Session Information: Corrosion Assessment and Modeling of Reinforced Concrete Structures

Presentation Title: Root Cause Analysis of a 30-inch Water Concrete Reinforced Pipe Rupture

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Abstract

With over 7 decades of wide scale use of concrete reinforced pipe within infrastructure and water utilities in the United States, the overall experience has generally been good. However, problems can occur intermittently and drastically affect its performance. One such high profile and never the less recurring problem associated with concrete reinforced pipe has been discussed in this paper.

In 2012 a rupture occurred on a 30-inch concrete reinforced water main pipe in the Northeastern United States. The 30-inch water main is a prestressed concrete cylinder pipe (PCCP). PCCP is a composite pipe material mainly composed of concrete (concrete core), steel cylinder (or steel liner), mortar/concrete coating and prestressed/high-tension wires wrapped around the steel cylinder which is outside of concrete core.

Penspen Corporation, Houston were contracted by the water main operator to carry out an independent diagnostic root cause analysis (RCA) to determine the probable physical root cause(s) of the concrete reinforced pipe rupture and subsequent functional failure of the water pipe, at the failure location, and to identify the contributing failure factors.

A detailed laboratory program for concrete and steel (wire and sleeve) specimens from both the immediate location of the rupture and locations away from the rupture for testing and comparison was recommended. The tests recommended included: visual inspection, comprehensive metallurgical analysis of the material, steel properties testing and concrete petrographic analysis.

Laboratory test results revealed an anomalous corrosion pattern that occurred near the sleeve. The results indicated that the corrosion to the sleeve and wires at the rupture location occurred primarily to the outside surface of the sleeve/wire construct. That is, only minor corrosion was noted on the inside surface of the sleeve even near the rupture location. This suggests that the thick outer mortar layer of the pressure pipe had been structurally compromised at some time during its life, and ground water had permeated onto the steel sleeve and wire. The test results also showed that the chlorine level was as high as 4.1 weight percent on the corroded wires and 3.0 weight percent on the corroded sleeve. These levels are alarmingly high and far above the levels normally found in soils, and therefore they support the fact that crevice corrosion attack occurred over a long time upon the outer surfaces of the sleeve and high strength wires.

Following a deductive-inductive analysis, the hypothesis “Soil with high dissolved salts (mainly Chlorides)” was identified as the most probable intermediate physical root cause, based on evidence obtained and laboratory testing results, for this RCA.

This paper provides an overview, adopted methodology, analysis, results interpretation for the different stages of this root cause analysis, key findings with a discussion of the contributing failure factors and key recommendations to be considered with same service PCCP and external environment.

Key words: Root cause analysis, Fault tree analysis, PCCP, Petrographic analysis, SEM/EDS and Metallographic analysis.