San Francisco Distribution System – Seismic Reliability using Earthquake-Resistant Ductile Iron Pipe

Part I: Procurement and Design

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Outline

- San Francisco’s Water Distribution Systems
- Pipeline Seismic Reliability Program
- Potable Water and AWSS Projects
- Materials Selection: Earthquake-Resistant Ductile Iron Pipe
- LADWP Pilot Program
- SFPUC Procurement Process
- Final Design Process
- Installation (Future)
- Conclusions
San Francisco’s Drinking Water Distribution System

- 23 pressure zones
- 16 reservoirs and tanks
- 9 pump stations
- 1,240 miles pipe
- >200 miles CI
- >100 years old
- 180,000 customers (population 850,000)
Auxiliary Water Supply System (AWSS) High-Pressure Fire Fighting System

- Dedicated non-potable water distribution system for fire-fighting
- Built after 1906 earthquake
- 130 miles mains, mostly cast iron
  - Thick, rigid restrained joints
  - 1,000 hydrants
- Rated for 350 psi pressure; 3 zones that can be interconnected
- Able to pump seawater through system
AWSS Fire-Fighting Network
1989 Loma Prieta Earthquake (M7.1)
Seismic Reliability Goals for Critical Distribution Network

- Developing Seismic Reliability Level of Service Goals for City Distribution + AWSS
  - 1 hour fire-fighting (AWSS)
  - 4-12 hours water to “critical nodes” (DW system reliability)
    - “sanitary” vs. “potable”
    - X hours/days “sanitary” water to y% customers or hydrants
    - Z days potable water restored to ___% customers
First Step: Evaluate Existing Seismic Reliability

- **Existing Pipe Reliability:**
  - Pipe material: cast iron, welded steel, newer ductile iron
  - Pipe condition: corrosion, age
  - Pipe fabrication: types of joints (restrained vs. unrestrained), bedding material, slope
  - Ground conditions: shaking; differential settlement due to landslides, liquefaction

- **Existing network reliability**
  - Ability to provide adequate flow to meet criteria
  - Valving and network redundancy
“Backbone” Critical Network
Next Step: Determine Critical “Nodes” or “Lifelines” to meet LOS

- AWSS: 47 Fire Station “Response Areas”
  - Fire fighting: water delivery % reliability in each area
  - LOS: minimum 50% reliability in each area
  - Existing LOS: 75-100% many areas, some areas 5-50%

- Potable water (under development)
  - Critical facilities (hospitals, emergency centers)
  - Major transmission pipelines
  - Predicted failures, valving capability
  - Distance to customers after x hours (hydrants)
Project 1: San Francisco General Hospital Seismic Upgrade Project
College Hill Reservoir to San Francisco General Hospital Seismic Upgrade Projects

- Series of 5 projects
- Total distance 5.5 miles
- 24”, 12”, 8” Diam
- Replacing pipes from 1880-1920
- Total cost $15-20M
- First project around SFGH
- Dedicated water main and hydrants for SFGH
- Completion in 2015 with SFGH re-opening
Project 1: SFGH Pipeline
Seismic Reliability
Project 2: AWSS for Candlestick Point Development

• Install new water and AWSS distribution systems for re-developed neighborhood
• AWSS connect to existing AWSS distribution
• SFPUC and Developer reviewed alternatives to standard AWSS design
  – Rigid highly-retrained joints
  – Expensive
  – Only one foundry makes pipe, fittings
• Challenge: extremely high pressure, up to 350 psi
Kubota Earthquake Resistant Ductile Iron Pipe (ERDIP)

- Learned about from seismic experts, and Los Angeles Dept. Water and Power
  - Dr. Craig Davis
- Kubota manufactures in Japan
- 20 years pipe in ground; ZERO failures during earthquakes
- Unique flexible joints:
  - 6-8 degrees deflection
  - 1% longitudinal contraction/expansion = 2-2.4 inches per joint
  - Pull-out resistance = 17,000 ft-lb x D (4”D = 68,000 lb)
Kubota ERDIP

Performance of the Joint

The joint performance of ERDIP is the highest in ISO 16134.

<table>
<thead>
<tr>
<th>Property</th>
<th>Performance</th>
<th>ISO 16134</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of expansion/contraction</td>
<td>±1% of L</td>
<td>Class S-1</td>
</tr>
<tr>
<td>Pull-out resistance</td>
<td>3D kN 17,000Dₘₑ (lbf) (3Dₘₙₜ(kN))</td>
<td>Class A</td>
</tr>
<tr>
<td>Joint deflection angle</td>
<td>6-8° *1</td>
<td></td>
</tr>
</tbody>
</table>

Note: L: Nominal pipe length
Dₘₑ: Nominal diameter of pipe (inches)
Dₘₙₜ: Nominal diameter of pipe (millimeters)
*1) Joint deflection angles depend on pipe diameters

Pull-out resistance 68,000(lbw) (300(kN)) ≈ 30 cars’ weight

Earthquake-Resistant Joint DN4” (100mm)
Kubota ERDIP Genex Joint
Field Demonstration
ERDIP: No Failures

ERDIP had no documented failures at the event of big earthquakes such as The 1995 Kobe Earthquake, The 2011 Great East Japan Earthquake.
LADWP’s “Pilot” Program

- Five projects, different pipe sizes, different construction conditions
- Evaluate on cost, constructability, feasibility for utility
- Two of five projects installed
- Sole-source purchase under “pilot” program
- Installed using LADWP in-house staff
- Findings: while cost 2x higher for materials, total construction cost about 13-20% higher
- Staff liked zinc-oxide epoxy pipe coating
SFPUC “Pilot” Program

- Procurement: use public works low-bid materials furnishing contract
  - “sole source” difficult to get approvals
- Installation: use public works low-bid construction contract with “owner-furnished” materials
  - small C&M staff already busy
- “Pilot” criteria includes:
  - Ease of importing
  - Ease of installation
  - Total construction cost
  - Schedule impacts
  - Concerns about metric conversion/repairs
Procurement

- For competitive bid, wrote purchase specifications
- Included unique features of pipe: joint flexibility, joint lateral movement, zinc-oxide epoxy coating
- Kubota worked with us on materials lists and cost estimates
- Contract to include purchase, shipping, U.S. customs, storage, and delivery
- Contract “shopped” to five pipe purveyors in Bay Area
- Three purveyors bid on purchase contract
Design Process

- Kubota collaborated with SFPUC engineers to assure joints, fittings properly located and specified.
- Communicated through (overnight) e-mail, and frequent visits to U.S.
- SFPUC required NSF certification (CA regulatory requirement); Kubota obtained.
- For high-pressure AWSS, Kubota worked on finding valves rated at 700 psi test.
- Difficult to detail connections: metric to S.I.
NEW 20" AWSS CONNECTION TO EXISTING 20" AWSS DETAIL

NOTES:
1) Use a hand steel bristle brush to remove loose corrosion on the cut end of the existing pipe. Wire area free of rust or debris with a cloth suitable for the task and recoat areas of damaged coating with an asphaltic repair paint.
Installation Requirements

• Construction contract includes required trainings by Kubota:
  – 1 day mandatory training to bid on contract
  – 3 days mandatory training to low bid contractor at NTP

• Rigorous inspection will be enforced
  – Measure joint stabs and zero deflection

• LADWP found slower installation at first, but speeded up over time
Construction Schedule

• SF General Project (No. 1):
  – Bids in Jan 2015
  – NTP March 2015

• Candlestick Redevelopment (AWSS)
  – Developer to purchase pipe Oct 2014
  – Install March 2015
    • Kubota 4 months to fabricate and ship
ERDIP Success in U.S.

• Several utilities first Kubota installations:
  – LADWP; Portland Water Bureau (OR); Menlo Park, CA; SFPUC

• US competitors developing stronger, more flexible DI joints
  – US Pipe: TR-Xtreme, TR-Flex
  – Am. DI Pipe: Flex-ring

• Zinc oxide coating becoming more readily available

• Kubota joint still offers most deflection and longitudinal movement; proven reliability (in Japan)

• Future success in U.S. dependent on market
### LADWP Acceptance Criteria

#### TABLE I. PILOT PROJECT ACCEPTANCE CRITERIA FOR THE CONTOUR DR. SITE.

<table>
<thead>
<tr>
<th>Item</th>
<th>Criteria</th>
<th>Status as of July 1, 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Near-term criteria</strong></td>
<td></td>
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</tr>
<tr>
<td>1</td>
<td>Acceptance of concept</td>
<td>Achieved</td>
</tr>
<tr>
<td>2</td>
<td>Application to network resilience</td>
<td>Able to meet concept outline</td>
</tr>
<tr>
<td>3</td>
<td>Ability to learn about the technology application</td>
<td>Achieved, January 2012</td>
</tr>
<tr>
<td>4</td>
<td>Ability to perform engineering design for ERDIP</td>
<td>Achieved by LADWP staff, spring 2012</td>
</tr>
<tr>
<td>5</td>
<td>Ability to purchase pipe</td>
<td>Achieved Fall 2012</td>
</tr>
<tr>
<td>6</td>
<td>Ability to train and certify installation crews for ERDIP</td>
<td>Achieved January 2013</td>
</tr>
<tr>
<td>7</td>
<td>Ability to adopt local installation procedures to the ERDIP technology (e.g., slurry trench fill)</td>
<td>Achieved, Summer 2012</td>
</tr>
<tr>
<td>8</td>
<td>Field crew ability to install correctly</td>
<td>Achieved, Feb./March 2013</td>
</tr>
<tr>
<td>9</td>
<td>Positive acceptance from LADWP Distribution Division</td>
<td>Achieved, management, supervision, and installation crews interviewed May 9, 2013.</td>
</tr>
<tr>
<td></td>
<td>(including management and supervisor levels)</td>
<td>Acceptable, similar installation rate compared to other hillside projects. Rate mostly constrained by trench excavation.</td>
</tr>
<tr>
<td>10</td>
<td>Installation rate (feet per day)</td>
<td>Acceptable, within an acceptable range at pilot stage.</td>
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<td>Construction: 8% to 13% increase, mostly attributed to increased material cost.</td>
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<td></td>
<td>Engineering: cost about doubled, increased total project cost by ~7%.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Project: 15% to 20% total project cost increase.</td>
</tr>
<tr>
<td>11</td>
<td>Cost in comparison with other ductile iron pipe projects.</td>
<td>Acceptable and overall positive input from field crews. Several aspects are different but easy to learn and implement.</td>
</tr>
<tr>
<td>12</td>
<td>Workability (the degree of ease the material can be cut, shaped or smoothed by hand or machines and capable of being put into effective operation)</td>
<td></td>
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<tr>
<td><strong>Long-term Criteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Investigation corrosion resistance of Genex coating</td>
<td>Not applicable</td>
</tr>
<tr>
<td>2</td>
<td>Actual seismic performance*</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

*Seismic performance is not a criterion for accepting use of this pipe on a full scale production level. We must accept the documented positive performance in Japan of no breaks or leaks for nearly 40 years.*
Conclusions

• Kubota ERDIP has proven track record in Japan’s large-magnitude earthquakes

• Procurement, design and installation took more time for first U.S. projects
  – Future projects should be more efficient

• Higher cost adds about 15-20% to total construction cost
  – Probably still less than HDPE, welded steel

• SFPUC likes high quality workmanship, excellent service, performance track record

• Constructability (by low-bid contractor) yet to be assessed.
Questions?