AUTOGENOUS HEALING OF CEMENT MORTAR AND CONCRETE

Cracks in cement mortar or concrete lining of Concrete Pressure Pipe are a common occurrence which may give unnecessary cause for concern that the lining would not provide the intended structural performance or protection to the steel. Cracks may develop due to drying shrinkage, temperature variations, and stresses caused by handling, shipping and installation. The cracks may develop at the manufacturer's plant, while stored at the project site, or after installation. Cracks can be fissures that penetrate the full thickness of the lining or pipe wall, or they can partially penetrate and should be distinguished from surface crazing. Surface crazing occurs in the thin laitance layer on the lining surface, often has a cobweb appearance, and is never of concern regarding the lining's performance. Cracks may be longitudinal, circumferential, diagonal or a combination of all. An offset and hollow sound at the crack may be noticed.

The AWWA Standards associated with various types of Concrete Pressure Pipe include provisions regarding the acceptability of some cracking, and acceptable repair procedures for cracks within the stated size ranges. As a general rule, those limits are intended for pipe (and fittings) when new and inspected for acceptance of delivery.

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Depending upon the time a pipe spends exposed to weather prior to installation, cracking of the pipe may increase. The information in this article is provided to assist in the judgment of whether such additional cracking is acceptable, requires repair, or makes the pipe considered for rejection.

Concrete and mortar usually has the ability to self heal cracking, provided water is not flowing through the crack excessively, as can happen at a breach in the pipe cylinder or on non-cylinder pipe. This has been demonstrated many times. A good historical example occurred during the manufacture of the Canadian River project in Texas during the early 1960s. The pipe supplied for the project was 295,310 feet of 96, 78, and 72-inch non-cylinder prestressed pipe. Since the pipe had no cylinder, each pipe had to be hydrostatically tested after prestressing but before mortar coating. Occasionally, pipe would show a leak through the pipe wall during hydrotesting. If the leak was not significant, the pipe could be left on the hydrotest machine overnight, and the leak would seal up completely. That pipeline continues delivering water to Amarillo, Lubbock, and nine other cities on the Texas High Plains today.

Longitudinal cracks in the lining of prestressed pipe away from the pipe ends are an indication of loss of prestress or other damage to the pipe, and therefore are not acceptable. Under most conditions, cracks wider than 0.060 inches will not occur in the interior of PCCP because the lining is in circumferential compression. However, there will nearly always be a circumferential crack between the end of the prestressed concrete and the concrete inside the un-prestressed spigot. Also, if the pipe interior core shrinks longitudinally due to hot, dry weather, there will sometimes appear a crack following the helical weld of the cylinder of the pipe, or occasional circumferential cracks in the body of the pipe. Such cracks occur due to tensile strain accumulation, particularly at the thinnest section of the concrete core, which occurs at the weld seam. Any such cracks are not detrimental to the pipe. In virtually all cases, once the pipeline is filled with water the interior cracks will close due to a combination of concrete re-expansion and autogenous healing.

When any concrete pipe is filled with water, the lining absorbs water and swells practically to its initial volume. The swelling will tighten the lining and the crack widths will be substantially reduced or closed tight. Additionally, it is well known that cracks in mortar or concrete will repair themselves in the presence of water through a process known as autogenous healing and the lining will retain its original effectiveness. Because the healing process is slow, it may take several weeks or months to completely fill a crack, depending on crack width and other factors.

Autogenous healing was recognized during the early development of concrete structures. It was noted that cracks visibly healed in the presence of water, such that not only did the cracks visibly close but strength was restored. The healing of cracks in concrete was first reported by the French Academy of Science in 1836. In 1913, the ability of concrete to heal itself was reported by D. A. Abrams.[1] He noticed during load testing of a concrete bridge 3 years after the initial load test that cracks from the first test did not open or they opened at a load much higher than was placed on the bridge in the earlier test. He concluded that concrete exposed to weather had healed in such a way as to form a joint even stronger than the younger, unbroken concrete. Three-edge testing of previously tested and cracked non-reinforced concrete pipe has shown strength increase when tested several years after the initial test. Many studies and observations have confirmed the ability of concrete to self heal.

The self healing ability of concrete in the presence of moisture is caused by the formation of calcium carbonate from excess calcium and hydroxide in the cement paste, and carbon from bicarbonate in the water. Cement mortar or concrete lined pipe is usually an ideal moist environment for concrete to self heal. Calcium carbonate crystals form when bicarbonate in water reacts with the calcium hydroxide in the mortar or concrete. The calcium carbonate crystals precipitate and grow from the surface of the crack. Over time, the accumulation of calcium carbonate crystals seals the crack. The healing product may appear as white deposits on the surface. The resulting bond at the sealed crack may be as strong or stronger than the original mortar or concrete. The healing requires the presence of bicarbonate (resulting from dissolved carbon dioxide) in the water, so healing will not

occur if the water is extremely pure and deficient in carbon dioxide or bicarbonate.

Some wider cracks, when examined during pipeline acceptance, may not appear to have closed completely after soaking. Usually, the interior of the crack will be completely sealed with calcium carbonate, which can be verified with a thin probe. With additional soaking time the crack will typically completely fill with calcium carbonate. Moisture in the soil will also heal cracks on the pipe exterior.

The swelling and healing of mortar or concrete also prevents steel corrosion at the bottom of the crack. The same water that may cause steel corrosion provides the environment for autogenous healing. The unique corrosion inhibiting properties of cement quickly forms a passivating layer preventing continuing steel corrosion at the bottom of the crack, even if some atmospheric corrosion had occurred prior to filling the pipe with water. The cement mortar or concrete will make the water in the crack highly alkaline. The alkaline environment is provided by the hydrated Portland cement which has a pH of about 12.5. The high alkaline environment forms a protective iron oxide film on the steel surface. A partially filled pipe may show rust stains at the crack-water-air interface. Completely filling the pipe will prevent further corrosion. As discussed above, the ability of concrete to self heal will eventually fill and permanently seal the crack.

It has been reported that cracks as wide as 5/16" in mortar-lined steel pipe have been observed to heal autogenously. Since Concrete Pressure Pipe generally has a thicker lining than steel pipe, the Concrete Pressure Pipe also typically has a larger reserve of excess calcium hydroxide for the formation of calcium carbonate than does steel pipe. Consequently, efforts to repair interior cracks are generally not recommended. The best remedy is most often to fill the pipeline with water and allow the cement mortar or concrete lining to swell and self heal. If there is some concern regarding the crack width, filling the crack with a neat cement paste has proven effective.

Notes

1. Test of a 40-ft reinforced concrete highway bridge", D. A. Abrams, (Amer Soc Testing Materials Proc. 13 (1913)) pp 884–922

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For more information about using 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**.

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