Underground Construction Technology
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PCCP Problems Potential Solutions in Sewer Applications

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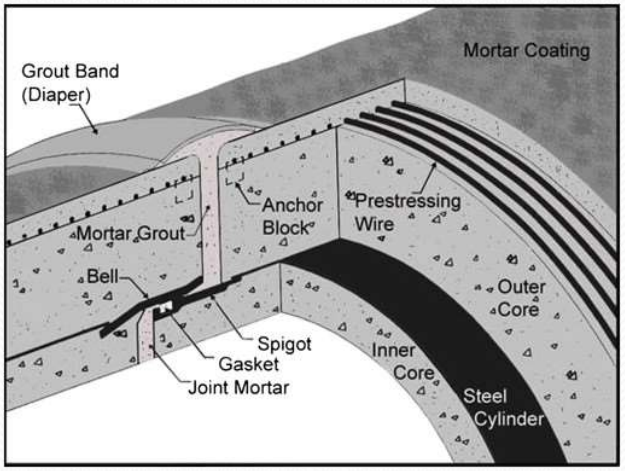
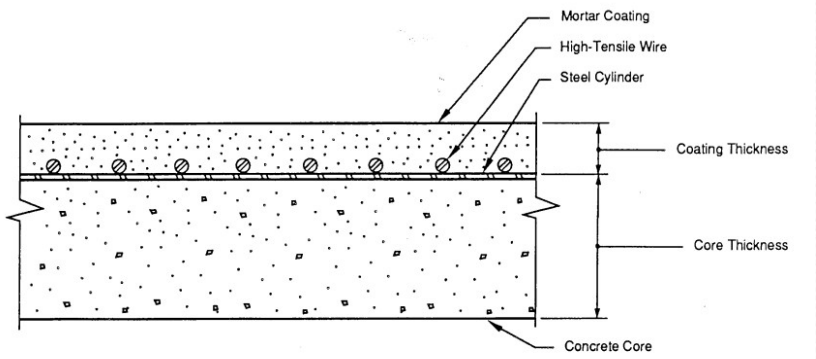
Background

- Pre-stressed Concrete Cylinder Pipe (PCCP) - concrete core, thin steel cylinder, high tensile pre-stressing wires and a mortar coating.
- Concrete core - main structural load-bearing component with the steel cylinder acting as a water barrier between concrete layers.
- Pre-stressing wires produce a uniform compressive pressure in the core that offset tensile stresses in the pipe.
- Mortar coating protects the pre-stressing wires from physical damage and external corrosion.



Background (Continued)

- First manufactured in 1942 as lined cylinder pipe. The prestressing wire in lined cylinder pipe is wrapped directly around the steel cylinder.
- Second type of PCCP known as embedded cylinder pipe developed in 1952 that has concrete encasement of the steel cylinder on both sides.
- Typical diameter ranges for lined and embedded cylinder pipe are between 16 to 60-inches and 30 to 256-inches, respectively.
- PCCP tends to be of large diameter, making failures of this type of pipe relatively catastrophic and costly.
- To date, most research has been focused on PCCP inspection technologies and performance prediction in order to minimize the risk to utilities from failures.



Lined-Cylinder Pipe

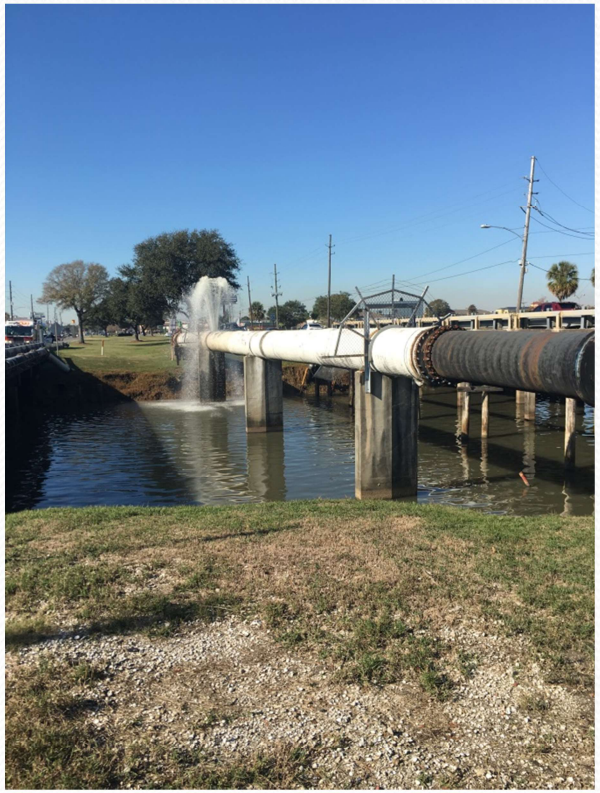
Causes and Modes of Failure

- Failure - loss of use of a pipe section or reduction in confidence in that pipe section to remain in service.
- Three categories or models of PCCP failure:
  - Catastrophic ruptures and leaks
  - Significant deterioration or structural weakness discerned by inspection
  - Loss of service

Some Common Reasons for Failure

- Rupture or break – broken wires found after the failure – many causes
- Leaking at joints – many causes including out-of-roundness of joint and construction damage
- Cracks in core – many causes including alkali-silica reactivity of the aggregate
- H_2S (force mains) – unlined
- Cracks in cylinder welds – poor cylinder fit-up
- High chlorides in soil – corrosive/aggressive soil Inadequate joint restraint – pipe moved exposing joint to environment
- Construction damage – coatings damaged and not repaired
- Inadequate prestress – wires broken and spliced without retensioning Cantilever (bending or broken back) – many causes including poor bedding
- Settlement – general and at structures
- Poor bedding – not corresponding to design assumption
- Surge – unanticipated and above design value
- Excess external load – greater than design assumption

Jefferson Parish Catastrophic Failure Example



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Jefferson Parish Catastrophic Failure Example (Continued)

Failure Statistics

- Deterioration and loss of service failures peak at the 26- to 30-year group.
- Initial design basis for manufacture of PCCP more conservative.
- As competitiveness with other pipe materials increased, changes made in the standard to reduce the unit cost of manufacture.
- Changes tended to increase the stress level in the pipe at working pressures and reduce margin for error.
- Result was significantly increased rate of failure for pipe installed between 1971 and 1979. 50% of the catastrophic leaks and breaks recorded were manufactured or installed between those years.

Failure Statistics (Continued)

- Trend toward reduced conservatism through revisions in the standard began to reverse course in 1984 with the issuance of AWWA C301-84.
- Allowed additions of fly ash and other pozzolans in an attempt to increase the density of the concrete coating and core
- ASTM C33 for concrete and mortar aggregate requirements,
- Slurry placement under the wire, and the
- Minimum coating thickness increased to 3/4 inch.
- Significant revisions to the standard in 1992 and adoption of the very detailed design standard C304-92 appear to have resulted in much improved performance of as-installed PCCP.

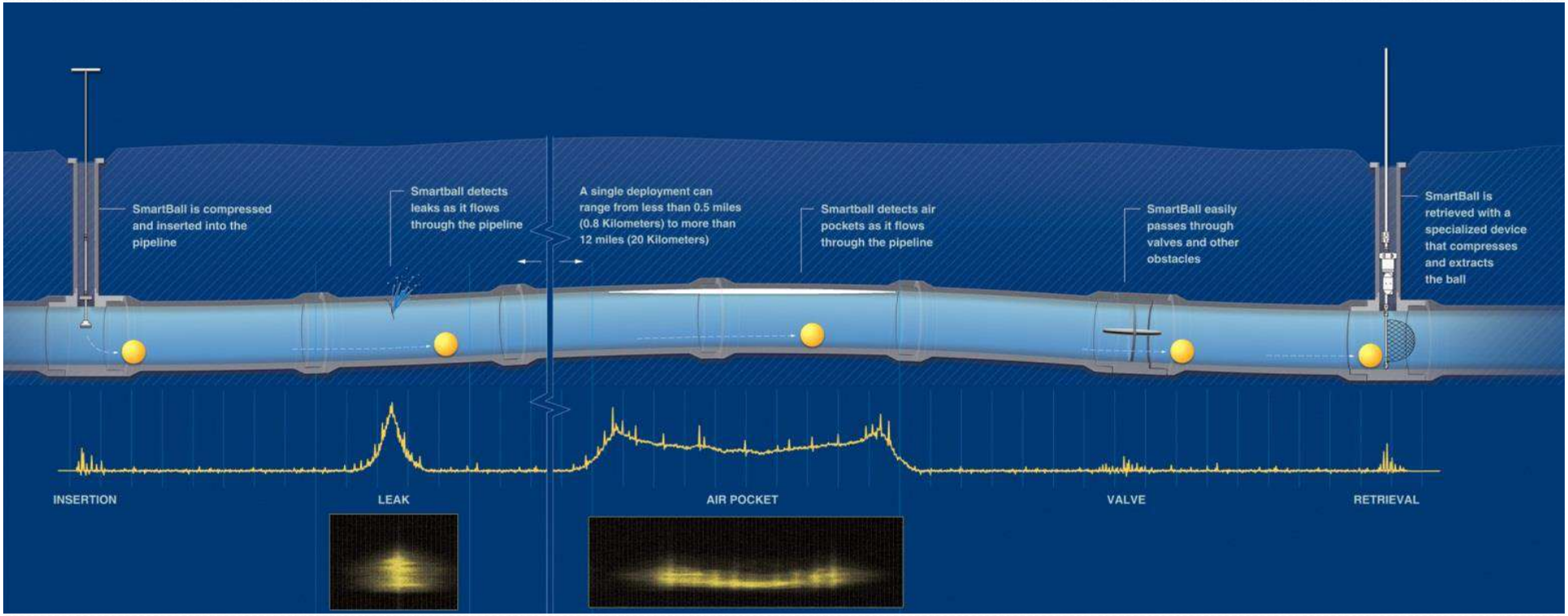
Inspection Technologies

- Visual Exterior Inspections
- Utilize the wires within the pipe as a radio-frequency measurable coil antenna
- Acoustic monitoring of in-service EC-PCCP pipelines to identify actively breaking wires
- Inductive scan imaging
- Above ground leak detection
- External electromagnetic assessment
- Transient Pressure Monitoring
- Closed Circuit Television Inspection
  - Requires access point
  - Requires taking pipeline out of service

Inspection Technologies (Cont.)

- Acoustic condition assessment
  - Requires access point and retrieval location
  - Detects leaks and air pockets of trapped gas
  - Leaks do not typically present themselves within the acoustic data at pressures less than 10 psi

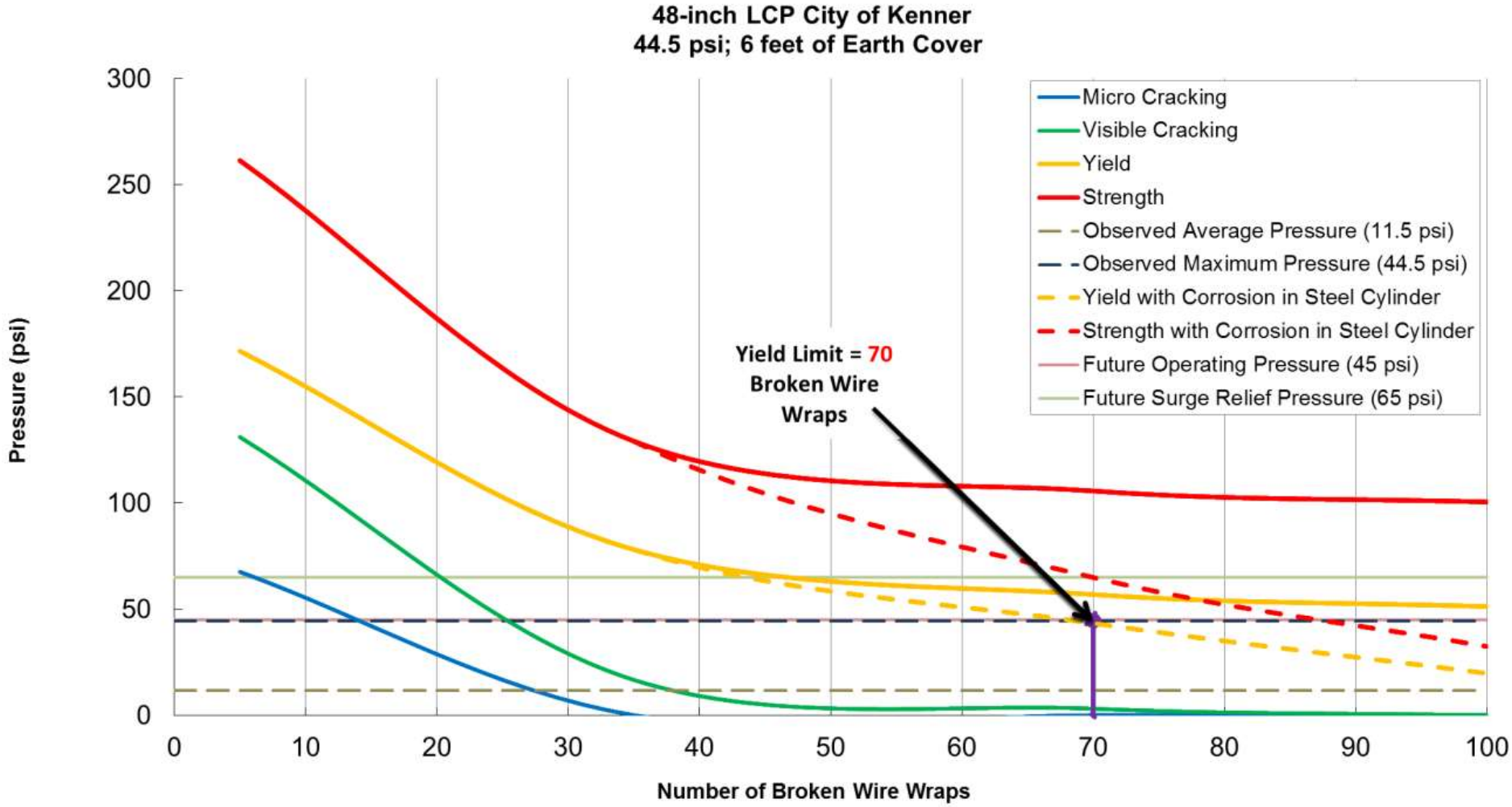
Acoustic Condition Assessment Figure



Inspection Technologies (Cont.)

- Internal free-swimming electro-magnetic condition assessment
  - Requires access point and retrieval location
  - Provides the location and quantity of broken pre-stressed wire wraps (the primary structural component of PCCP)
  - Finite Element Analysis model under known external loading conditions while increasing the internal pressure and varying the number broken wire wraps
  - Develop a FEA performance curve, which defines specific performance limits for a distressed PCCP
  - Yield Limit shown on the performance curve as the threshold for rehabilitation recommendations

Example FEA Performance Curve



Potential Solutions

- Replacement
  - The cost of replacement of the nation's inventory of PCCP has been estimated at over $40 billion (Megalas, 1998)
- Monitoring through Inspections
- Point Repair Failures and Weak Spots
- Lining

References

- Failure of Pre-stressed Concrete Cylinder Pipe (AWWA/EPA 2008 Edition)
- City of Kenner PCCP Condition Assessment, July 2015

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