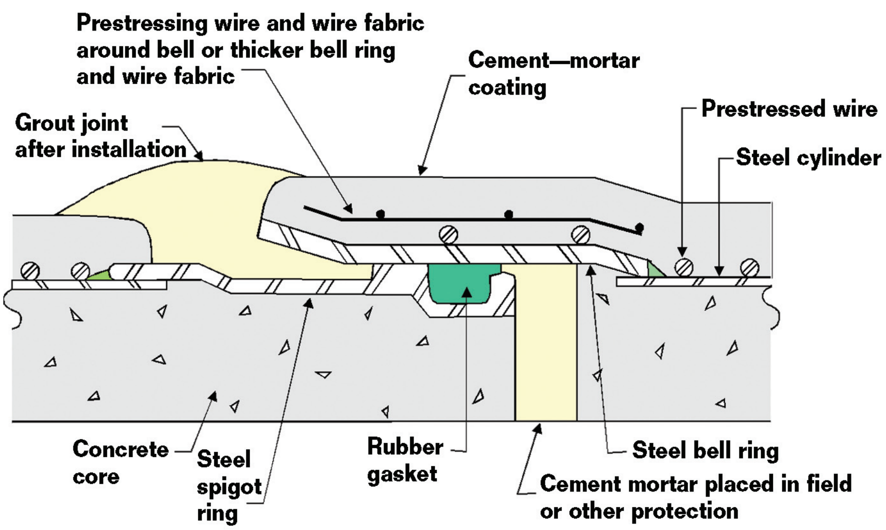
CASE HISTORY

Corrosion and Cathodic Protection of Prestressed Concrete Cylinder Pipe

R.A. GUMMOW, *Corrosion Service Co., Ltd.*

FIGURE 1



Prestressed concrete cylinder pipe with the prestressing wire wrapped around the steel cylinder.

Prestressed concrete cylinder pipe (PCCP) used for water and sewer transmission service is composed of a thin wall steel cylinder, lined on the interior and exterior with cement mortar, and reinforced by prestressing wire either wrapped around the steel cylinder or embedded in the exterior mortar (Figures 1 and 2). These large-diameter composite pipes are often thought to be immune to corrosion because the steel cylinder and prestressing wire are covered by concrete whose alkalinity promotes the formation of a protective passive film on the steel surfaces. As with many passive films, however, the protective film is subject to breakdown by chlorides, and there has been an increasing number of failures on PCCP piping because of chloride attack. Once the film is penetrated and corrosion is initiated on the prestressing wires, which are typically under ~200 ksi (1,400 MPa) tension, stress corrosion cracking occurs, often causing catastrophic failure of a major water transmission main.

A high soil concentration of chlorides is normally not required for chloride attack to occur if the pipe is subjected to a variable water table. This situation produces wet/dry cycles, whereby the pipe surface is wetted and then dried by evaporation; chlorides left behind on the concrete surface become concentrated to a point sufficient enough to migrate through the mortar cover, and then they attack the underlying steel. This has been the cause of numerous failures like that shown in Figure 3.

Cathodic protection (CP) has been used to prevent this problem on the Pockwock 42-in. (107-cm) diameter water transmission line, the main water feed for the city of Halifax.[1] In 1985, within 10 years of its installation, this pipeline had its first failure, which was closely followed by five more failures. Galvanic CP was applied in 1991 to the piping section where the failures had occurred. The CP system consisted of 80-in. (2-m) long zinc anodes weighing 8 lb (3.6 kg), surrounded by a sulfate/bentonite backfill and pack-

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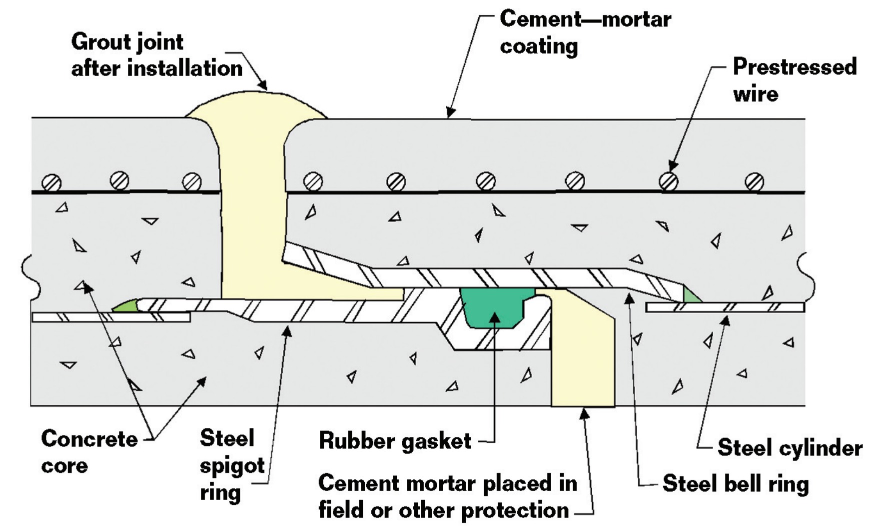
FIGURE 2



Prestressed concrete cylinder pipe with the prestressing wire embedded in the exterior cement mortar.

FIGURE 3

Typical corrosion failure of a prestressed concrete cylinder pipe.

aged in a cardboard tube. Every other pipe joint was excavated, so the joint was electrically bonded and two of the packaged zinc anodes were installed at each location. Zinc was chosen to limit the polarized potential on the pipe to less negative than –975 mV vs copper/copper sulfate ($Cu/CuSO_4$) electrode to minimize the risk of causing hydrogen embrittlement (HE) of the prestressing wire. The current requirements turned out to be so low (<200 mA/m^2), that many of the originally installed zinc anodes were subsequently disconnected.

Prestressing wire is particularly susceptible to HE because of its alloy and hard-drawn manufacturing process. An HE susceptibility test (ASTM A227[2]) has been developed, which has led to improved performance. Lewis[3] has demonstrated from the results of this test that many existing PCCP piping systems contain prestressing wire that is vulnerable to HE. A number of HE failures have occurred where the PCCP piping has been in close proximity to a CP groundbed.

References

1. C.E. Henderson, C. Yates, "Corrosion Protection of the 48″ Dia. C301(L) Pockwock Transmission Main, Halifax, Nova Scotia," NACE Eastern Canadian Region Conference (Montreal, QB: November 7, 1994).

2. ASTM A227, "Standard Specification for Steel Wire, Cold-Drawn for Mechanical Springs" (West Conshohocken, PA: ASTM, 1993).

3. R. Lewis, "Improving Prestressed Wire Reliability in Prestressed Concrete Cylinder Pipe," MP 41, 7 (2002): pp. 48-54.

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R.A. GUMMOW is President of Corrosion Service Co., Ltd., 205 Riviera Drive, Markham, ON, L3R 5J8, Canada. A NACE-certified Corrosion Specialist, Gummow has more than 40 years of experience in the application of CP to a wide variety of structures in many industries. He has a diploma in natural gas technology from Ryerson Polytechnical Institute and a degree in electrical engineering from the University of Toronto. A 42-year member of NACE, he has presented many technical papers and has instructed NACE CP courses for more than 26 years. He received the NACE Technical Achievement Awards in 1989 and 1992 and the R.A. Brannon Award in 2004. MP