Electrically Isolated Tendons
Post-Tension Supplier’s Experience

FHWA Workshop at Lehigh University
October 24, 2018

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Contents

- Introduction EIT
- Technical Guidelines, Recommendations
- EIT-specific Features and References
- DSI Experience on Coplay-Northampton Bridge Project
- Monitoring
- Summary
Introduction of Electrically Isolated Tendons (EIT)

What is EIT?
- Fully leak-proof encapsulated tendons and anchors are electrically isolated from surrounding concrete and ordinary reinforcement

Why specifying EIT?
- Leak-proof encapsulation of tendon provides highest level of protection against ingress of moisture and corrosion

What are the main advantages?
- Offers long-term monitoring
- Considerable longer expected service life
- More economical in a long-term prospect
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Technical Guidelines & Recommendations

ASTRA 12 010:

- Guideline to ensure durability of post-tensioning tendons
- Flowchart for selection of required protection level
- Design principles for electrical layout on tendons
- Requirements on protection against “stray current”
- Table for minimum required values of resistances for measuring criteria monitoring, fatigue and stray current

fib Bulletin 33: Durability of post-tensioning tendons

- Specification of measures to enhance durability
- General recommendation for detailing PT-systems
- Definition of three protection levels (PL)

Protection Levels:

- PL1: duct with corrosion protection
- PL2: PL1 + leak-tight encapsulation
- PL3: PL2 + Monitoring
Recommended Monitoring Values

fib Bulletin 33: Durability of post-tensioning tendons

<table>
<thead>
<tr>
<th>Type of duct</th>
<th>Limiting values</th>
<th>Control values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>specific resistance $\rho^*$</td>
<td>specific capacitance $C_s^{**}$</td>
</tr>
<tr>
<td>Ø 59 mm</td>
<td>&gt; 500 kΩm</td>
<td>&lt; 2.35 nF/m</td>
</tr>
<tr>
<td>Ø 76 mm</td>
<td>&gt; 400 kΩm</td>
<td>&lt; 3.05 nF/m</td>
</tr>
<tr>
<td>Ø 100 mm</td>
<td>&gt; 300 kΩm</td>
<td>&lt; 3.35 nF/m</td>
</tr>
<tr>
<td>Ø 130 mm</td>
<td>&gt; 250 kΩm</td>
<td>&lt; 4.30 nF/m</td>
</tr>
</tbody>
</table>

The Guideline [35] is currently under revision. The revised document should be available in late 2006. Based on recent field experience and laboratory tests, the values in Table 3.2 are verified and may be changed.

ASTRA 12 010

<table>
<thead>
<tr>
<th>Duct</th>
<th>Monitoring</th>
<th>Fatigue</th>
<th>Stray Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ø 60 mm</td>
<td>Minimum value of the length normalised electrical resistance $R_l(=R_{LJ})$</td>
<td>50 kΩm</td>
<td>20 Ω</td>
</tr>
<tr>
<td>Ø 75 mm</td>
<td>50 kΩm</td>
<td>20 Ω</td>
<td>200 kΩm</td>
</tr>
<tr>
<td>Ø 100 mm</td>
<td>50 kΩm</td>
<td>20 Ω</td>
<td>150 kΩm</td>
</tr>
<tr>
<td>Ø 130 mm</td>
<td>50 kΩm</td>
<td>20 Ω</td>
<td>125 kΩm</td>
</tr>
</tbody>
</table>

Fig. 5.1: Limit Values (28 days after injection)
Requirements for System according to new fib Bulletin 75

- Leak tightness of anchorage-duct assembly
- EIT performance of duct system
- EIT performance of anchorage duct assembly
- Full scale duct system assembly
- Leak tightness of assembled duct system
Tightness and EIT-Performance Test

Test Setup acc. to Fib Bulletin 75 for NEW MA-EIT Anchorage Assembly

- Tank with Ca(OH)$_2$ solution required
- On finished assembly no visible water leaking permitted
- 30 days ≥ 15 kOhm -> Test successfully passed
- External control by Technical University of Munich
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EIT-specific Features

DSI First Generation EIT Plate-Anchorage (ca. 2005)

- Isolation plate providing load transfer from wedge plate to anchor plate and not conducting electricity
- Protection cap made from non-metallic material
EIT-specific Features

Isolated Duct System

- Duct, transition tube and connector made from plastic with low dielectric coefficient (PP, PE)
- Connections to be sealed with heat shrink sleeves
- Tight fitting of grout/vent tubes and closing-off by plastic caps or plugs
- Block-out at top of slab to trim vent tubes, fit them with a plug and fill the block-out with cement grout
EIT-specific Features

Electrical Fittings for Monitoring

- Measuring cable: connection from anchor to measuring box
- Connection cable: connection from reinforcement to measuring box
- Measuring box: terminals for connection to LCR-meter
Reference Project: Steinsvik Bridge, Bergen/Norway (2014)

Structural Properties

- Alternating current run tram bridge => EIT specified
- Two-span continuous bridge with spans of 25m and 30m
- Deck width: 8.8m; deck thickness: 0.4m along edges and 1.0m in the center

Post-Tensioning Properties

- 16 No. of continuous tendons with lengths ranging from 54m to 59m
- DSI tendons acc. to ETA-06/0025: 2 No. of 12 strand tendons and 14 No. of 19 stand tendons
Reference Project: Sandsli Bridge, Bergen/Norway (2015)

Structural Properties
- Alternating current run tram bridge => EIT and protection against Stray Current specified
- Four-span continuous bridge with a total length of 100m
- Deck width: 13.5m; deck thickness: varies between 0.5m and 1.3m

Post-Tensioning Properties
- 19 No. of continuous tendons of 19 strand tendons with lengths of 100m
- DSI tendons acc. to ETA-06/0025
Post-Tensioning Properties

- 10 No. of continuous tendons of 22 strand tendon with a length of 54m
- DSI tendons acc. to ETA-06/0025

Structural Properties

- Alternating current run tram bridge => EIT and protection against Stray Current specified
- Single-span bridge with a length of 54m
- Tendons accommodated within parapet girders
- Deck width: 16.4m; deck thickness: 0.27m
DSI Experience

- DSI successfully completed several projects providing all electrically isolated components
- Liaising with planners at planning stage with regard to EIT-specific requirements
- All tendons successfully passed initial acceptance measurements and are qualified electrically isolated tendons
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Advanced EIT System based on MA-Anchorage

Isolation Plate

Permanent Plastic Cap with Grouting Port

New MA-Anchor with integrated trumpet

Internal PT

External PT

Corrugated Plastic Duct

Duct Coupler with Grout Port

Isolation Plate

Trumpet

MA-Body

Wedge Plate

Plastic Grout Cap

External PE-Duct

External Trumpet

Internal PE-Duct

Internal Trumpet

MA-Body

Wedge Plate

Plastic Grout Cap
Copoly-Northampton Bridge: Project Layout

Properties
- Owner: Lehigh County (Contract No. (ECMS): 11614)
- Stewardship and Oversight: Pennsylvania DOT

Structural Properties
- Multispan bridge with five lines of precast tee beams
- Four tendons per girder
- Main spans of 3 x 185ft average length
- Only at top of each girder one electrically isolated tendon

Special Features
- First EIT Project in USA
- First DSI Project using EIT together with Precast Girders
- First EIT Project using MA-Anchorage
Coplay-Northampton Bridge: Works at Precast Yard

Mounting of Anchorage Assembly

- before shrinking

- after shrinking

Protection Shell

Duct Coupler with Heat Shrink Sleeve

Finished Girder in the Precast Yard
Coplay-Northampton Bridge: Site Works

- Installed Girders before CIP Closure
- Duct Coupler at CIP Closure
- Overlapping reinforcement at CIP Closure
Coplay-Northampton Bridge: Site Works

- Installation of isolation plate
- Stressing of tendon
- Stressed tendon
- Measuring cable to wedge plate
- Measuring cable through cap
- Measuring of Electrical Resistance
### Copley-Northampton Bridge: Measured values

#### Readings after stressing and prior to grouting and after grouting on October 24th @ 2pm

<table>
<thead>
<tr>
<th>Reading on Pier 3</th>
<th>Length [m]</th>
<th>Pre-Grout R</th>
<th>Post-Grout R_l</th>
<th>Reading taken after grouting [hrs]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>min R*) [Ω]</td>
<td>min R_l, 28d *) [kΩm]</td>
<td>Measured **) [kΩm]</td>
</tr>
<tr>
<td>Beam B16</td>
<td>166.83</td>
<td>20</td>
<td>172,000</td>
<td>50</td>
</tr>
<tr>
<td>Beam B17</td>
<td>166.00</td>
<td>71,000</td>
<td>50</td>
<td>61.4</td>
</tr>
<tr>
<td>Beam B18</td>
<td>165.31</td>
<td>44,500</td>
<td>50</td>
<td>33.4</td>
</tr>
<tr>
<td>Beam B19</td>
<td>164.62</td>
<td>166,500</td>
<td>50</td>
<td>42.4</td>
</tr>
<tr>
<td>Beam B20</td>
<td>163.92</td>
<td>113,400</td>
<td>50</td>
<td>32.3</td>
</tr>
</tbody>
</table>

**A set of readings will be taken after 28 days from grouting.**

*) Minimum values taken from ASTRA 12 010 (for electrical resistance before grouting of 20 Ω and length normalized electrical resistance of 50 kΩm).

**) Measured reading in kΩ is multiplied by the length of the tendon and compared against the normalized threshold value of ASTRA 12 010.
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### Monitoring

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Monitoring – Measurement Values

Impedance Value R

- Ohmic resistance between tendon and reinforcement
- Measured with alternating current at a frequency of 1 kHz
- Compliance with minimum values as to ASTRA 12 010
- Usually rising with increasing age of the structure (dehydration)

Capacitance Value C

- Depending on duct cross-sectional geometry and dielectric coefficient of duct
- Constant for same duct type, if equal in size, material and manufacturer

Loss Factor D

- Ratio of Ohmic and capacitive resistance
- Non-dimensional value
- Typical acceptance limit is factor 0.1
Monitoring – Preliminaries

Inspection Plan

- Specification of limit values
- Sequence in accordance to agreed inspection plan and recorded on inspection sheets

LCR-Meter

- High resolution performance for measurement of impedance, capacitance and loss factor
- Measurement frequency of 1 kHz
- min. voltage of 0.5 V
Monitoring – Inspection Procedure – Assessment

**Construction stage**

**Measurements**
- Measured straight from connection to strand and reinforcement bar
- Only impedance measured and recorded

**Assessment**
- Required minimum value is 20 Ω
- Ruling out any short circuits

**Service stage**

**Measurements at service stage**
- Measured from dedicated labelled terminals in the measuring box
- All values (impedance, capacitance and loss factor) measured and recorded

**Assessment**
- R and C values related to 1m length for comparison with normalized acceptance values
- C value indicates degree of filling with grout within the duct
- R value steadily rising with increasing age due to dehydration
- Significant drop of R value indicates leakage → ingress of moisture
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Electrically Isolated Tendons for a Durable Bridge Structure

- **Characteristics**
  - Durable post-tensioning system due to leak-proof encapsulation of tendon

- **Safety**
  - Convenient long-term monitoring
  - Highest level of protection against ingress of moisture and corrosion

- **Economic Benefit**
  - Amortisation due to longer expected service life
Thank you!