PCCP Inspection Truthing and Education Demonstration

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14. ABSTRACT
Two distressed sections of pre-stressed concrete cylinder pipe were removed from service and sent to the Denver Federal Center to be used for inspection truthing and a hands-on educational demonstration. After installation, walkways around the pipe sections were installed, prestressing wires were exposed, and the pipe sections were inspected. Course work was developed, and a presentation was prepared for the Materials and Corrosion Lab's annual coatings and corrosion school.

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The Science and Technology Program, Bureau of Reclamation, sponsored this research. Tarrant Regional Water District kindly provided the pipe sections used for construction of the educational demonstration.

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prepared by

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Bureau of Reclamation
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Acronyms and Abbreviations

EC	Electrical Continuity
EM	Electromagnetic
GIS	Geographical Information System
PCCP	Prestressed Concrete Cylinder Pipe
Reclamation	Bureau of Reclamation
TRWD	Tarrant Regional Water District
UAV	Unmanned Arial Vehicle

Contents

Page

Executive Summary

Two distressed sections of pre-stressed concrete cylinder pipe (PCCP) that had been removed from service and were brought to the Denver Federal Center to be used for inspection truthing and a hands-on educational demonstration. After installation of the pipe, walkways around the pipe sections were constructed for access, prestressing wires were exposed, and the pipe sections were inspected. Course work was developed, and a presentation was prepared for the Materials and Corrosion Lab's annual coatings and corrosion school. An inventory of items relevant to prestressed concrete cylinder pipe were placed on display within the interior of the PCCP sections.

Visual inspection found extensive damage to the bell and spigot joints, exterior gouging, staining, and delamination. Sounding did not produce audibly different results indicating a lack of voids or delamination in the mortar lining. Electrical continuity (EC) tests confirmed that the prestressing wires were not broken. Electromagnetic (EM) inspection results were unavailable for the pipe sections received. Photogrammetry was used to create a virtual model of the completed demonstration to be used in the classroom presentation. The educational material will be debuted at the Spring 2023 Corrosion School, taught by the Reclamation Technical Service Center Materials and Corrosion Laboratory Group.

1. Introduction

1.1 Background

Prestressed concrete cylinder pipe (PCCP) is a composite pipe consisting of a concrete core helically wrapped by a tensioned wire that is embedded in mortar. Reclamation's inventory of PCCP has been in service for 25-60 years as very large diameter, 8 to 20 feet, main and transmission pipelines. Failures of Reclamation-built PCCP spurred the need to survey the history of Reclamation PCCP, update and input inventory into a Geographical Information System (GIS) format, and push for inspection of all PCCP that is owned by Reclamation. To complement this inspection effort, a permanent installation of PCCP at the Denver labs was proposed. The goal of the project is to provide a tool to develop and maintain Reclamation staff capabilities in visual, sounding, and electrical continuity (EC) inspection of PCCP as well as aiding in the interpretation of electromagnetic (EM) field inspection results. Additionally, the pipe will be available for further forensic analysis including petrographic and physical analysis of the concrete core and mortar coating, and removal of prestressing wire for mechanical and chemical analysis.

1.2 Previous Work

This work follows two S&T projects related to PCCP: PCCP Condition Assessment, Repair, and Replacement Strategies, S&T Report No. ST-2019-7108-01 and Economic Analysis of Prestressed Concrete Cylinder Pipe Maintenance, S&T Report No. ST-2021-20059-01 (Torrey, 2019; Jermyn & Gaston, 2021). This work builds on these previous works by helping Reclamation ground truth PCCP inspection results and maintain capability of staff in PCCP inspection.

1.3 Partners

The distressed pipe sections used for this project were provided by Tarrant Regional Water District (TRWD).

2. Installation of PCCP Educational Demonstration

Distressed sections of PCCP installed at TRWD, located in North Texas, were scheduled for replacement. After being removed from service, two of the PCCP sections were loaded and shipped to Denver. Prior to arrival, the concrete saddle supports shown in Figure 1 were designed and cast in place in the courtyard of Building 56 on the Denver Federal Center. After arrival in Denver, the PCCP sections were offloaded and installed by a contracted crane service. A photograph of the installation is shown in Figure 2.

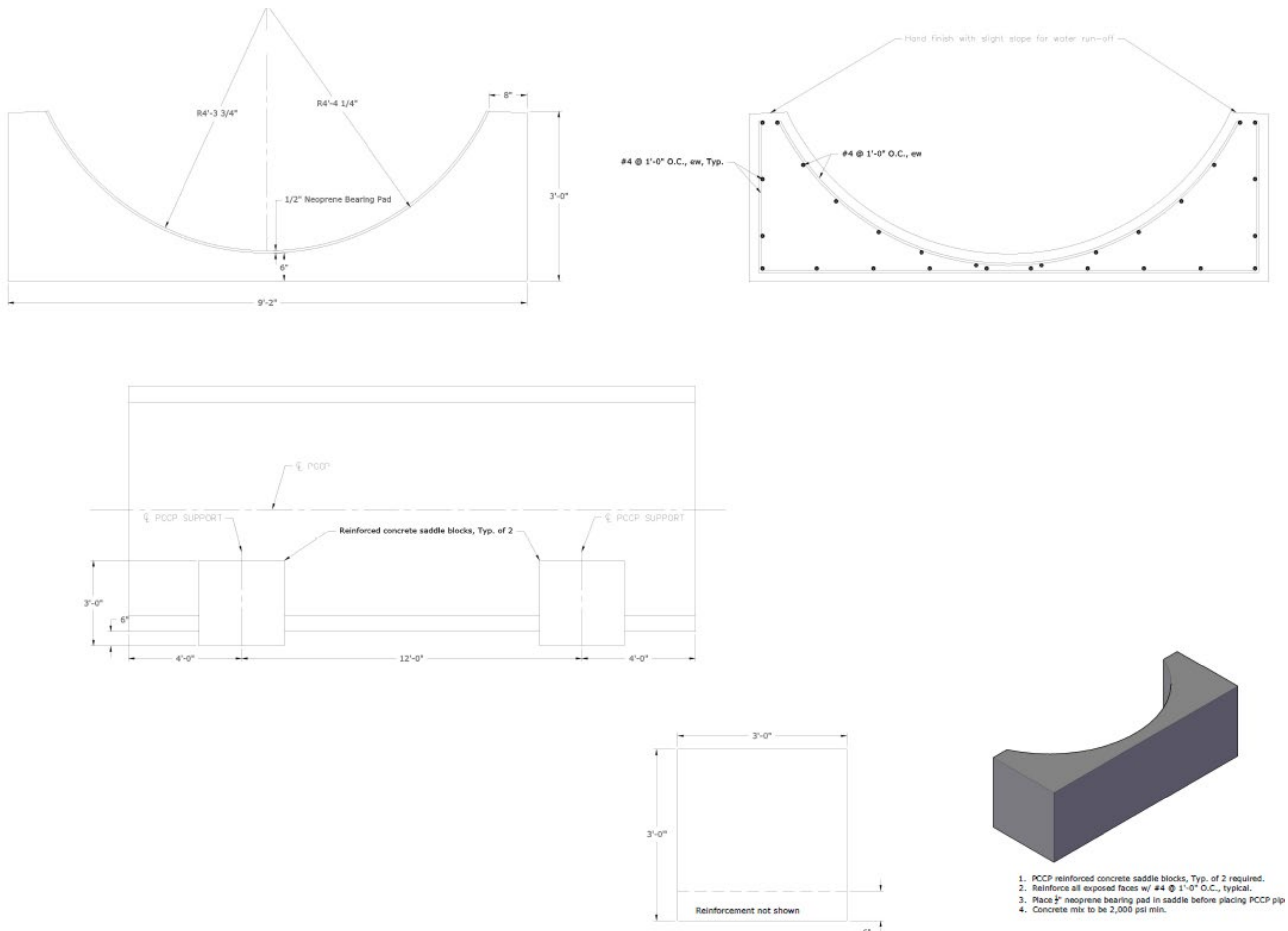


Figure 1. Concrete Saddle Support Design

Figure 2. Installation of two PCCP sections within the courtyard of Building 56 on the Denver Federal Center.

After final placement within the pipe supports, access walkways were designed to facilitate inspections and demonstrations. Fabrication of the walkways was completed in-house by Reclamation staff. The completed walkways are shown in Figure 3.

Figure 3. Educational Demonstration after installation of walkways.

Lastly, a section of mortar coating was removed from the PCCP section to the West to expose the embedded prestressing wires. A weatherproof container was affixed to the exterior of the pipe to protect the exposed wires from the elements while also maintaining the ability to perform EC inspection demonstrations. The completed EC demonstration area is provided in Figure 4 with the exposed prestressing wires shown in Figure 5.

Shelves displaying individual PCCP components, including wires, mortar, and a concrete coring from failed PCCP installations, were installed on the interior of the West PCCP section as seen in Figure 6. These demonstrate various failure modes for the prestressing wire and line corrosion of the wires on the mortar.

Figure 4. The EC demonstration area is visible on the West PCCP section’s exterior.

Figure 5. Exposed prestressing wires used for EC inspection demonstration.

Figure 6 Display shelves with individual PCCP components from failed PCCP installations; items include pieces of prestressing wire, exterior mortar, steel liner, and a concrete core.

A classroom presentation was prepared for the Material and Corrosion Lab's annual Corrosion School. The classroom presentation was developed to provide students with a background knowledge in PCCP and the PCCP inspection techniques that will be employed in the hands-on demonstration. Due to COVID-19 restrictions, presentations have not yet been delivered; however, an in-person Corrosion School is scheduled for the FY 2023 where these course materials will be debuted. The classroom presentation and handouts can be found in Appendices A and B.

3. Inspection Techniques and Classroom Demonstrations

3.1 Visual Inspection

Visual inspections can provide a useful starting point to identify areas for further investigation. The hands-on demonstration provides student inspectors with an opportunity to apply the classroom knowledge provided and make visual observations on real PCCP sections. Inspectors are taught to document signs of damage such as cracks, signs of corrosion, concrete staining, or delamination, as well as techniques for documenting damage with photographs. A hands-on module instruction document is attached in Appendix B.

3.2 Sounding

By striking the surface of the PCCP sections with a dead-blow hammer, an audible response is produced that can be heard and compared with the response from neighboring areas. Differences in the acoustic response indicate a local variation in the material that is commonly due to either delamination or an un-grouted area. The student inspectors are provided with a dead blow hammer and taught the striking technique used to listen for changes in the audible response. Microphones can also be used to quantify acoustic responses more accurately. After inspection, software can be used to perform analysis on the audible response data and quantify the difference from one location to the next. A hands-on module instruction document is attached in Appendix B.

3.3 Electrical Continuity

Measurement of electrical continuity between prestressing wires is an effective way to test for the existence of breaks between wraps of prestressing wires; a high resistance or lack of measurable continuity would indicate that a wire is damaged or broken. Some PCCP includes bonding straps between prestressing wires that helps to distribute cathodic protection current; in these cases, EC testing would not provide conclusive results. Direct measurement of electrical continuity requires that prestressing wires are exposed, as shown in Figure 5, which necessitates removal of the exterior mortar coating. For this inspection, student inspectors are taught to use electrical probes on adjacent windings and take measurements to verify electrical continuity. Results from this test can be useful for verifying EM inspection results. A hands-on module instruction document is attached as Appendix B.

3.4 Electromagnetic Inspection

Using specialized tools, EM inspection techniques can identify both the location and number of broken prestressing wires in PCCP sections. For this inspection, current is induced within the prestressing wire using an exciter coil that is then detected using a separate detector coil (United States Patent No. US6127823A, 1997). Like EC inspections, changes in electrical current passing through prestressing wires are detected that provide an indication of the wire condition; broken prestressing wires will display a decrease in the current detected. Unlike EC inspections, EM inspections are carried out from the interior of the PCCP and do not require physical contact with prestressing wires. Thus, EM inspection is a nondestructive examination technique. Due to the specialized equipment and training required, this inspection is not carried out by Reclamation staff. For the educational demonstration, example reports from prior EM inspections are discussed and presented in the classroom portion of the course.

3.5 Photogrammetry

Photogrammetry is a technique that utilizes photographs of a subject taken from different positions to acquire accurate spatial data in three dimensions (Aber, Marzolff, & Ries, 2010). Among other uses, the data can be used to generate dimensionally accurate virtual models of the subject under investigation. For this inspection, a drone was used to collect arial photographs of the educational demonstration while scale markers were placed on and around the PCCP sections to provide reference dimensions. The photographs were then fed into software to generate a virtual model for demonstration during the classroom presentation.

4. Results and Discussion

4.1 Visual Inspection

Visual inspection was completed on the distressed PCCP sections after installation.
Severe cracking was observed around all bell and spigot joints and the metallic ring was severely bent; an example of bending in the joints can be seen in Figure 7. This damage likely occurred as the pipe sections were being removed from service.

Figure 7. Example of damage found on joints

Severe gouge marks were found in the exterior mortar coating indicating transport by heavy machinery, an example of which is shown in Figure 8. While the damage likely occurred during removal from service, it was not possible to determine if the damage occurred at the initial placement or after removal from service.

Figure 8. Example of Gouging found on exterior of PCCP sections.

Mortar delamination and exposed prestressing wires were found near both joints on the West PCCP section, shown in Figure 9. It was not possible to determine if this damage occurred in service or during the removal process.

Figure 9. Mortar delamination is visible on the West PCCP section.

Gouges like those shown in Figure 10 were found in the interior of the East PCCP section. Interior gouges can be caused of number of factors, including debris; however, the clean surface of these marks and presence of drill holes indicates this damage likely occurred during or after removal of the section from service.

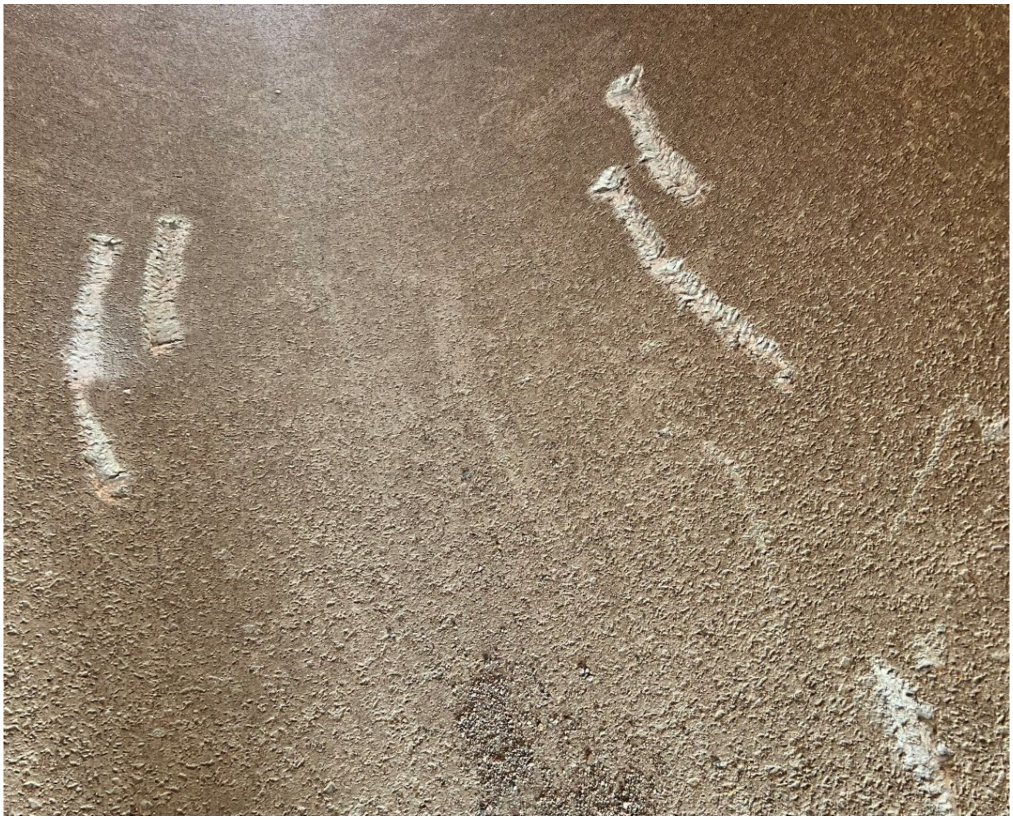


Figure 10. Example of gouges found on the interior of PCCP sections.

While not all the damage observed on the PCCP sections is typical of normal wear and tear found on in service pipelines, it provides a good opportunity for student inspectors to practice documenting observations found during a visual examination.

4.2 Sounding

Sounding was performed on all accessible interior and exterior portions of the PCCP sections. The sounds heard during the inspection were considered uniform throughout both pipe sections excluding regions that are within roughly 5 feet from the ends of the PCCP sections. The regions near the ends produce a notably lower pitch sound. The consistent sounds heard within the body of the PCCP sections indicate that there are no delaminations or voids in the concrete and mortar coating. While there is visible evidence of delamination near the ends of the PCCP sections, the lower pitch sounds heard in these regions are due to end-effects where the material is less constrained and more able to move or vibrate. However, for the purpose of demonstration, this difference in audible response provides student inspectors an opportunity to hear sounds like those that can be heard in cases of delamination or voids within functioning PCCP sections in the field.

4.3 Electrical Continuity

A small portion, roughly 12in by 6in, of the exterior mortar coating was removed to expose prestressing wires for the EC testing. A weather enclosure was added to protect the exposed wires from further corrosion. An image of the portion tested and intended for use in educational demonstrations is shown in Figure 5, with the corresponding results are provided in Table 1 where wires were numbered sequentially from left to right. Testing revealed that all exposed prestressing wires were electrically continuous indicating that no wires were broken. To provide learning opportunities for student inspectors, wires 5 and 6 were later cut with an angle grinder to provide discontinuous readings.

Table 1 Electrical Continuity Results

Wire	Result
1	Electrically continuous with wire 2
2	Electrically continuous with wire 3
3	Electrically continuous with wire 4
4	Electrically continuous with wire 5
5	Wire cut to demonstrate discontinuity
6	Wire cut to demonstrate discontinuity
7	Electrically continuous with wire 8
8	Electrically continuous with wire 9
9	Electrically continuous with wire 10
10	Electrically continuous with wire 11
11	Electrically continuous with wire 12
12	Electrically continuous with wire 13
13	Electrically continuous with wire 14
14	Electrically continuous with wire 15
15	Electrically continuous with wire 16
16	Electrically continuous with wire 17

4.4 Electromagnetic Inspection

EM inspection results were unavailable for the pipe sections received. After removal from service, information regarding the pipe sections' original service location was not retained and no markings were present to uniquely identify the individual sections so that TRWD could provide correlating EM inspection data. While it is likely that these sections were removed from service due to indications found upon EM inspection, it was not possible to identify which EM results applied to the pipe sections received. Typical EM results found on other inspections are instead used for the class portion of the educational demonstration.

4.5 Photogrammetry

After installation and inspection, an unmanned aerial vehicle (UAV) was used to collect the photogrammetry data needed to generate a virtual model of the educational demonstration. Images of the virtual model are shown in Figure 11 and Figure 12. In the virtual model, details of exterior distress and staining are easily seen. The virtual model created will be used for the classroom portion of the PCCP course.

Figure 11. Isometric view of virtual model created by photogrammetry

Figure 12. North side of PCCP educational demonstration virtual model.

References

Aber, J. S., Marzolff, I., & Ries, J. B. (2010). *Small-Format Aerial Photography.* Tier: University of Trier.

Atherton, D. (1997). *United States Patent No. US6127823A.*

Jermyn, M., & Gaston, T. (2021). *Economic Analysis of Prestressed Concrete Cylinder Pipe Mainenance.* Denver: Department of Interior Bureau of Reclamation.

Torrey, J. (2019). *PCCP: Condition Assessment, Repair, and Replacement Strategies.* Denver: Department of Interior Burea of Reclamation.

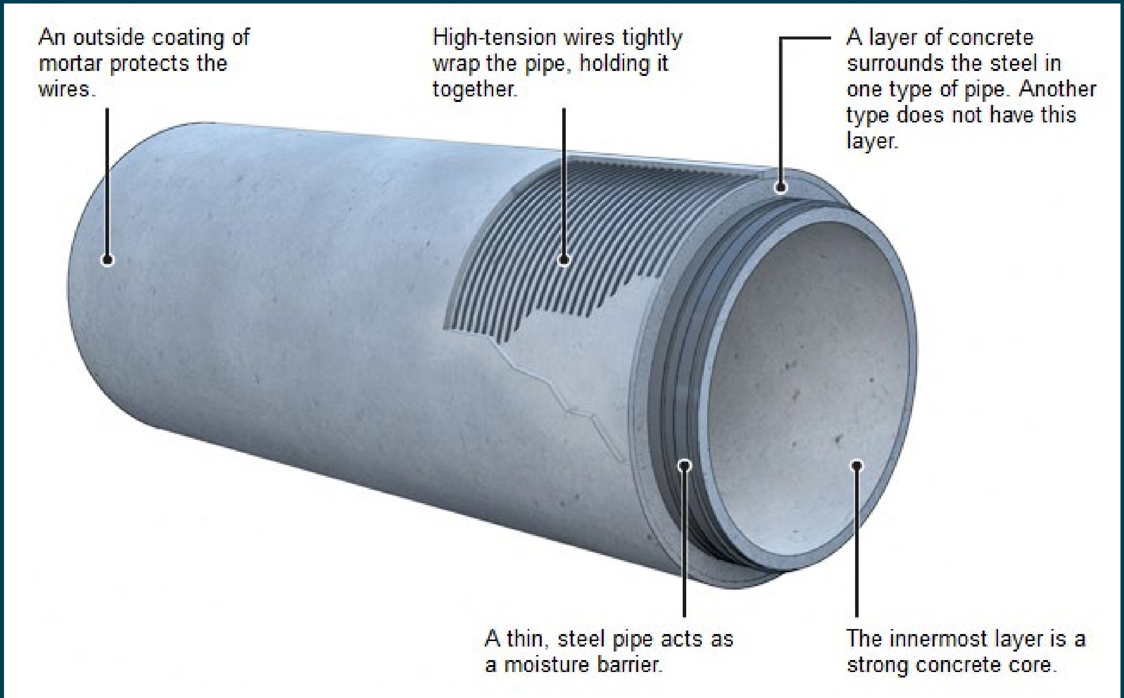
Appendix A PCCP Educational Demonstration Classroom Presentation

Prestressed Concrete Cylinder Pipe (PCCP)

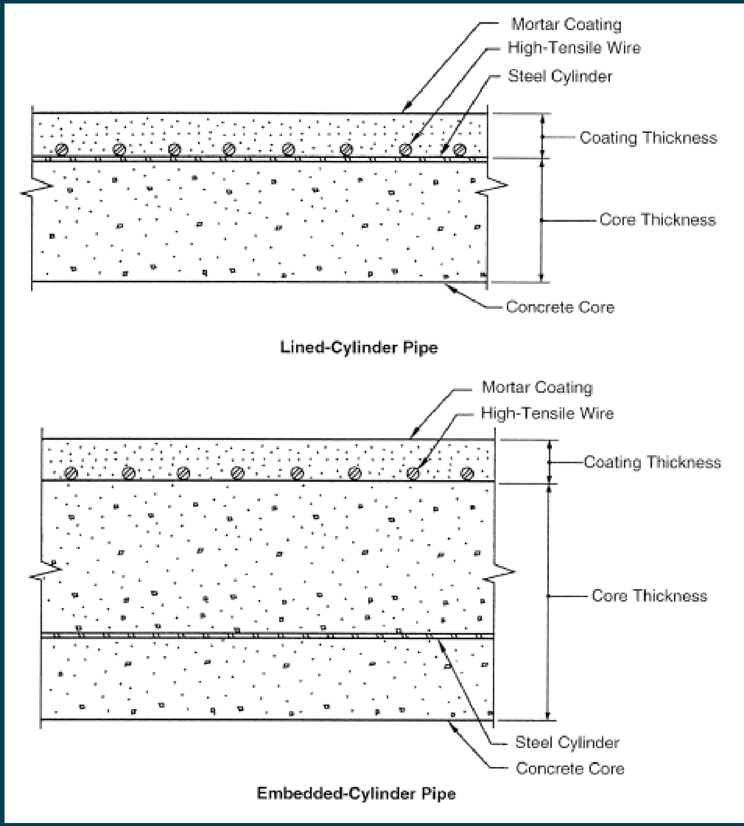
I. Background

What is PCCP?

Prestressed Concrete Cylinder Pipe



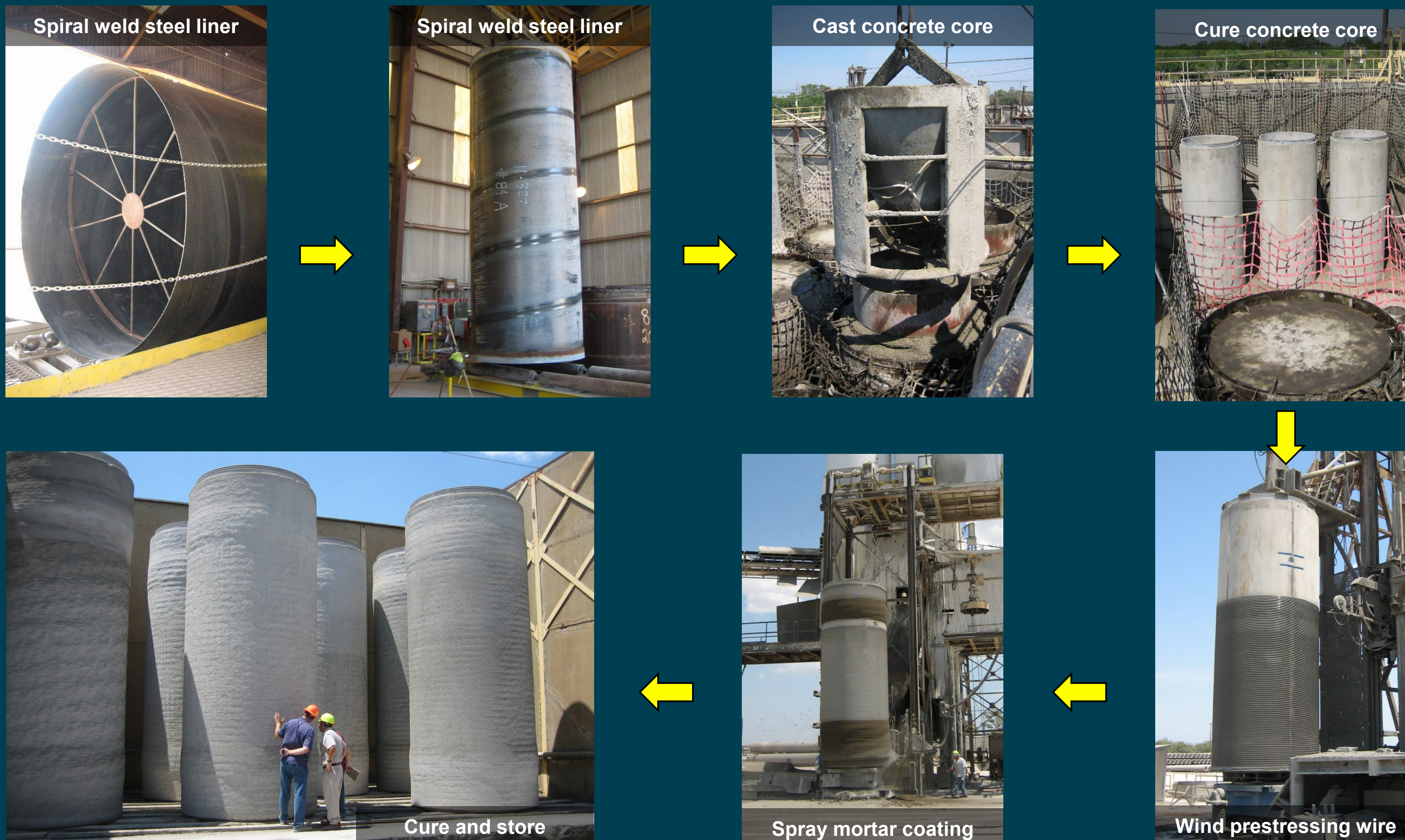
Source: Pure Technologies, www.puretechltd.com



Source: AWWA C304-07, Design of Prestressed Concrete Cylinder Pipe

Note: also non-cylinder pipe

What is PCCP (cont'd)?



Historical Perspective

- Reclamation specified PCCP from ~1960 to 1990
- Current Reclamation-owned active inventory:
  ~90 miles in 48 sections
- In the 1970's, Class II and IV wire were introduced, and one manufacturer in particular produced pipe with wire that exhibits a high probability of failure
- After several failures, Reclamation stopped installing PCCP in 1990
- AWWA C301 and C304 are the manufacture and design standards

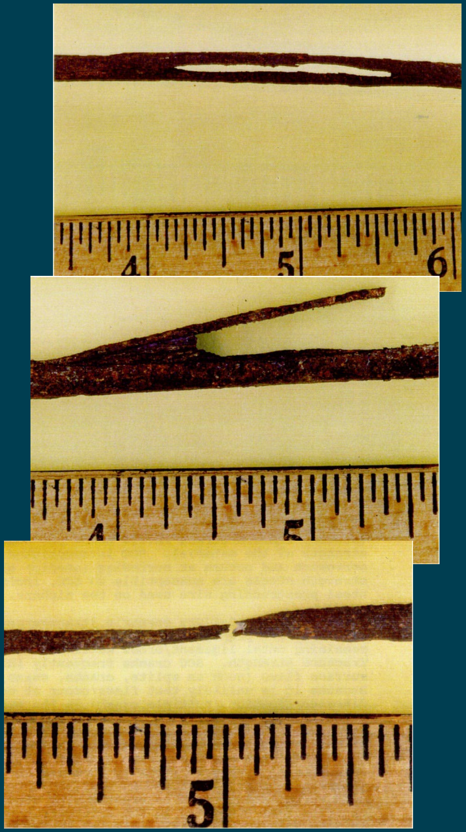
PCCP: Principle Causes of Failure

- Corrosion of Wire leading to Breaks
  - Defective prestressing wire
  - Incomplete encasement of wire with mortar/cement slurry
  - Insufficient mortar cover
  - Cracking of mortar
  - Carbonation of mortar

Cracking of mortar

Insufficient mortar cover

Defective prestressing wire



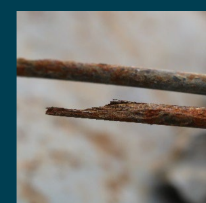
Defective prestressing wire

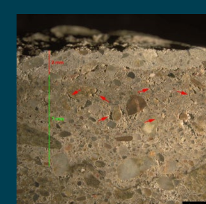
Reclamation PCCP Failures

- 1984
  - Failed one month after going into service
  - Defective wire had longitudinal cracks, was wound exceeding specified tensile stresses
  - 2.3 miles repaired with steel liner at cost of ~$5 million
- 1990
  - 6.5 miles of 21′ diameter PCCP siphons constructed from 1975-1980
  - 223 units were exposed and inspected, 40% were distressed and needed repair, 10% of those needed replacement
  - Estimated cost of implementing repairs at the time was $117 million
- 2015
  - Catastrophic failure of 8′ diameter PCCP section after 31 years of service
  - Prior inspections found broken prestressing wires, failure occurred following a power outage and subsequent valve closures
  - Affected pipe section replaced at a cost of ~$1.4 million and over 20 million gallons of water were estimated to be lost
- 2016
  - Catastrophic failure of 17.5′ diameter PCCP section after 44 years of service
  - Broken prestressing wires found during inspection doubled between 2003 and 2010
  - Put 75,000 acres of irrigated land out of service

Historical Failures

- Common failure mode: corrosion leading to broken wires
  - Corrosive soil
  - Microcracking and carbonation in mortar coating





Repair

- Emergency Repair:
- Replaced with cement mortar lined and coated steel pipe

Initial Emergency Repair:

- Replace with steel
- Fill with CLSM, no corrosion protection

Subsequent Repair ~1 Year later:

- Line steel sections with epoxy
- Install cathodic protection at repair

Lessons Learned

- Prevention!
  - Know your system- risk assessment
  - Regular electromagnetic (EM) inspections for wire breaks, 3-5 yrs
  - Timely action to address problem areas or institute more frequent monitoring
  - Install corrosion protection
  - Schedule future repairs/replacement for deteriorating sections

- Prepare for future emergencies
  - Have spare replacement sections and butt-straps on hand
  - Have design ready for future replacements
  - Have emergency action plan ready

- Maintenance and planned repairs are cheaper than reacting to pipe breaks.

Condition Assessment

- Site Evaluation
  - Topographic and geologic evaluation: near-surface groundwater, high corrosivity soils, arroyos and washes
  - Man-made features that could increase corrosion potential: electrical transmission lines, foreign line crossings, roadways
  - Soil resistivity surveys or corrosivity laboratory analysis

- Potential Surveys
  - Pipe-to-soil/close interval survey or cell-to-cell survey
  - Conducted above ground to identify areas of anomalous potential gradients indicating corrosion is occurring

Condition Assessment (Cont'd)

❖Visual Inspection (Pipe Interior)
  – Cracks in core
  – Leaks at joints

❖Acoustic Inspection
  – Manual sounding- delamination of concrete or un-grouted areas/hollows
  – Impact Echo Testing- delamination, hollows, cracks
  – Free-floating acoustic sensor- leak detection

❖Electrical Continuity Inspection
  -Requires removal of mortar coating
  -Locate broken prestressing wires

- Electromagnetic Inspection
  – Number and location of prestressing wire breaks
  – Can be conducted for in-service or dewatered pipe
- Acoustic Fiber Optic Monitoring
  – Continuous monitoring for wire breaks
  – Cables installed inside pipe
  – Requires monthly/annual monitoring contract

❖ = Hands-on demonstration!

Repair Methods

- Interior Crack and Joint Repair
  - Reclamation's "Guide to Concrete Repair, 2nd ed."
  - Surface preparation, repair product application, curing
- Installation of Cathodic Protection
  - Requires electrical continuity of protected sections
  - Should not be polarized more negative than -1000 mV_{CSE} to avoid hydrogen embrittlement
- Wire Splicing and Tendon Wrapping
  - Exterior repair requiring pipe excavation
  - Use anchor blocks and tensioning devices to install replacement wire or tendons
- Structural Liner
  - Internal repair to provide structural support for distressed sections
  - Carbon Fiber Reinforced Polymer (CFRP)
  - Spray-in-Place Pipe (SIPP)

Resources

- TSC – Materials and Corrosion Laboratory (S&T Research Projects)
  - POCs Matthew Jermyn and Jessica Torrey
  - Project ID 7108: Critical Review of PCCP at Reclamation
  - Project ID 19275: PCCP Inspection Truthing and Educational Demonstration
  - Project ID 20059: Life-Cycle Costs of PCCP Maintenance
- TSC – Water Conveyance Group (EM Inspection Coordination)
  - POCs Kylie Pelzer and Chris Duke
- Policy Office – Asset Management Division (Inspection Contract and Viewer)
  - POC Nick Casamatta
- Corrosion Webinar Series

II. Hands-On Demonstration

Inspection Techniques

- Visual Inspection
- Sounding
- Electrical Continuity

Appendix B PCCP Educational Demonstration Classroom Handouts

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Visual Inspection

Background

Visual inspections can provide a useful starting point to identify areas for further investigation. The hands-on demonstration, shown in Figure 1, provides student inspectors with an opportunity to apply the classroom knowledge provided and make visual observations by documenting signs of damage such as gouges, corrosion, concrete staining, and delamination.

Figure 1. PCCP educational demonstration to be used for visual inspection.

Equipment and Supplies

- Camera
- Scale bar
- Notepad
- 25′ Tape Measure

Procedure

For this inspection, you will practice making visual observations on two PCCP sections.

Part 1: Visual Inspection

1. Walk from one end of the PCCP section towards the other and make note of any signs of damage on the sheet provided.

2. For each observation, measure the distance from the end of the PCCP section and make note of any other location information such as interior or exterior and approximate clock position. If using clock positions, make sure to note which direction you were facing.

3. Photograph of the areas of concern. Where possible, place or hold a scale bar next to the area of concern in photographs for size reference.

Observation	Observation notes (*including location information*):
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Part 2. Questions and Discussion

1. Did you find any major areas of concern?

2. Looking at the observations you noted, is it possible to go back and find the area of concern?

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Sounding Inspection

Background

By striking the surface of the prestressed concrete cylinder pipe (PCCP) sections with a dead blow hammer like the one shown in Figure 1, an audible response is produced that can be heard and compared with the response from neighboring areas. Differences in the acoustic response indicate a local variation in the material. These variations are commonly due to either delamination or an un-grouted area.

For this inspection, student inspectors are provided with a dead-blow hammer and taught the striking technique used to listen for changes in the audible response.

Figure 1. Dead-blow hammer used for sounding inspections.

Equipment and Supplies

- Dead-blow hammer
- 25′ Tape Measure
- Chalk
- Notepad

Procedure

For this experiment, you will document the audible response produced by striking the surface of the PCCP sections with a dead-blow hammer.

Part 1: Sounding

1. Starting at one end of the PCCP sections, use a dead-blow hammer to strike the surface of the PCCP section and listen to the resulting sound. Try to strike the surface with consistent force based on your sense of feel.

2. Continue striking the surface while moving in a logical progression from one area to the next. Overhead areas can be hard to reach; do not attempt to strike areas outside your comfortable reach. Mentally compare audible responses as you progress.

3. When you reach an area that produces an audibly different result (lower or higher in pitch), stop and record the observation in the table below. Use chalk to outline the area.

4. Using a tape measure, measure and record the distance to the observation.

Clock Position (as if facing 6th street)	Distance to observation (feet)	Observation notes:

Part 2. Questions and Discussion

1. Which areas produced a different audible response to neighboring areas?

2. How do the audible response results compare with your visual observations?

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Electrical Continuity Inspection

Background

A continuous electrical connection is an effective way to verify there are no breaks between wraps of prestressing wires. Direct measurement of electrical continuity (EC) requires that prestressing wires are exposed, as shown in Figure 1, which necessitates removal of the exterior mortar coating. Under normal field circumstances this portion of the mortar would be removed using an angle grinder and/or chisel and then repaired with new mortar before returning the pipe to service.

Figure 1. Exposed pre-stressing wires for EC inspection.

For this inspection, student inspectors will take measurements to verify electrical continuity between adjacent pairs of prestressing wires. In addition to locating broken prestressing wires, the results from this test can be useful for verifying electromagnetic (EM) inspection results. EM results from a past inspection were modified and provided for comparison.

Equipment and Supplies

- Multimeter
- Two test leads with pointed tips
- Prestressing wires
- 25′ Tape Measure

Procedure

In this experiment, you will measure and document electrical resistance between adjacent pairs of prestressing wires. You will use your measurements will then be compared to identify broken wires.

Part 1: Electrical Continuity

1. Using a tape measure, measure and record the distance of the exposed prestressing wires from the nearest end of PCCP section.

Distance from End (Feet)	

2. Connect the negative (black) lead into the COM port of the multimeter and the positive (red) lead to the V port of the multimeter. Set the multimeter dial to Ohms.

3. Using light pressure, press one lead wire, either positive or negative will work, to the left-most prestressing wire and the other lead wire to the adjacent wire. This can be done using one-hand; however, having a partner hold the multimeter makes this process easier.

4. Record the measurement results in the provided table. Numbering is sequential from left to right. Note that an "OL" reading indicates an open circuit.

5. Repeat steps 1 to 3 for all wires.

Wire	Multimeter Reading (Ohms)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	

Part 2: Comparison with EM results

1. Below is an example EM Report that was modified from the original for this demonstration. For this demonstration, the West PCCP section relates to Reference Number 10437 in the table below. Compare with EC Results.

Reference Number	Diameter (inches)	Low Station	Pipe Length (feet)	High Station	Inspection Date (manned/unmanned)	Break Region Location (feet from Low Station)	Number of Broken Wire Wraps by Region	Total Number of Broken Wire Wraps	Comments
10432	96	96+00	20	96+20	February 25, 2020 (unmanned)				
10433	96	96+20	20	96+40	February 25, 2020 (unmanned)				
10434	96	96+40	20	96+60	February 25, 2020 (unmanned)				
10435	96	96+60	20	96+80	February 25, 2020 (unmanned)				
10436	96	96+80	20	97+00	February 25, 2020 (unmanned)				
10437	96	97+00	20	97+20	February 25, 2020 (unmanned)	10.5	2	2	
10438	96	97+20	20	97+40	February 25, 2020 (unmanned)				
10439	96	97+40	20	97+60	February 25, 2020 (unmanned)				
10440	96	97+60	20	97+80	February 25, 2020 (unmanned)				
10441	96	97+80	20	98+00	June 3, 2020 (Manned)				
10442	96	98+00	20	98+20	June 3, 2020 (Manned)				
10443	96	98+20	20	98+40	June 3, 2020 (Manned)				
10444	96	98+40	20	98+60	June 3, 2020 (Manned)				

Part 3. Questions and Discussion

1. How many broken pre-stressing did you find?

2. How do your results compare with those from the previous EM inspection?