MINUTES
PTI M-50 / ASBI Bonded Tendon Task Group
Sunday, October 22, 2017, 1:00 PM – 5:00 PM
Marriott Marquis, New York, Room O’Neill

Voting Members Present (12 of 30; Quorum=12)
Dave Martin, Co-Chair
Guido Schwager, Co-Chair
Ken Bocchicchio
Tommaso Ciccone
Guy Cloutier
Tom DeHaven
H.R. Hamilton
Joe Harrison
Reggie Holt
Elie Homsi
Ian Hubbard
Gregory Hunsicker
Larry Krauser
Bryan Lampe
Brian Merrill
Andrew Micklus
R. Kent Montgomery
Alan Moreton
Ralph Salamie
Greg Redmond
Robert Robertson, Jr.
Mike Schwager
Leo Spaans
Michael Sprinkel
Bob Sward
Teddy Theryo
Dustin Thomas
Scott Tumpaugh
John Crigler, TAB Contact, NV
Randy Cox, NV
Ted Neff, NV
Miroslav Vejvoda, Secretary, NV

Associate Members Present
Yosbani Ballate
Mike Beauchamp
Robert Bennett
Thomas Helm
Bijan Khaleghi
David Konz
Jim McTaggart
Shannon Meeks
Marcel Poser
Mário Salice
Joe Salvadori
Don Singer

Dywidag-Systems International USA, Inc.
Schwager Davis, Inc.
Caltrans
TENSA
LCPT International Consulting, Inc.
Figg Bridge Engineers
University of Florida
LMS Reinforcing Steel Group
Federal Highway Administration
Parsons
Parson Brinkerhoff
VSL
General Technologies, Inc.
Dywidag-Systems International USA, Inc.
Wiss, Janney, Elstner Associates, Inc.
Freyssinet, Inc.
Figg Bridge Engineers
Corven Engineering, Inc.
Finley Engineering Group
Mexpresa
PT-Technologies
Florida DOT
Kiewit Infrastructure West
Janssen & Spanns Engineering, Inc.
Virginia Transportation Research Council
VSL
Florida Department of Transportation
Minnesota DOT
Traylor Bros., Inc.
VSL
ASBI
VSL
Caltrans
RS&H
NOVA
Washington State DOT
Atkins Global
Consultant
Parsons
Tectus Group
Schwager Davis, Inc.
Dywidag-Systems International USA, Inc.
DYWIDAG-Systems International Canada, Ltd.
Eric Sommer
Jack Torok
Zuming Xia

VSL
Target Products
VSL

Visitors
Shahid Islam, DSI
Dale King, Bekaert
Tony Ledesma, WSP
Natassia Brenkus, Ohio State
Shane Taylor, Precision Hayes
Mike Kiggins, Kiewit

David Konz, Atkins
Shukre Despradel, Kiewit
Xiao Fu, Kiewit
Jacob Myer, Schwager Davis
Don Hill, Trenton Corp.
Edgar Zuniga, DSI

ACTION ITEMS FROM LAST / THIS MEETING

<table>
<thead>
<tr>
<th>Item #</th>
<th>Subject</th>
<th>Action</th>
<th>Responsible</th>
<th>Deadline / Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>CRT-70 Items for M-50</td>
<td>Ballot M-50</td>
<td>Staff</td>
<td>Asap</td>
</tr>
<tr>
<td>D.1</td>
<td>Bulletin 7 vs. 75</td>
<td>Review Bulletin 7 vs. 75 or other plastic duct requirements</td>
<td>TG: Krauser, Sward, Myer</td>
<td>Before next meeting</td>
</tr>
<tr>
<td>D.1</td>
<td>Loops</td>
<td>Address requirements for loop tendons</td>
<td>TG: M. Schwager, Sward</td>
<td>Before next meeting</td>
</tr>
<tr>
<td>D.1</td>
<td>Replaceable tendons</td>
<td>Review draft and address diabolos</td>
<td>TG: Holt, M. Schwager</td>
<td>Before next meeting</td>
</tr>
<tr>
<td>D.1</td>
<td>Monitorable tendons</td>
<td>Review draft</td>
<td>TG: Krauser, Ciccone, Holt, Salvadori</td>
<td>Before next meeting</td>
</tr>
<tr>
<td>D.1</td>
<td>Flexible fillers</td>
<td>Address flexible filler requirements</td>
<td>TG: Brenkus, Hamilton, Hill, Bennett, Ballate, Hunsicker</td>
<td>Before next meeting</td>
</tr>
</tbody>
</table>

Agenda Item | Expected Outcome / Actions Taken
---|---
A. General | A.1 Meeting called in order at 1:05 pm by Co-Chair G. Schwager.
A.2 Introductions / Attendance Sheet (Exhibit A.2) | A.2 All present introduced themselves.
A.3 Committee Roster | A.3 The official committee roster is on the PTI website.
A.4 PTI Antitrust Policy (Exhibit A.4) | A.4 All present were reminded of the PTI Antitrust Policy and asked to initial the right-hand side column on the Attendance Sheet to confirm their knowledge of and adherence to the policy.
A.5 Committee Annual Report | A.5 The Annual Report was discussed in reference to goals. Goals for M-50:
  * Ballot remaining items
  * Publish commentary
  * System certification (time table: end of the year CRT-70
<table>
<thead>
<tr>
<th>Agenda Item</th>
<th>Expected Outcome / Actions Taken</th>
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<tbody>
<tr>
<td></td>
<td>final draft; RFP draft very soon; 1 ballot, CAB, public review;</td>
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<tr>
<td></td>
<td>• Replaceable tendons</td>
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<td></td>
<td>• Monitorable tendons (TG:</td>
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<td></td>
<td>• Loops, diablos, tangent length at anchorages</td>
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<td>• Bulletin 75 vs. 7</td>
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<td></td>
<td>• Flexible filler</td>
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</table>

**B. Agenda & Minutes**

B.1 Approval of Agenda

B.2 Approval of Minutes (Meeting ballot required)

<table>
<thead>
<tr>
<th>B.1 Any changes to the agenda? No additions to agenda were requested.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.2.1 Motion / Second to approve Meeting Minutes from 4/30/17: Krauser / Sward, 12-0-0 (Y-N-A)</td>
</tr>
</tbody>
</table>

**C. Actions Taken Between Meetings**

C.1 No letter ballots
C.2 No Web Meetings

| C.1 |
| C.2 |

**1. Action Item 1: Commentary**

1.1 Status of Commentary: Approved

1.1 Document with the approved Commentary is ready for publication. There are some items CRT-70 identified that may need to be balloted in M-50 and included in the next publication.

**2. Action Item 2: PT Systems Qualification Testing**

2.1 Progress report from CRT-70 Chair Hunsicker

2.1 CRT-70 Chair Greg Hunsicker reported on the progress from the CRT-70 meeting on October 5, 2017:

• All items were reviewed during the meeting in Cancun
• One last ballot in CRT-70 is necessary to ensure all changes were incorporated
• CAB review will be followed by Public review

Items to be still finalized:

• Inspection agency / Auditor
• PTI website (this will be incorporated in the new PTI website)

**3. Action Item 3: Monitorable, Replaceable and Assessable PT Research Project**

3.1 Progress update of the FHWA Task 5009

3.1.1 Replaceable Grouted Tendons including diablos (Exhibit 3.1.1)

3.1 The final drafts are for review and comment. The final and official versions should be balloted by M-50 when available. Initially, a review of these section by Task Groups is desirable. The TGs should review the items and report to M-50 at the next meeting in Minneapolis in May 2018.

3.1.1 Final draft with Specification and Commentary for replaceable grouted tendons was attached to the minutes from
<table>
<thead>
<tr>
<th>Agenda Item</th>
<th>Expected Outcome / Actions Taken</th>
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</thead>
<tbody>
<tr>
<td>3.1.2 Monitorable Tendons (Exhibit 3.1.2)</td>
<td>3.1.2 Final draft with Specification and Commentary for monitorable tendons was attached to the minutes from April 30, 2017. TG to review document: Larry Krauser, Tommaso Ciccone, Reggie Holt, Joe Salvadori</td>
</tr>
<tr>
<td>3.2 Discussion and time table for integration into M-50</td>
<td>3.2 These items will be addressed in M-50 as new business (after the document publication with commentary).</td>
</tr>
<tr>
<td><strong>4. Action Item 4: Next Edition of M-50 Specification</strong></td>
<td>4.1 The next edition will be published as soon as possible and include items that have already been balloted. There might be a few more items to ballot that were brought up by CRT-70. Possible inclusion of items identified by CRT-70 to be resolved by M-50. See attached list with items to be balloted in M-50 and possibly included in the next edition (Exhibit 4.1).</td>
</tr>
</tbody>
</table>
| 4.2 Time table to completion of the next edition. | 4.2 The next step to publication are:  
- M-50 ballot of items identified by CRT-70  
- Assemble final document  
- M-50 short review  
- TAB review  
- M-50 responses to TAB review comments  
- TAB compliance check  
- Public review  
- M-50 responses to public review  
- TAB review  
Overall time: approximately 4 months |
| **5. Action Item 5: AASHTO Bridge Construction Specification** | 5.1 Progress report from the TG (Zuming Xia): The goal of M-50 remains to have AASHTO adopt the 95% $f_{pu}$ (MUTS).  
5.2 This is an ongoing effort. |
| 5.1 Status of 95% MUTS (TG: Xia, Myer, Micklus, Ciccone, Holt) | |
| 5.2 AASHTO Updates (TG: Merrill, Cloutier, Krauser, Cox, Hunsicker) | |
| **6. Action Item 6: Flexible Fillers** | |
| 6.1 Status | 6.1 Training class report from Randy Cox: The class took place in Tallahassee FL in May 2017 with nearly 100 people attending. |
| 6.2 Action items? | 6.2 Refer to Item D; Flexible filler should be included in the |
### Agenda Item

<table>
<thead>
<tr>
<th>Expected Outcome / Actions Taken</th>
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<tbody>
<tr>
<td>CRT-70 program but would have to be first addressed by M-50.</td>
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</tbody>
</table>

### D. New Business

**D.1 New items?**

- **Bulletin 7 vs. Bulletin 75** or other plastic duct requirements ([Exhibit D.1](#)): **TG:** Larry Krauser, Bob Sward, Jacob Myer
- **Loops:** **TG:** Mike Schwager, Bob Sward
- **Tangent length** (straight part of tendon) at anchorages
- **Replaceable tendons & diablos:** **TG:** Reggie Holt, Mike Schwager
- **Monitorable tendons:** **TG:** Krauser, Tommaso Ciccone, Reggie Holt, Joe Salvadori
- **Flexible fillers:** refer to Item 6; **TG:** Natassia Brenkus/Trey Hamilton, Don Hill, Robert Bennett, Yosbani Ballate, Greg Hunsicker

### E. Next Meeting

- **E.1 PTI Convention**
  - **TG:** Jamie Bucy, Mark Haines
  - **Description:** E.1 Sunday, May 6, 2018, at the Minneapolis Hilton in Minneapolis, MN
- **E.2 Web Meetings**
  - **TG:** Mike Schwager, Regina Green
  - **Description:** E.2 As needed

### F. Adjourn

- **TG:** Jamie Brooker, Mike Schwager
- **Description:** F. The meeting was adjourned at 4:45 pm

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**AGENDA / MINUTES EXHIBITS**

<table>
<thead>
<tr>
<th>Exhibit #</th>
<th>Subject</th>
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<tbody>
<tr>
<td>A.2 / A.4</td>
<td>Attendance Sheet / PTI Anti-Trust Policy</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Replaceable Grouted Tendons Draft</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Monitorable Tendons Draft</td>
</tr>
<tr>
<td>4.1</td>
<td>CRT-70 List of Items for M-50 with Actions</td>
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<tr>
<td>D.1</td>
<td>fib Performance Testing Requirements Comparison B7 to B75</td>
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<tr>
<td>#</td>
<td>Name</td>
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<tr>
<td>1</td>
<td>Larry Krause</td>
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<td>Joe Salemian</td>
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<td>Shahid Islam</td>
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<td>Dale King</td>
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<td>5</td>
<td>Jack Torok</td>
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<td>6</td>
<td>Vittorio Ballato</td>
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<td>Bob Swardo</td>
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<td>Tony Lomas</td>
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<td>Natassia Brekus</td>
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<td>Shane Taylor</td>
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<td>Xiao Fu</td>
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<td>Randy Cox</td>
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<td>Reggie Holt</td>
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<td>Tom Helm</td>
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<td>Brian Merrill</td>
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<td>20</td>
<td>Mario Saucy</td>
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<td>21</td>
<td>Mike Schaefer</td>
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# Committee Attendance Sheet

**Committee:** M-50 PTI/ASBI Joint TG  
**Date:** October 22, 2017  
**Meeting Location:** Marriott Marquis New York, NY  

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*I have read, understand, and agree to comply with PTI Anti-Trust Policy (See reverse).

**Note to Committee Members and Visitors:** All Committee meetings of the Post-Tensioning Institute should be conducted in a manner encouraging free and open discussion and debate of agenda items and matter properly before that Committee. Committee members and visitors are cautioned that such discussion and debate is solely for the purposes of the Charter of the Committee and PTI business. To that end, Committee discussions and debates are not considered public in nature, and, as such, are to be held in confidence and do not become the official policy of PTI until properly reported, balloted, and published pursuant to procedures established by or by the adoption by the PTI Board of Directors. Committee members and visitors shall not quote, publish, use, or make use of, any oral or written drafts, drawings, calculations, or other materials, which are uttered or transcribed during the course of such meetings.

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<table>
<thead>
<tr>
<th>#</th>
<th>Name</th>
<th>Company</th>
<th>Voting / Associate / Guest</th>
<th>E-Mail (or phone)</th>
<th>Initial Policy</th>
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<tr>
<td>1</td>
<td>Jacob Myer</td>
<td>Schweiger Davis</td>
<td>Guest</td>
<td><a href="mailto:jacobm@scheigerdavis.com">jacobm@scheigerdavis.com</a></td>
<td>JM</td>
</tr>
<tr>
<td>2</td>
<td>Jon Hubbard</td>
<td>WSP</td>
<td>Voting</td>
<td><a href="mailto:jon.hubbard@wsp.com">jon.hubbard@wsp.com</a></td>
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</tr>
<tr>
<td>3</td>
<td>Gregozi Hunsicker</td>
<td>Structural VSL</td>
<td>Voting</td>
<td><a href="mailto:g.hunsicher@vsl.net">g.hunsicher@vsl.net</a></td>
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<td>4</td>
<td>Guido Schmeisser</td>
<td>SBI</td>
<td>Voting, Guest</td>
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<tr>
<td>5</td>
<td>Don Hill</td>
<td>Trenton Corp</td>
<td>Guest</td>
<td><a href="mailto:d.hill@trentoncorp.com">d.hill@trentoncorp.com</a></td>
<td>D</td>
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<td>6</td>
<td>ELIE HOMSI</td>
<td>Parsons</td>
<td>Voting, Guest</td>
<td><a href="mailto:elie.homsi@parsons.com">elie.homsi@parsons.com</a></td>
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<td>7</td>
<td>EdmJ ZurnaFTIPTI</td>
<td>DSJ</td>
<td>Guest</td>
<td><a href="mailto:edmj.zurna@dsjtech.com">edmj.zurna@dsjtech.com</a></td>
<td>C</td>
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<td>8</td>
<td>Ted Neff</td>
<td>PTI</td>
<td>STAFF</td>
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</tr>
<tr>
<td>9</td>
<td>CHMAROS CICONE</td>
<td>Tensa</td>
<td>Voting</td>
<td><a href="mailto:t.cicone@tensainternational.com">t.cicone@tensainternational.com</a></td>
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<tr>
<td>10</td>
<td>Robert Bennett</td>
<td>TCS/CH</td>
<td>A</td>
<td><a href="mailto:robert.bennett@tcsandch.co">robert.bennett@tcsandch.co</a></td>
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<tr>
<td>11</td>
<td>MIOSLAV VEIVODA</td>
<td>PTI</td>
<td>STAFF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Greg Redmond</td>
<td>PT-TECH</td>
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<td><a href="mailto:greg@pt-tech.com">greg@pt-tech.com</a></td>
<td></td>
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<tr>
<td>13</td>
<td>Drew Micklus</td>
<td>Freyssinet</td>
<td>Voting</td>
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PTI POLICY STATEMENT ON COMPLIANCE WITH ANTITRUST LAWS

At a meeting on October 8, 1980, the Board of Directors first discussed the Institute's status and policies regarding compliance with antitrust laws. After review of both the internal and external compliance procedures, the following resolution was approved:

"The staff, officers, directors and members of the Post-Tensioning Institute are reminded that they are required to comply with the spirit and specific requirements of the antitrust laws on all activities within the scope of, and related to, the official functions of PTI. Further, this restated position, along with appropriate explanatory material, should be placed in all meeting folders/books periodically, beginning with the 8th of October meeting of PTI."

On July 24, 2012 and again on October 7, 2015, the Executive Committee authorized Legal Counsel to review and update this Policy Statement in the perspective of the Department of Justice Business Review Letter of July 30, 1997 and current case law. As a continuing guide for your participation in PTI's meetings, please review and continue to adhere to the following "Legal Limitation on Discussions at PTI Meetings."

LEGAL LIMITATION ON DISCUSSIONS AT PTI MEETINGS AND EVENTS

A free exchange of ideas on matters of mutual interest to the members is necessary for the success of all meetings. Indeed, such an exchange of views is essential to the successful operation of every trade association and the law specifically allows legitimate exchange of views pertaining to, e.g., quality control, safety, building design and construction integrity, etc.

It is not the purpose of this memorandum to discourage the exploration in depth of any matters of legitimate concern to meeting participants. Nevertheless, to ignore certain antitrust ground rules, either through ignorance or otherwise, is to create a civil and criminal hazard businessmen simply cannot afford.

It is for these reasons that PTI provides you with a reminder that certain areas of formal and informal communication between competitors or between manufacturers and their suppliers and customers must be avoided, as posing potential antitrust problems.

The Sherman Antitrust Act, the Clayton Act, the Federal Trade Commission Act, and the Robinson-Patman Act comprise the basic federal antitrust laws, which set forth the broad areas of conduct considered illegal as restraints of trade. In general, agreements or understandings between competitors that operate as an impediment to free and open competition are forbidden. Federal antitrust prohibitions forbid any "agreement or understanding...to substantially lessen competition or tend to create a monopoly in any line of commerce."

An important point to keep in mind is that communications and discussions between competitors or between sellers and customers, about matters which may be considered anti-competitive, often comprise the evidence from which courts infer antitrust violations. It is the policy of the Post-Tensioning Institute that such agreements, understandings or communications shall not be tolerated at any formal or informal meetings or social events of the Institute.

The general prohibitions contained in the federal antitrust laws, have been particularized in the form of a series of consent decrees, originally entered against a number of member companies of various trade associations and the associations themselves. It is important to note that these laws not only apply to PTI members, but also to PTI itself. Often trade associations have been and are presently co-defendants in cases brought by the Justice Department and the Federal Trade Commission ("FTC"). Recently, the FTC has stated: "Because trade associations are by their nature collaborations among competitors, the Commission and courts have long been concerned with anti-competitive restraints imposed by such organizations under the guise of codes of conduct. Competing for customers, cutting prices, and recruiting employees are hallmarks of vigorous competition. Agreements among competitors not to engage in these activities injure consumers by increasing prices and reducing quality and choice."

Similar "codes" or policies and requirements that encourage directly or indirectly members' unlawful activity are strictly forbidden by PTI in the course of its business with its members.
SPECIFIC EXAMPLES OF ACTIVITIES AND PRACTICES PROHIBITED
AT ALL PTI MEETINGS AND EVENTS:

Included in activities and practices which are forbidden, and are contrary to the policy of the Institute, both under the general antitrust laws and the consent decrees, subject to the said Business Review Letter, are the following:

- Agreeing to allocate markets, customers or suppliers among competitors, classify certain customers or suppliers being entitled to preferential treatment by manufacturers, and establish geographic trading areas.

- Participating in any plan designed to induce any manufacturer or distributor to sell or refrain from selling, or discriminate in favor of, or against any particular customer or class of customers.

- Agreeing in any manner to fix or otherwise establish bids, prices (including price increases, decreases, standardization or stabilization), profits, costs, contract terms affecting price (such as discounts and credit terms), etc. because, e.g. prices were too low, with the exception of certain resale pricing agreements between manufacturers and retailers or distributors.

- Agreeing in any manner to limit or restrict the quality of products to be produced (e.g., restrictions on selling coated strand to certain customers).

- Participating in any plan which has the effect of discriminating against, or excluding competitors, suppliers or customers.

These examples are provided to guide you in your discussions during formal and informal PTI meetings and social events. If the occasion arises, more specific advice will be provided by legal counsel, who is required by Article IV, Section 7 of the PTI By-Laws to be present at all meetings of the Board of Directors and the Executive Committee.
# Replaceable Grouted External Tendon Specification Language

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Introduction

This appendix provides suggested specification language that can be incorporated into a future version of PTI/ASBI M50.3 “Guide Specification for Grouted Post-Tensioning”.

The following document presents changes and additions to M50.3-12 necessary to accommodate replaceable grouted external tendons into that specification. Suggested changes are based on the 2012 version of M50.3 and are made to the relevant passage and numbering. Underlined text means an addition to the current version of M50.3; strike-through means that text needs to be removed from the current version of M50.3.
1.0—INTRODUCTION

1.3—Referenced standards and specifications

   European Organization for Technical Approvals (EOTA)

   European Technical Assessment Guidelines (ETAG) 013, Guideline for European Technical Approval of Post-Tensioning Kits for Prestressing of Structures
2.0—DEFINITIONS AND ABBREVIATIONS

2.1—Definitions

*Diabolo* - A formed void in a deviator or diaphragm with trumpet shaped ends to align and direct an external tendon through the concrete section.

*Guide pipe* – A structural assembly that aligns and directs the tendon at the anchorage location, and provides separation between the anchor body/trumpet and duct to the surrounding concrete section.

*Replaceable tendon* - Post-tensioned tendon designed and detailed to allow speedy removal and replacement without causing structural damage.
4.0—MATERIAL AND PERFORMANCE REQUIREMENTS

4.3—Component standards

4.3.13 – Guide pipes

Guide pipes used for replaceable external post-tensioning anchorages shall align the tendon and allow anchorage replacement.

Plastic guide pipes shall be made of high-density polyethylene or polypropylene. For steel guide pipes, use galvanized ASTM A53, Grade B, Schedule 40 steel pipes or galvanized ASTM A500 structural steel tubing.

Ensure guide pipes:

- Are sufficiently stiff to withstand handling, installation, and concreting;
- Are dimensioned with inside diameter sufficient to allow free movement and replacement of anchorage;
- With a diabolo end are designed with an additional deviation angle of 3 degrees at exit end;
- Shall contact the tangent portion of the tendon duct within 1/8” tolerance where tendon deviation is required; and
- Shall be sealed against leakage of concrete paste at the bearing plate.

4.3.13 – Diabolos

Provide diabolos with a minimum inside diameter at least 1/2 in. larger than the outside diameter of the tendon duct. Diabolos may be constructed using permanent or removable forms.

Permanent forms may be constructed using solid nylon or polyethylene shells. Steel is allowed for temporary/removable forms.

Ensure diabolos:

- Are sufficiently rigid to maintain their shape during handling, installation, and concreting;
- Provide a smooth surface with no kinks; and
- Are designed with an additional deviation angle of 3 degrees.

C4.3.13 – Diabolos

The stressed tendon will deform the duct into an oval shape as it bends through the diabolo. The 1/2 in. gap is to ensure the deformed duct can be removed from the diabolo if replacement is required.
4.4.3—Duct testing

Duct and duct connections installed and cast into concrete prior to prestressing steel installation shall be capable of withstanding 10 ft of concrete fluid pressure. Duct and duct connections for use with straight preinstalled prestressing steel, installed prior to concreting, shall be capable of withstanding 5 ft of concrete fluid pressure. Duct and duct connections shall not permanently dent more than 1/8 in. under 150 lb of concentrated force applied between corrugations, using No. 4 reinforcing bar. Apply force for 2 minutes and measure the dent 2 minutes after force removal. The duct shall have adequate longitudinal bending stiffness for smooth placement.

Ducts for replaceable external tendons shall meet the following requirements:


2. EOTA, ETAG 013, “Guideline for European Technical Approval of Post-Tensioning Kits for Prestressing of Structures,” Section 6.1.5-I.
5.0—INSTALLATION DRAWINGS AND STRESSING CALCULATIONS

5.2—System drawings

Submit post-tensioning system drawings showing all components required for the tendon installation, both temporary and permanent (to include part numbers as appropriate). Define the nominal geometry and material composition of all components to be used.

As a minimum, show all applicable:

- Details for tendon protection level (that is, PL-1, PL-2, or PL-3);
- Wedge plates, wedges, bearing plates, trumpets, couplers, and local zone reinforcement;
- Permanent grout caps with installation accessories (if required);
- Ducts, couplets, and typical connection details;
- Typical details for all vents and inspection points in the anchorages and along the ducts;
- Duct inner diameter (ID) and outer diameter (OD) (major and minor) or other defining internal and external dimensions;
- Tendon types and sizes and duct types and sizes associated with different tendon lengths;
- Tendon “Z” factors (center of gravity of strand [cgs] offsets) for all duct and tendon size combinations;
- Friction coefficient and wobble details;
- Steel pipes, boots, and clamps;
- Duct minimum radius of bending and maximum support spacing;
- Methods for supporting all hardware before concreting;
- Minimum stressing tails for all tendon types;
- Minimum concrete blockout dimensions for equipment access and concrete cover;
- System seating losses (anchor set);
- Minimum concrete strength for stressing;
- Newly developed features not mentioned previously;
- Details for segmental duct couplets;
- Details for guide pipes and diabolo forms (if required);
- System-specific details for full encapsulation of tendons (if required); and
- System-specific details for electrically isolated tendons (if required).
9.0—BEARING PLATE AND DUCT INSTALLATION

9.4—Anchorage components

Install bearing plates against the formwork and anchorage blockouts as shown on the approved installation drawings. The bearing plate and guide pipe (if required) longitudinal axes shall be within 2 degrees of their design directions. Trumpets shall be perpendicular to the faces of the bearing plates and securely fastened in place. Local zone reinforcement shall be centered on the anchorage and positioned per the PTS supplier’s installation drawings.

9.5—Deviation pipes and diabolo forms

Curves in pre-bent pipes and diabolo forms shall be inspected for proper radii, smoothness, and kink-free fabrication. Install and securely fasten pre-bent pipes and diabolo forms as shown on the approved installation drawings. Verify the pipe or diabolo form is oriented correctly before releasing the installation for concreting. Ends of pipes shall be sealed until the duct is attached. Ends of diabolo forms shall be sealed until concreting is completed.
Monitorable post-tensioning systems

Sub task 2 – State-of-the-art report

Appendix B – EIT Specification Language

Final Draft (working)
November 2016
# EIT Specification Language

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Introduction

The 1st edition of PTI/ASBI M50.3-12 "Guide Specification for Grouted Post-Tensioning", issued in 2012, recognizes three protection levels for post-tensioning tendons. Protection Level 3 requires electrical isolation or encapsulation of the tendons and “to be monitorable or inspectable at any time”. However, there are no guidelines on PT material / hardware system requirement, installation and performance measurement, and test procedures for the EIT system. This appendix provides suggested specification language that can be incorporated into a future version of PTI/ASBI M50.3-12 "Guide Specification for Grouted Post-Tensioning".

The following document presents changes and additions to M50.3-12 necessary to incorporate electrically isolated tendons into that specification. Suggested changes are based on the 2012 version of M50.3 and are made to the relevant passage and numbering. Underlined text means an addition to the current version of M50.3; strike-through means that text needs to be removed from the current version of M50.3.
2.0—Definitions and Abbreviations

2.1—Definitions

**Half-shell** - Plastic half-shells are placed between the duct and tendon support bars to protect the duct from being damaged during tendon stressing.

**Isolating plate** - Plate (typically made from fiber-reinforced plastic) that transfers the load from the anchor head to the cast-iron anchorage body, while ensuring that the anchor head is electrically isolated from the anchorage body.

**Longitudinal main conductor** - Reinforcing steel bar (or another uncoated metallic component) installed in the reinforced concrete structure in longitudinal direction in order to guarantee continuous electrical conductance of the reinforcing steel cage. Usually, relatively thick reinforcing steel bars are used (e.g. #11 bar (diameter 35.8 mm)).

**Transverse main conductor** - Reinforcing steel bar (or another uncoated metallic component) installed in the reinforced concrete structure in transverse direction in order to guarantee continuous electrical conductance of the reinforcing steel cage. Usually, relatively thick reinforcing steel bars are used (e.g. #11 bar (diameter 35.8 mm)).

**Resistance (R)** - Ohmic resistance between the prestressing steel and the reinforcing steel in the surrounding concrete. Used to assess the quality of the encapsulation of the tendon. (Ω)

**Specific resistance (R_l)** - Product of the measured resistance of a tendon (R) and the tendon length (L):

\[ R_l = R \cdot L \ (Ωm) \]

**Capacitance (C)** - Capacitance of the plastic duct (F).

C2.1—Definitions

Longitudinal main conductors are typically used when there is concern that electrical continuity is not continuous through the reinforcing steel cage such as when epoxy-coated reinforcement is used. Thus, to guarantee the presence of a continuous conductor acting as counter electrode in the AC impedance measurement, it is recommended to install “longitudinal main conductors” in the structure. It is recommended to have at least two of the “longitudinal main conductors” and to connect them to each other at least at both ends with help of “transverse main conductors”.

The ohmic resistance is affected by the presence of duct perforations, i.e. with increasing size and number of duct perforations R decreases.

The length of a tendon strongly affects R. Low values of R may not always indicate the presence of perforations, but may also arise from high tendon lengths.

The capacitance is significantly affected by dielectric properties, diameter, and wall thickness of the duct. C decreases with...
Specific capacitance \((C)\) - Capacitance per unit length of tendon. \(C = C / L \text{ (F/m)}\) where \(L\) is the tendon length.

Loss factor \((D)\) - Ratio of the real and imaginary component of the impedance \(Z\). The loss factor \(D\) has no unit and it is independent of the length of the tendon. \(D\) depends on the number of defects in the duct, i.e. the magnitude of \(D\) increases with increasing number of defects.

Increasing wall thickness, and for a given wall thickness, \(C\) increases with increasing duct diameter. However, \(C\) is relatively unaffected by the presence of duct perforations.

The capacitance of a given duct type increases proportionally with an increase in duct length.

Assuming a parallel equivalent circuit of \(R\) and \(C\), the loss factor can be written as:

\[
D = \frac{\text{Re}(Z)}{\text{Im}(Z)} = -\frac{1}{\omega RC}
\]

where \(\omega\) is the angular frequency of the imposed A.C. measuring signal and \(\text{Re}(Z)\) and \(\text{Im}(Z)\) are the real and imaginary parts of the impedance, respectively.
3.0—Post-Tensioning System (PTS) Tendon Protection Levels (PL)

3.4—Protection Level 3 (PL-3)

PL-2 plus electrical isolation of tendon or encapsulation to be monitorable or inspectable at any time.

Performance requirements:

- PTS shall provide complete electrical isolation of the entire tendon and meet the system pressure tests contained in Section 4.4.5; the wedge plate and prestressing steel shall be electrically isolated from the bearing plate with a non-conductive insert.
- PTS shall have the ability to be monitorable or inspectable at any time. Junction boxes with electrical terminals and electrical cable connections made directly to the prestressing steel shall be installed meeting the requirements of section 4.3 to ensure continuous monitorability;
- Bare strand or bar per Sections 4.2.1 and 4.2.2, respectively;
- Electrically isolate the tensile elements;
- Permanent grout caps meeting the requirements of Section 4.3.3;
- Envelope to be watertight and impermeable to water vapor over entire length. Envelope material to be chemically stable, without embrittlement or softening during anticipated exposure temperature range and service life, no free chloride ions extractable from material. Duct shall meet the requirements of Section 4.3.5 and may be one of the following:
  - Plastic duct per Section 4.3.5.2;
  - Plastic pipe per Section 4.3.5.3;
  - Duct connections per Section 4.3.6;
- Precast segmental duct couplers for precast segmental construction per Section 4.3.8;
- Filling material to be chemically stable, nonreactive with prestressing steel and tendon duct, and shall conform to:

C3.4—Protection Level 3 (PL-3)

PL-3 provides better protection against corrosion as the protection provided by PL-2. In addition to the protection offered by PL-2, the completely electrically isolated tendon in PL-3 has no macro-cell interaction with reinforcing steel. Thus, even in the case of perforations in the duct and chloride penetration to the prestressing steel, the corrosion rate is lower than in the cases PL-1 and PL-2. Additionally, PL-3 allows to monitor or inspect the tendon for corrosion or deterioration and to verify the duct envelope has not been damaged during construction.

Selection criteria for PL-3 may be the exposure environment (from lowly to highly corrosive), the durability of the design (cover depths, joints, etc.) and selected materials of the construction, the importance of the structure, the ability to monitor the structure over its service life, etc.

In order to achieve a watertight and impermeable to moisture envelope over the prestressing element, only plastic duct or plastic pipe can be used in PL-3. Galvanized ducts are not watertight and impermeable to moisture penetration and do not provide electrical isolation.

Precast segmental duct couplers maintain a leak tight barrier against intrusion of water at segment joints.

PTI M55.1-12, “Specification for Grouting of Post-Tensioned Structures” provides additional information of grouts and grouting.
Engineered grout Class C or D per PTI’s “Specification for Grouting of Post-Tensioned Structures”; and Thixotropic in nature.

Grout filling procedure to leave no voids in duct.

Grout procedures leaving no significant voids are critical to the long-term performance of the tendon.

Complete electrical isolation is achieved by using electrically isolating materials not only for the duct, but also at the anchor head (protective cap and inserts as sketched in Figure 1. Schematic illustration of tendon system for protection level 3 (PL-3) (according to the Swiss guidelines [2-4])).

Typically, the load from the wedge plate (anchor head) is transferred to a cast-iron anchorage body or bearing plate. To achieve electrical isolation, the wedge plate and the cast-iron anchorage body (or the bearing plate, respectively) are separated by a fiber-reinforced polymer disc, which ensures that load is transferred to the anchorage body while maintaining electrical isolation of the tendon. This requires the isolation system to be integrated into the anchorage system, which is typically proprietary. Thus, different solutions are possible, depending on the type of anchorage.

The main advantage of EIT in PL-3 is that this solution is non-destructively monitorable over time. Figure 1 shows “electrical connections” at both ends of the tendon. These connections permit contacting the tendon with measurement equipment that allows assessing the condition/quality of the encapsulation or other parameters at any point in time during the service life of the structure.

The main goal of long-term monitoring during the life of a structure is to detect ingress of moisture or chlorides through defects in the encapsulation into the tendon early, i.e. before
they can cause any damage to the prestressing steel.

This is possible by performing electrical impedance measurements over time and evaluating the change in measurement rather than the absolute value.

In principle, the ohmic resistance of a tendon with perforations should increase over time due to continuing cement hydration of the grout and the concrete surrounding the duct. When the logarithm of the resistance is plotted vs. the logarithm of time, this corresponds approximately to a straight line. A deviation from this trend, usually a pronounced decrease of the electrical resistance, indicates the ingress of water or chlorides at the duct defect. For more information about long-term monitoring and data interpretation, refer to [10, 11].
4.0—Material and Performance Requirements

4.3—Component standards

4.3.1—General

Ensure all connectors, connections, and components of post-tensioning system hardware are completely sealed against leakage of concrete paste. All hardware, components, and connections for PL-2 and PL-3—as defined in Section 3—shall be airtight and watertight and pass the pressure test requirements herein.

Metal half-shells and steel tie wires are not allowed for protection levels PL-2 and PL-3.

For PL-2, use smooth plastic duct for external tendons except where steel pipe is required. Use corrugated plastic duct for all internal tendons except where steel pipe is required.

For PL-3, use smooth plastic duct for external tendons and corrugated plastic duct for internal tendons.

4.3.2—Post-tensioning anchorages

Permanent grout caps for PL-2 shall be nonmetallic, stainless steel, or galvanized ferrous metal with a minimum thickness of zinc of 120 µm. Permanent grout caps for PL-3 shall be nonmetallic and non-conductive.

Trumpets associated with PL-2 anchorages shall be made of either ferrous metal or plastic. Trumpets for PL-3 anchorages shall be made of plastic. For plastic trumpets, the trumpet shall be made of high-density polyethylene or polypropylene. The thickness of the trumpet at the duct end shall not be less than the thickness of the duct.

4.3.3—Permanent grout caps

Use permanent grout caps made from approved polymer, ASTM A240 Type 316 stainless steel or ASTM A123 galvanized ferrous metal for PL-2. Use permanent grout caps made from approved polymer for PL-3. The approved resins for use in the polymer shall have ultraviolet (UV) stabilizer added. Seal the cap to the bearing plate with “O”-ring seals, gaskets, or precision-fitted flat gaskets. Place a grout vent on the top of the cap. Grout caps shall be pressure tested prior to grout injection and certified to a
minimum pressure of 150 psi by the PTS supplier. Use ASTM F593 Type 316 stainless steel bolts to attach the cap to the anchorage.

4.3.13 – Electrical Components for PL-3

Wiring used for electrical measurements on PL-3 tendons shall be at least #12 AWG solid copper. Wiring shall have water-proof insulation. When cast into concrete, the insulation shall be resistant to alkaline environment in the concrete. Alternatively, wiring shall be permitted to be placed in non-conductive electrical conduits.

Electrical contacts to the tendon shall be located at the anchorage at both ends of the tendon (Figure 2). Contact shall be made by means of a bolted cable strap. Galvanized conductors and contact bolts shall not be permitted. Prior to installing the bolted cable strap, any surface rust on the components shall be removed to ensure unimpeded electrical contact.

A junction box with electrical terminals shall be installed at each anchorage. Junction boxes shall be provided with an air ventilation opening protected with anti-insect mesh at the lowest position of the box. Junction boxes shall be installed in an easily accessible position on the structure and shall be suitable to protect all cables and measuring connections from weather and mechanical damage.

Wiring shall be soldered to the terminals and sealed permanently with heat shrink tubes. Terminals shall be adequately labeled in the junction box including the tendon identification and whether the connection is with the tendon or reinforcement.

Reinforcing steel bars (or other approved metallic component) shall be installed in concrete section both parallel and perpendicular to the tendon to ensure continuous electrical conductance of the reinforcing steel cage. Bar size shall be at least #11 bar (diameter 35.8 mm). Contacts to these bars shall be made by means of bolted cable straps. Galvanized conductors and contact bolts shall not be permitted. Prior to installing the bolted cable strap, any surface rust on the components shall be removed to ensure unimpeded electrical contact. The wiring shall be connected to the junction box.

After installation of connections and cables, the electrical connections shall be checked for continuity by appropriate electrical measurements.

Junction boxes are required at each anchorage as shown in Figure 2. Electrical measurements can then be made independently from either anchorage. This ensures redundancy, for instance if one of the connections fails over time. In addition, having the possibility to electrically connect the tendon from both ends facilitates localizing defects in the duct.

Guidance may be found in standard ISO 12696.
4.4—System approval testing

4.4.5—System pressure tests

4.4.5.3—Internal duct systems

Perform a system test of the assembly for compliance with the requirements of Chapter 4, Article 4.2, Stage 1 and Stage 2 Testing contained in fib Technical Report, Bulletin 75, “Corrugated Plastic Duct for Internal Bonded Post-tensioning.” For bar systems, modify the system test length to 15 ft.

The stage 1 performance test confirms that the components of an internal duct system from grout cap-to-grout cap can be successfully assembled and profiled within tolerances without profile discontinuities and without excessive duct deformations.

The stage 2 performance tests that the fully assembled system from stage 1 is sufficiently leak tight.

For PL-3, EIT performance of the assembled duct system (including duct, connectors and vents) shall be tested with the method (“EIT performance of duct system”) described in appendix B.2 of fib Technical Report, Bulletin No. 75 and shall satisfy the corresponding requirements.

The objective of this test is to demonstrate that the polymer duct system components can achieve sufficient electrical resistance to meet the EIT requirements for PL-3 on site.

For PL-3, EIT performance of the anchorage-duct assembly (including anchorage, trumpet, duct and duct connector) shall be tested with the method (“EIT performance of anchorage-duct assembly”) described in Appendix B.3 of fib Bulletin No. 75 and shall satisfy the corresponding requirements.

The objective is to confirm that the electrical resistance of the anchorage-duct assembly is sufficiently high to be used for PL-3 tendons. Another important aspect is to verify that the materials used in the anchorage-duct assembly (such as eventual coatings of metallic surfaces of anchorage members) have long-term stability in alkaline environments.
6.0—Quality Assurance and Quality Control (QA/QC)

6.1—QA program

The PTS suppliers shall have a QA program and a qualified person of authority who is responsible for implementing and enforcing this QA program. Based on this program, project-specific procedures and controls shall be developed to ensure all system specifications and contract requirements are met. For each project, carefully plan, implement, and document this process.

C6.1—QA program

Quality Control (QC) and Quality Assurance (QA) under this section for manufacturing and production of post-tensioning elements by the PTS supplier are slightly different from the broader definition in Section 2.1.

Quality Control for manufacturing and production of post-tensioning elements includes all acts of examining, witnessing, inspection, testing to determine conformity with the PTS supplier’s own QA/QC program as well as any project specific requirements including sampling and testing that may apply.

Quality Assurance for manufacture and production of post-tensioning elements includes the total effort of developing, documenting and implementing procedures, defining roles and responsibilities and assigning specific QA/QC tasks to individuals to achieve and verify Quality in accordance with specified requirements.

The quality of the execution on-site is crucial for the technology of EIT to be successful. Hence, post-tensioning systems should be installed only by specialized companies that are capable of documenting corresponding experience and have suitably trained (eventually certified) personnel. These companies should have a quality plan, adapted to the size and importance of the project, which describes all key processes such as duct placing, tendon installation, stressing, and application of the permanent protection. During execution, these processes should be supervised by a qualified supervisor. Installation on-site must be done in accordance with the general procedures defined by the system supplier.

The owner may wish to develop a long-term monitoring plan that incorporates electrical resistance readings. To ensure the usefulness of the long-term monitoring data, it is important that the methodology used when taking readings after stressing and after grouting be thoroughly documented along with the results for comparison and use on future monitoring.
When PL-3 is specified, the owner shall specify the electrical readings required and the corresponding acceptance criteria:

- Immediately after post-tensioning, but before grouting.
- 28 days after grouting.

These specifications should describe the measurement methods, test equipment, measuring points, and acceptance criteria to meet the project requirements.

Before starting installation, a meeting shall be held between all parties involved in the construction of PL-3 tendons to ensure that all relevant information is shared with all parties and all interfaces are well covered.

For acceptance criteria and threshold values please compare sections 12.9 and 13.3. The Swiss guidelines [3, 4] may also be consulted for further information.
8.0—Shipping and Storage of Materials

8.5—Plastic duct

Plastic ducts are an important part of EIT as they ensure the leak-tight encapsulation of the tendon over its length. They are particularly susceptible to damage during transport, storage and handling. Plastic ducts and other components of the encapsulation must thus be carefully handled and stored in clean environments in order to avoid damage (compare fib bulletin no. 75).
9.0—Bearing Plate and Duct Installation

9.6—Ducts

Before concrete placement, inspect the installed ducts for damage and make repairs as necessary. Remove dents and seal any pulling holes using the appropriate sealing method for Tendon PL, as shown on approved PT installation drawings. Ensure nothing infringes on the in-side dimension(s) of the ducts before releasing the installation for concreting.

For PL-3 tendons, plastic duct shall be visually inspected before installation. In case of damage, they shall be rejected.

For curved PL-3 tendons, the duct shall be protected from damage caused by support bars placed along the inside radius of the duct. At locations where the duct is in contact with support bars along the inside radius, plastic half-shells shall be placed between the duct and the support bars. Half-shells shall be fixed in place using plastic ties (metal ties not allowed).

Ensure that external tendon ducts are straight between connections to internal ducts and pipes at anchorages, diaphragms, and deviation saddles and are supported at intermediate locations per the approved installation drawings.

During tendon assembly and concrete placement, ducts may be indented at locations of high curvature on duct support bars. Half-shells can protect the duct from mechanical damage at these locations. If damage occurs to the duct, then the strand may cut through the duct and make contact with the support bar, thus severely diminishing the electrical isolation of the tendon.
12.0—Stressing Operations

(Insert this new section at 12.9 and renumber all following sections.)

12.9 – Verification of Electrical Isolation (PL-3)

12.9.1 AC impedance measurement

Prior to grouting (but after stressing the tendon) the AC impedance shall be measured between the tendon and the reinforcing steel using the terminals in one of the junction boxes.

C12.9—Verification of Electrical Isolation (PL-3)

C12.9.1 AC impedance measurement

To assess the quality of the encapsulation of EIT (leak-tightness, etc.) and for monitoring the condition over time, the AC impedance between the tendon and the ordinary reinforcing steel is measured. This is schematically shown in Figure 3.

To simplify matters, the AC impedance measurements will be referred to as “electrical resistance measurements”. This may be justified by the fact that the ohmic resistance is the main component of interest of the measured AC impedance.

Figure 3. Schematic illustration of electrical impedance measurement.

12.9.2 Measurement instrumentation

The instrument used to measure AC impedance shall satisfy the following requirements:

- AC measuring frequency of 1 kHz
- At least 0.5 V AC output voltage
- Digital display
- Measuring Ranges:
  - R: 0.1Ω – 10 MΩ (with a resolution of 0.1 Ω at the lower end of the range)
  - C: 0.1 nF – 100 μF
  - D: 0.001 – 10

C12.9.2 Measurement instrumentation

Typically, LCR-meters are used that can automatically resolve the ohmic and capacitive component of the AC impedance (assuming a parallel R-C circuit).
12.9.3 Interpretation of impedance measurements

Measured resistances <10 Ω indicate the presence of a metallic contact between the tendon and the reinforcing steel.

C12.9.3 Interpretation of impedance measurements

In theory, if the tendon is electrically isolated, the ohmic resistance will be controlled by the resistance of the polymer duct, which is relatively high. In the presence of duct perforations, the ohmic resistance will be lower.

During post-tensioning, the strands move relative to the plastic duct, which can gouge the inside of the ducts (wear damage). If not properly installed the duct may be damaged at locations of high curvature (at duct support bars) severely enough such that the prestressing steel is in direct contact with reinforcing steel. Metallic contacts may also arise at the anchorages, e.g. due to improper installation of the anchorage head. Such direct contacts tendon/anchorage–reinforcing steel can easily be detected by performing electrical resistance measurements after tensioning, but before grouting. The reason is that such metallic contacts strongly depresses the electrical resistance and that the absence of grout does not yet blur the results. Values of $R$ (not related to the tendon length) lower than approx. 10 or 20 Ω have been found to indicate the presence of such a metallic contact [2-5].

Prior to grout injection only resistance is measured; capacitance (C) and loss factor (D) measurements are only meaningful after the grout has been injected.

Additional resistance measurements may be taken during the stressing process to provide feedback on the tensioning process, i.e. to indicate whether or not damage is caused to the plastic duct and thus to the encapsulation.

12.9.4 Acceptance criteria

Readings shall be compared to the threshold limits or other assessment criteria established for the project and action taken as dictated by the project requirements.

C12.9.4 Acceptance criteria

Acceptable limits for non-compliance for each structure or specific structural member should be specified. Criteria may depend strongly on a number of factors, such as the type of structure, the exposure conditions, the presence of additional measures of corrosion protection, considerations regarding structural load-bearing behavior, but also on the objectives of using EIT (e.g. to improve quality control, for monitoring purposes, etc.).
At this stage, AC impedance measurements permit detecting the presence of metallic contacts between tendon and reinforcing steel. The following rules may be applied:

- The acceptable non-compliance rate is 10% or less.
- If non-compliance is in the range of 10% to 20%, the payment is reduced to PL2 rate for the non-compliance tendons.
- For non-compliance rates above 20%, the non-compliance tendons must be repaired until the threshold value of the AC impedance measurement is satisfied.

Note, however, that from a durability (corrosion) viewpoint, repairing such metallic contacts may be problematic, because whenever concrete is removed and the plastic duct is locally "repaired" there is a risk for creating additional pathways for ingress of chloride. As an alternative to repair, the owner may ask the contractor to localize the defects non-destructively and document their location for future considerations.
13.0—Grouting Operations

13.2–Inlet and vent seals

Inlets and vents must be properly sealed after grouting with leak-tight plastic caps.

Inlets and vents can potentially create an electrolytic connection to the concrete and thus decrease the electrical resistance of EIT.

13.3–Post-Grouting Electrical Measurements (PL-3)

13.3.1 AC impedance measurement

This second AC impedance measurement shall be made at approximately 28 days after grouting. See section 12.9 for details regarding the measurement, measurement instrumentation, and data interpretation.

If measurements are taken at a time different from 28 days after grouting, the time effect shall be taken into account using the following equation:

\[ R = R_t \cdot \sqrt{\frac{28}{t}} \]

where resistance \( R_t \) is measured at time \( t \) (age of the grout in days = time after grouting) and \( R \) is the value converted to 28 day age.

Measurements shall be taken at ambient temperatures in the range 10 to 30 °C (50 to 86 °F).

Temperature strongly affects the electrical resistivity of mortar and concrete and thus the AC impedance measurements. To reduce the error, it is recommended to perform measurements only within a pragmatic range of ambient temperatures. In a range of 10 to 30 °C, for instance, the temperature can induce deviations for resistance measurements of up to 30%. The local temperature inside the concrete of a structural member is often unknown and is also likely spatially variable. Temperatures measured at the outer concrete surface or in the air are poor indicators for the temperature in the concrete.

At this stage, the measurement allows assessment of the leak-tightness of the tendon encapsulation, and thus the quality of the installation.

It will also be possible to detect metallic contacts as described in section 12.9 (i.e. if \( R < \text{ca. 10} \ \Omega \)). If such metallic short circuits are present, however, then they will completely dominate the results and no other imperfections, such as perforations in the duct...
13.3.2 Acceptance criteria

Readings shall be compared to the threshold limits or other assessment criteria established for the project and action taken as dictated by the project requirements.

C13.3.2 Acceptance criteria

Acceptable limits for non-compliance for each structure or structural member should be specified. Criteria may depend strongly on a number of factors, such as the type of structure, the exposure conditions, the presence of additional measures of corrosion protection, considerations regarding structural load-bearing behavior, but also on the objectives of using EIT (e.g. to improve quality control, for monitoring purposes, etc.). If monitoring is the objective, the Swiss guidelines [3, 4] suggest that tendons with a specific resistance that is less than 50 kΩm shall be considered to have failed. Up to 10% of the tendons are permitted to fail specific resistance thresholds without penalty [3, 4].

Note that for precast segmental bridge construction or for use of epoxy-coated reinforcing steel, there is currently no experience upon which threshold values and acceptance criteria can be based.
References

6. fib (Fédération internationale du béton), *fib Bulletin no. 75 "Polymer duct-systems for internal bonded post-tensioning"*. 2014.
Changes Recommended to M50

- **Section 4.4 (& others) Independent Lab:**
  o Revise language to indicate certification to ISO 17025 or corresponding AMRL (John Pearson to provide information on AMRL equivalent). For old tests (prior to publication of the document) the independent auditor engaged by PTI will determine if the old tests are acceptable. The acceptance criteria must be met however acceptance of the test based on the credentials of the lab will be judged based on the auditors’ review (in cases where the lab was not AMRL or A2LA certified or documentation not provided of some aspects). Ballot Item 6.

- **Section 4:** Bar nuts not mentioned. Recommend including similar requirements to PT wedge plates, however specific to bars. **New business**

- **Section 6.4:** under “acceptable ranges” it refers to section 12.5 which appears to be the incorrect section. Remove reference; would have to refer to 4.0; other bullet points don’t have references. Ballot Item 7

- **Section 4.4.3:** “The duct shall have adequate longitudinal bending stiffness for smooth placement”. This is too vague and should be revisited by the committee. **New business**

- **Section 4.3.9:** Second paragraph, line 6: delete “EPDM couplers made of” or add commas before and after this phrase. Ballot Item 1.

- **Section 4.4.2:** Recommend removing “in concrete” as it is not necessary for this testing. Ballot Item 3.

- **Section 4.4.2:** PL1b requires permanent grout caps and therefore recommend it should have similar requirements as PL2 and PL3 grout caps. (Previously discussed) Ballot Item 2.

- **Flexible Filler:** Recommend consideration of Flexible Filler PT System requirements. Previously Discussed in M50 ((part of M-50 minutes from November 6, 2016 meeting) **New business**.

- **Section 4.4:** Equipment for testing needs specifics (calibrations, photos, hand written notes, etc.) Testing Equipment such as load cells, jacks, etc. from a laboratory should be traceable to NIST. Discussion: Tests performed before publication of document with this requirement would be excluded. A TG to look into QA issues: M. Schwager, Krauser (Negative #6 & others) **New business**.

- **Section 4.4.1:** 95% vs. 96% AUTS/GUTS – Already being addressed (Negative #25 & others) **New business**
Section 4.3.2: Inspectability behind Bearing Plate should read behind wedge plate within bearing plate. Replace “bearing plate” with “wedge plate” where borescope inspection access is specified. Discussion: Include this on the M-50 ballot (Negative #19) Ballot Item 4.

Section 4.3.2: Bolting grout cap to anchorage vs. bearing plate (negative #35) New business

Section 4.4.4: – What constitutes a change in material property or geometry (Negative #53) New business

Section 4.3.10: No reference can be made to minimum bend radius without procedure and criteria (Negative #58) New business

Section 4.3.10: “Duct in deviator and diaphragm shall not be allowed.” Seems to conflict with earlier part of the segment. Proposed to add “Standard” before “duct” (Negative #61). Ballot Item 5

Section 4.3.10: Does this effectively prohibit the use of diabolos, which are attractive for replaceable tendons? (Negative #65) New business

Section 4.4.5: Remove segmental couplers for internal duct test, not practical (otherwise provide guidance) (Negative #81) New business

Section 4.4.5: Consider S,M,L or some family testing rather than all sizes. (Negative #94) New business

Connection between grout cap and bearing plate/anchorage: Does an O-ring or gasket need to be used? Discussion: The wording in Section 4.3.3 is OK as is. New business
# Performance Testing Requirements - Comparison of Bulletin 7 to Bulletin 75

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<td>± 1% or ± 0.5 mm (larger limit governing)</td>
<td>- Existence of fabrication drawings</td>
<td>- Dimensions and tolerances of actual components to comply with specified dimensions and tolerances</td>
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<td><strong>Notes for guidance</strong></td>
<td>Data Sheets should be presented in system supplier’s information package</td>
<td>Assembly drawings should be presented in system supplier’s information package</td>
<td>Polymer duct system supply should be accompanied by certificate confirming compliance with specification and this report</td>
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<td>- Maximum duct support spacing calculated according to Section 6.2 with actual flexural stiffness such as to limit duct deflection between supports under defined load</td>
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<tr>
<td><strong>Acceptance criteria</strong></td>
<td>Document load @ 20 mm deflection and after unloading</td>
<td>Friction parameters satisfactory</td>
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<td>Rigidity satisfactory to retain duct profile during concreting</td>
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<td><strong>Notes for guidance</strong></td>
<td>Site test as per 4.1.9</td>
<td>Generally it would be expected that the duct should be rigid enough not to be displaced from profile by more than about 10 mm between each duct support.</td>
<td>Duct support spacing is calculated in accordance with Section 6.2 based on actual tested stiffness of duct but should in general not exceed 10-12 times duct diameter without prestressing steel installed or slightly more with prestressing steel installed prior to pouring concrete</td>
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<td>- at room temperature 23°C</td>
<td>- No visual damage to duct or connector</td>
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<tr>
<td></td>
<td></td>
<td>- at low temperature -15°C</td>
<td>- No deformation of cross section &gt; 5%</td>
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<td><strong>Acceptance criteria</strong></td>
<td>No visual damage, deformation of cross section not greater than 5%</td>
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<tr>
<td><strong>Notes for guidance</strong></td>
<td>Duct has to be flexible enough to be able to be bent to profile</td>
<td>Duct should be flexible enough to bend to minimum radius of curvature for field installation or coiling (if applicable) without significant deformation in cross section</td>
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<td>Deformation of duct cross section when bent to minimum radius of curvature for field installation ≤ 10% under negative pressure of 0.75 bar or 0.25 bar for Class I or Class II, respectively</td>
<td>Criterion corresponding to 3m or 1 m for Class I (general use) or Class II (use in shallow concrete members only), respectively, hydrostatic pressure of normal weight concrete may not cover applications at low temperature, very rapid concrete placement and use of self-compacting concrete</td>
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