After 31 Years in Atlantic Ocean Outfall, RCP Still Exceeds Specs[1]

Rinker Materials recently load-tested a 30-year old concrete pipe that had been in service in a tidal marine environment until it was removed during a marina reconstruction project. Even after 30 years in salt water, the old steel-reinforced concrete pipe (RCP) exceeded – no, greatly exceeded – the minimum required design and yield loads for a pipe of its strength class. Further, not only had the RCP sat in tidal seawater for 30 years, but prior to loading, Rinker had removed a 1-foot by2-feet coupon from the pipe wall. Despite all of that, the 30-year old RCP with a 1x2 feet hole in it still greatly exceeded the minimum required loads.

History of the 30-Year Old RCP

In 2013, the City of Dania Beach, Florida contracted with Shoreline Foundation to construct a $7.5M renovation of the Dania Beach Marina. Craven Thompson & Associates designed the marina renovations. The original marina was developed over 30 years ago. However, in 2007, a city-commissioned engineering report determined that "the entire dock system has exceeded the expected service life and should be replaced." The report recommended the replacement/repair of the crumbling seawall, a more efficient marina design, pump-out facilities and a fish cleaning station.[2]

Figure 1. Barnacles attached to the inside barrel of concrete pipe after 30-years in the tidal Dania Beach marina.

[1] Article originally published by Douglas Holdener on LinkedIn, March 3, 2016, https://www.linkedin.com/pulse/after-30-years-ocean-outfall-concrete-pipe-still-holdener-p-e-

[2] Abraham, Randy, "City plans $7.5M renovation of Dania Beach Marina," *Sun Sentinel*, November 9, 2012, http://articles.sun-sentinel.com/2012-11-09/news/fl-cn-marina-1111-20121109_1_dania-beach-marina-docks-city-plans.

The installation of a new stormwater pollution control structure necessitated removal of two pieces of old RCP from the original marina development, which dated back to 1982.[3] The two sections of old 30-inch RCP were removed from the construction site and taken to Rinker Materials Miami Pipe Plant for examination and testing.

Figure 2. A 1-foot by 2-feet section was cut from the barrel to observe and measure steel reinforcement. Minor steel corrosion was observed, but with no damage to the adjacent concrete.

Rinker observed the 30-year old RCP to be of sound structural condition.[4] In order to examine the reinforcement, a rectangular 1-foot by 2-feet section was cut from the pipe wall. Some of the steel had visible signs of corrosion but no concrete appeared corroded or spalled. Minor corrosion stains were visible at the longitudinal tips in the bell face. The inside barrel of each pipe was covered in barnacles.

Marina site observations indicated that, at the RCP outfall, the newly installed concrete pipe was measured to be at an elevation approximately seven feet down to the pipe crown (outside top) from the top of seawall. Observations and conversations with the Dockmaster indicate that high tide water elevation is approximately three feet below the top of the sea wall, which indicates that the top of pipe is submerged in four feet of seawater. During low tides, the top of the pipe is sometimes visible. A second concrete pipe outfall – that was not replaced – is often fully visible during low tides.[2] This suggests that the 30-year old RCP functioned in a tidal environment.

Load Testing the 30-Year Old Pipe

On February 26, 2015, Rinker Materials load tested a 6.6-feet section of the 30-year old RCP obtained from the marina. The load test was conducted using a three-edge bearing (3EB) apparatus, which is routinely used to certify that RCP finished-product strengths meet the

[3] Based on conversations with Kevin Land of Shoreline Foundation and Marina Dockmaster Frank Arcuri in November 2013.

[4] The pipe was observed to have minimal corrosion on the steel and no spalling or concrete wall damage. On the spigot end of one pipe, approximately 1.4 feet of the pipe was missing (broken off), which most likely occurred during its removal from the seawall structure. This resulted in a 6.6-feet section of RCP. Otherwise, the pipe had no signs of structural damage due to environmental or service load conditions.

minimum design and yield loads for the applicable ASTM C 76 strength class (e.g., Class III). It is noteworthy that the 30-year old RCP had not only been setting in tidal seawater for 30 years but also was tested with a 1x2 feet section removed from its barrel wall. For the 30-year old RCP, the minimum design and yield load targets were determined to be 22,300 pounds (and 33,000 pounds, respectively.[5]

The initial hairline crack (< 0.01 inch wide) was not observed until 36,000 pounds had been loaded on the 30-year old RCP. A 0.01-inch wide crack did not develop until 42,000 pounds, and the old RCP did not yield until 51,600 pounds. The old RCP – after 30-years of service in tidal conditions and then having a large section cut from its wall – still exceeded the design service load (0.01-inch crack) by a factor of 1.9 and exceeded the yield load by a factor of 1.6 times.

Figure 3. A three-edge bearing (3EB) strength load test was conducted on a 30-year old section of RCP that had been removed from a tidal marina. Prior to loading, a section was removed from the wall for examination. Despite this, the RCP was able to support 51,600 pounds. .

Concluding Remarks

The Dania Beach marina was reconstructed because the marina docks had corroded and deteriorated. Interestingly, despite the dock corrosion, the original concrete pipe had minimal, insignificant corrosion. Even after a large rectangular coupon had been removed from the old marina pipe just prior to load testing, the pipe exceed its minimum required design load by a factor of nearly two. It is difficult to say which is more remarkable: (a) that the RCP remained this strong after 30 years in a tidal marina environment or (b) that the pipe exceeded its design

[5] Prior to loading the pipe, Rinker had removed a 1-foot x 2-feet coupon in order to examine the cross-section. Using a micrometer gauge, circumferential steel was measured to be 0.24 inch diameter at 3-inch spacing, and thus resulting in a reinforcing area of 0.18 sq.in./ft., which is the minimum steel reinforcing area required per ASTM C76 Class III B-Wall 30-inch RCP. The Class III design load target is 1,350 pounds per foot diameter per foot length(lbs/ft/ft), and the yield load target is 2,000 lbs/ft/ft. Therefore, the target design and yield loads for the 30-inch (1.5 feet) diameter and 6.6-feet length test pipe were calculated to be 22,300 pounds and 33,000 pounds, respectively.

loads despite having a large section intentionally removed from its barrel. Or, to the contrary, this could be considered typical – even expected - of reinforced concrete pipe that has structurally performed - without history of failure - in even the most extreme conditions for decades.

Figure 4. A lift hole, cored into the pipe at casting, is visible in the 30-year old steel reinforced concrete pipe removed from the Dania Beach marina renovation. Although installed at an outfall in a tidal seawater environment, there is no visible deterioration adjacent to the lift hole.