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Asbestos Cement Pipelines – Sampling, Testing, and Condition Assessment

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ABSTRACT

The East Bay Municipal Utility District (EBMUD) is a major metropolitan water district located near San Francisco, California, with over 4,100 miles of distribution mains including 1,100 miles of asbestos cement (AC) pipe with an average age of 50 years. A surge in AC pipe failures led to a first phase of collection and testing that showed that AC mains were deteriorating from both inner and outer wall corrosion. A second phase of collection and testing, using state-of-the art sampling, testing, and condition assessment methods using acoustic technology, is currently underway in collaboration with Water Research Foundation (WRF). Results from both studies will be used to complete statistical analyses and remaining service life predictions, to assess the need for water quality changes to reduce the rate of inner AC wall deterioration and to implement a model that can be used to develop a cost-effective program to replace or rehabilitate AC pipes.

1.0 INTRODUCTION

The District provides water service to over 1.3 million customers on the east side of San Francisco Bay. The District's service area covers approximately 322 square miles in Alameda and Contra Costa counties. The primary source of the District's water comes from the Mokelumne River basin snow melt stored in Pardee Reservoir on the slope of the western foothills of the Sierra Nevada mountain range. This water is transmitted westward over 90 miles through three large steel transmission pipelines, the Mokelumne Aqueducts. The District has approximately 4,180 miles of distribution pipes including 1,150 miles of asbestos cement (AC) pipes, 1,300 miles of cement mortar lined (CML) steel pipes, 1,350 miles of cast iron pipes, and 380 miles of other pipe materials (e.g. plastic).

The AC pipe is distributed throughout the service area with the highest densities located in the communities of Hercules, Castro Valley, and the San Ramon Valley. Most of the AC pipe was installed between the 1950s and 1970s at 6 and 8-inch diameters.

1.1 Phase 1 Study

In 2007, the District observed an increase in AC pipe failures, and field staff reported a peculiar loss of the pipe's material properties (the pipe was reported to be soft), prompting an investigation of the cause of the failures. From 2008 to 2011, the District collected, tested, and analyzed over 30 AC pipe samples, as part of the Phase 1 AC Pipe Study. The District retained the services of JDH Consultants to complete a study and laboratory testing of AC pipe samples. The findings were presented in a technical report titled: Phase 1 AC Pipe Corrosion Study. The report summarized the current condition of the AC pipes and made recommendations for future asset management. Figures 1.11 and 1.12 show samples that were part of the Phase1 Study.

Figure 1.11 – AC Samples

Figure 1.12 – AC Samples

1.2 Phase 2 Study

In 2012, the District began a second phase of AC sample collection, testing, and analyses. This study is a collaboration between the District and Water Research Foundation (WaterRF), estimated to be completed within a 2-year period at a total cost of approximately $2 Million. The objective of this study is to perform condition assessment and remaining life prediction, explore rehabilitation and replacement alternatives, and implement statistical modeling to guide a cost-effective program for replacement or rehabilitation of AC pipe. The specific scope includes:

- Collection and testing of AC pipe samples, to gain more information on the District's AC pipes.
- Development of a prediction model for rehabilitation or replacement of AC pipe
- Research of replacement or rehabilitation methods and technologies.
- Development of an AC pipe replacement plan for the existing AC pipes.
- The study is currently in progress and scheduled for completion in 2014.

2.0 CONDITION ASSESSMENT

2.1 Collection

A sample collection plan was developed prior to the field collection of in-service AC pipe samples throughout the distribution area. The field collection effort would be performed entirely by District Forces. AC samples were collected based on the following criteria:

- Located in areas with different water quality zones
- From 6 and 8-inch diameter AC mains
- Sample Size: 3-feet samples and 3-inch coupons
- Varying Age (installed from 1950s to 1970s)
- Collect samples from breaks (unplanned) or planned locations

Since the start of the Phase 2 Study, over 70 AC samples have been collected by District Forces. These samples were collected throughout the distribution area representing two main water quality zones: Mokelumne Aqueduct and Mix. The Mokelumne Aqueduct zone is located primarily along the area east of the Oakland/Berkeley Hills. The Mix zone receives water from a combination of local watersheds as well as the Mokelumne Aqueducts. Mix zones are located mainly along the area west of the Oakland/Berkeley Hills.

All of the pipe samples were collected from in-service pipes of various age and mostly from 6 and 8-inch diameter AC mains, since this size makes up the majority of the AC pipe inventory. Planned samples were selected at locations which minimize impacts to the service area including residential areas and locations with light traffic. The planned samples were collected in two methods: coupon or 3-feet samples. Coupon collection was performed by District forces using a hot-tap operation to remove a 3-inch coupon at selected locations. The coupon alternative resulted in less impact to the service area requiring no shutdown of the main line. Also, since the size of the excavation was smaller, it was a less costly operation. The 3-feet samples were also collected. This operation required shutdown of the mainline, installing a new PVC replacement section, and flushing and cleaning of the main. Table 2.15 provides a cost breakdown between the two collection methods.

Figure 2.11 – Coupon Sample

Figure 2.12 – Pipe Tap Machine

Figure 2.13 – AC Pipe Sample

Figure 2.14 – AC Pipe Excavation

TABLE 2.15 - Cost of District Forces to Collect AC Pipe Samples		
Coupon Sample	$5,000	Cost includes: Excavation, backfill, paving.
3-feet Sample	$15,000	

Samples were also collected from unplanned events from on-going pipe breaks and leaks. The unplanned sample sizes ranged from 3-ft to 6-ft in length. By mid-2012, District forces collected over 70 samples from planned and unplanned locations.

2.2 Testing and Analysis

The District hired JDH Corrosion to perform laboratory testing and analysis of the AC samples. JDH Corrosion performed the following tests: strength, chemical analysis of soil in excavation, pH, density, SEM-EDX, and petrographic examination.

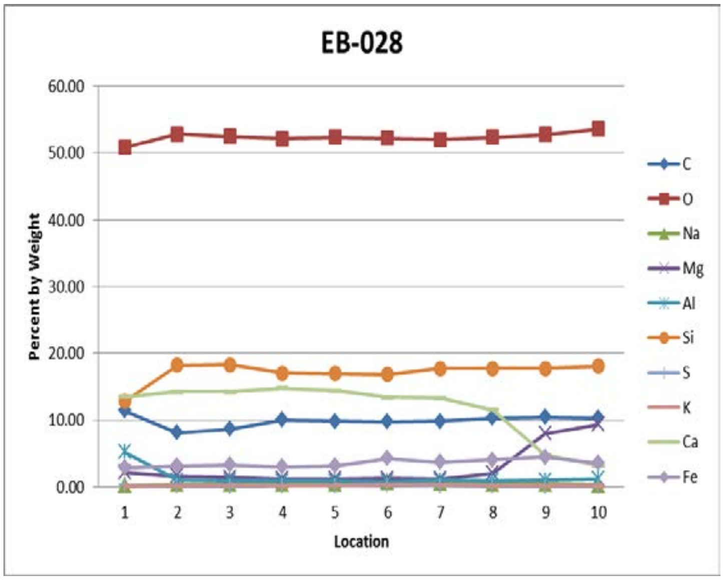

Figure 2.21 – SEM/EDS Analysis of an AC sample in Tareyton Ave, San Ramon, CA

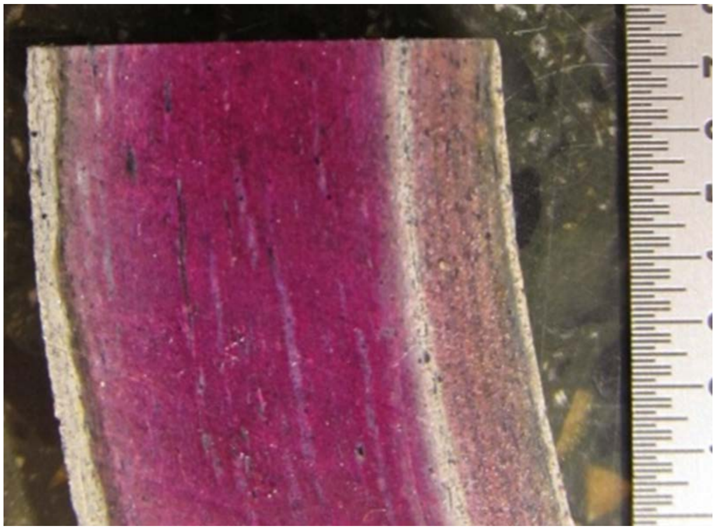

Figure 2.22 – Phenolphthalein Stain of an AC sample in Tareyton Ave, San Ramon, CA

2.21 Elemental and Petrographic Analysis

The elemental and petrographic analysis uses scanning electron microscope/energy dispersive spectrograph (SEM/EDS) to measure aluminum, calcium, iron, magnesium, silicon, and sulfur across the wall thickness (ASTM C295 and C856). Calcium concentration across the wall thickness shows the degree of lime that has leached out from the pipe. Figure 2.21 shows the result of the SEM/EDS chemical analysis for a sample taken from an AC pipe in Tareyton Avenue in San Ramon in 2012.

2.22 Phenolphthalein Staining

Phenolphthalein staining is used to measure the thickness of calcium hydroxide (lime) left in the pipe matrix. In this test, phenolphthalein is sprayed on a freshly exposed, smoothly ground, cross-section of a pipe sample. The cross-section areas that still have lime (a pH greater than 8.2) turn pink (basic) and the areas where the lime has leached out remain white (acidic). Phenolphthalein is a relatively simple, inexpensive and effective way to track the loss of calcium hydroxide in the AC pipes. The results of phenolphthalein tests have been well correlated with SEM/EDS results. Figure 2.22 presents a sample AC pipe phenolphthalein test. The inside and outside surfaces of the pipe wall did not stain, indicating that the leaching or corrosion has occurred.

2.23 Mechanical Tests

JDH Corrosion conducted crush and bending strength test to determine the maximum internal, external, and bending stresses of each AC pipe sample. The strength tests follow the American Society for Testing and Materials (ASTM) C296 for Standard Specifications for Asbestos-Cement Pressure Pipe and C500 for Standard Test Method for Asbestos Cement Pipe.

The crush strength tests conducted on the pipe samples indicated that all of the test samples met the requirement of as-manufactured (new) pipe for Class 150 AC pipe.

Figure 2.23 – Crush Strength Test

Flexural testing was performed on two samples, each requiring a minimum length of 9-feet. The flexure test results indicated that the samples met the requirement for new Class 150 AC pipe.

Figure 2.24 – Flexural Test **Figure 2.25 – Flexural Test**

2.3 Non-Invasive Testing

Recent advances have led to development of non-invasive measurement of the remaining wall thickness of AC pipes. The new technology developed by Echologics works by measuring how quickly acoustic signals are transmitted along a section of pipe. Acoustic signals are induced in pipes by releasing water at fire hydrants in a controlled manner. Then, they are measured using acoustic sensors positioned at two longitudinally separated points on a pipe. The sensors are attached at easy-to-access points, such as fire hydrants and control valves, or directly on pipes in existing access manholes. The acoustic propagation velocity is calculated based on the sensor spacing and time delay between the measured acoustic signals. Average wall thickness of the pipe section between the acoustic sensors is then back calculated from this.

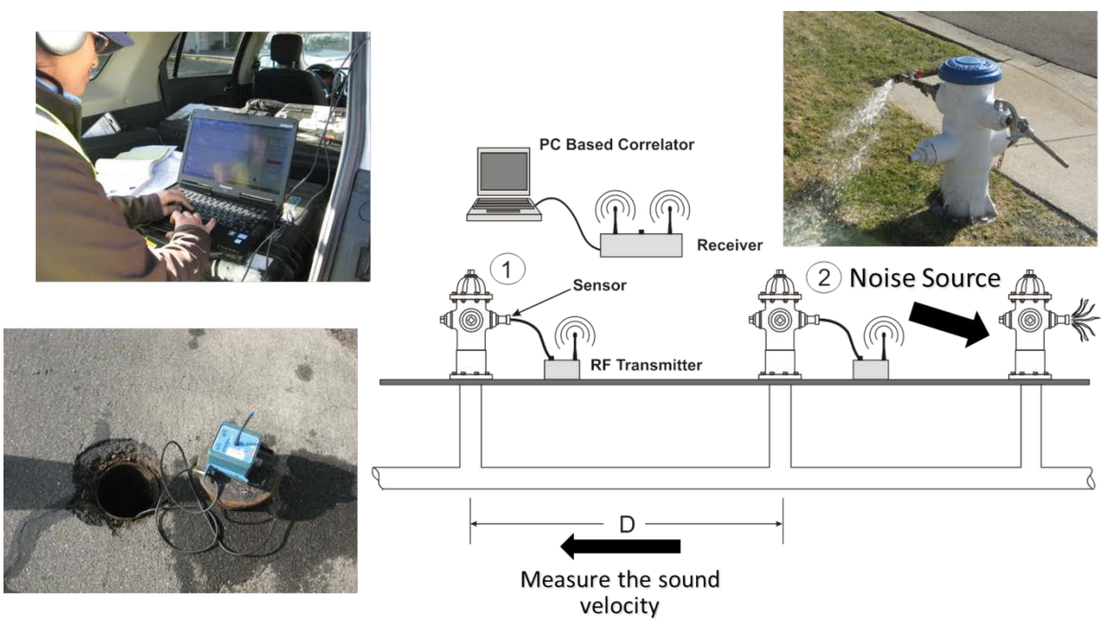

Figure 2.3.1 – Echologics Testing of AC Mains

Echologics was hired by the District to survey approximately 2 miles of AC Pipe at the same locations where 3-feet and coupon samples were collected. The 2 mile inspection was comprised of various residential locations located east and west of the Oakland/Berkeley Hills. The objective was to determine if there were correlation between the phenolphthalein (stain) test results and the Echologics acoustic survey. The results are shown on Table 2.3.2.

Street Name	Location	Coupon or 3' Sample	Diameter	Year Installed	Echologics % Loss	Stain % Loss	Good Correlation Ech v Stain
Narcissus Court	Castro Valley	Coupon	6	1978	40%	0%	No
Todd Court	Castro Valley	Sample	6	1976	58%	48%	Yes
Lakeridge Road/La Costa Avenue	Castro Valley	Sample	6	1985	38%	48%	Yes
Nordell Avenue	Castro Valley	Coupon	6	1953	60%	29%	No
Wisteria Street	Castro Valley	Coupon	8	1963	21%	21%	Yes
Greenway Drive	Richmond	Coupon	8	1977	11%	27%	No
Park Central Court	Richmond	Coupon	6	1978	15%	18%	Yes
Raton Court	Richmond	Coupon	6	1959	57%	38%	No
Encinal Drive	Walnut Creek	Coupon	6	1960	38%	48%	Yes
Montin Court	Walnut Creek	Coupon	6	1975	29%	33%	Yes
Leroy Lane	Walnut Creek	Coupon	8	1965	57%	19%	No
El Suyo Drive	San Ramon	Sample	8	1976	22%	23%	Yes
Tangerine Road	San Ramon	Sample	8	1964	28%	26%	Yes
Wyndale Drive	Castro Valley	Sample	6	1955	35%	74%	No
Carlwyn Drive	Castro Valley	Sample	8	1955	26%	58%	No

Table 2.32 – Echologics versus Stain Test Results for 3-ft and Coupon Samples

The stain test results for the 3-ft pipe samples had better correlation with the Echologics survey results. A total of 4 out of the 6, 3-ft pipe samples showed correlation between the two tests. Only 4 out of 9 coupon stain test results correlated with Echologics.

3.0 AC PIPELINE REPLACEMENT PLAN

The Phase 1 AC Pipe Study produced a preliminary predictive model which was developed to determine the future rate of replacement. Based on this simple model, by the year 2020, 41 miles of AC pipe will achieve 80% corrosion, leaving no reserve strength in the pipe, and by 2050, a per year average of 27 miles of AC pipe will exceed the 80% pipe wall corrosion level. As a result, the preliminary predictive model indicated that the District is approaching an immediate problem and must initiate a comprehensive sample collection program and pipeline replacement plan to understand and manage the aging AC pipe infrastructure.

3.01 Existing Pipeline Replacement

Presently, there is no specific pipeline replacement plan that focuses on AC pipe. The District currently focuses on maintaining a stable leak rate in the distribution system as an indicator of overall system integrity. The leak rate utilized is 20 breaks per 100 miles of pipe per year. AWWA has indicated that this rate is considered to be a “well run system.” The District calculates a pipeline replacement rate using the AWWA Research Foundation software program KANEW to maintain a leak rate below the AWWA limit. KANEW computes replacement rates using pipe characteristics, such as age and material, and user defined survival functions to forecast optimistic and pessimistic pipe life expectancies. The District maintains an average replacement rate of 8 miles per year or a 0.2% (476-year return period) of the total distribution system per year. In 2012, The District implemented a plan to replace at least two miles of AC pipe year.

The current pipeline replacement program prioritizes the total pipe calculated in KANEW by spatially grouping pipe extensions having two to three leaks within 500 to 1,000 feet, respectively, within a seven-year moving window. Pipe extensions meeting this criterion undergo an economic analysis to determine whether it is cost effective to replace the pipeline using a cost ratio (CR), where CR is equal to the cost of pipe repair divided by the cost of pipe replacement. The CR prioritizes the pipe replacement program, where high priority projects have a CR greater than 1.7 and low priority projects are less than 1.7.

3.02 Proposed Pipeline Replacement

To date, over 100 AC samples have been collected, tested, and analyzed as part of the first and second phases of the study. Based on the new and previous sample data, a new statistical model will be developed to help determine the future AC pipe replacement rate. The District will be implementing a new proactive program to ramp up AC pipe replacement and accelerate the renewal of the aging AC system after the Phase 2 Study is completed. The findings from this study will help refine the prediction model and rank and prioritize the replacements.

4.0 CONCLUSION

The District will be completing the Phase 2 AC Pipe Study in 2014. The preliminary findings have shown that the AC mains are experiencing both inner and outer deterioration. Through extensive collection, testing and analysis of the AC main population, the District is now equipped with the vital information to develop a prediction model to help plan for future replacements.

5.0 REFERENCES

Echologics Engineering (2013). Table 2.32.

JDH Corrosion (2010 – 2013). Photos for: Figures 1.11, 1.12 2.21, 2.22, 2.23, 2.24, 2.25, 2.31