AGENDA

PTI M-55 Grouting Committee Meeting

April 24, 2016
1:00 – 5:00 PM

Renaissance Long Beach Hotel, Long Beach, CA

Voting Members Present (8 of 22)

- Greg Hunsicker, Chair
- Gordon Clark
- Guy Cloutier
- Randy Cox
- John Crigler
- Antonio Garcia
- Al Ghobranpoor
- H.R. Hamilton
- Reggie Holt
- Bryan Lampe
- Brian Merrill
- Andrew Micklus, Jr
- Alan Moreton
- Randall Poston
- José Luis Quintana
- Michael Sprinkel
- Aamer Syed
- Teddy Theryo
- Jack Torok
- Brice Urquhart
- Yash Paul Virmani
- Peter Yen
- Jim Beicker, TAB Contact, NV
- Ted Neff, NV
- Miroslav Vejvoda, Secretary, NV

VSL
Ramboll
General Technologies, Inc.
Consultant
VSL
Garcia Bridge Engineers, P.A.
University of Wisconsin - Milwaukee
University of Florida
Federal Highway Administration Office of Bridge Technology
Dywidag-Systems International USA, Inc.
Wiss, Janney, Elstner Associates, Inc.
Freyssinet, Inc.
Corven Engineering, Inc.
Whitlock Dalrymple Poston & Associates, Inc.
Mepressa
Virginia Transportation Research Council
Sika Corporation
Parsons Brinckerhoff, Inc.
Target Products Ltd.
Figg Bridge Inspection
Federal Highway Administration
Bechtel National Inc.
J.L. Beicker Company
PTI Staff
PTI Staff

Associate Members Present

- Robert Bennett
- Chris Erb
- Liao Haixue
- Paul Kelley
- Ivan Lasa
- Kingsley Lau
- Sharath Murthy
- Eric Musselman
- Jacob Myer
- Nandish Pethani
- Mario Salice
- Bryan Smith
- Jeffrey West
- Zuming Xia

RS&H, Inc.
Omnipro Services, LLC
Vector Corrosion Technologies
Simpson Gumpertz & Heger
Florida DOT
Florida International University
Structural Technologies
Villanova University
Schwager Davis, Inc.
Nektor Engineers PT
Schwager Davis
US Mix Co.
University of Waterloo
VSL

Visitors Present
# ACTION ITEMS FROM LAST / THIS MEETING

<table>
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<tr>
<th>Item #</th>
<th>Subject</th>
<th>Action</th>
<th>Responsible</th>
<th>Deadline / Completed</th>
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<tr>
<td></td>
<td>ASTM C1090</td>
<td>TG (Merrill, Xia, Smith, Lau, Flouroy) to check limit requirements</td>
<td>TG</td>
<td></td>
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<tr>
<td></td>
<td>Grout repair</td>
<td>Draft guide or instruction on grout repair</td>
<td>Lau, Holt, Hunsicker</td>
<td></td>
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<tr>
<td></td>
<td>Grout repair</td>
<td>Provide information on grout material compatibility</td>
<td>Neff, Flouroy, Lau</td>
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<tr>
<td></td>
<td>Pressurizing</td>
<td>Draft a Commentary paragraph on pressurizing during grouting</td>
<td>Hunsicker, Lampe</td>
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<td></td>
<td>Ballot</td>
<td>Ballot document</td>
<td>Staff</td>
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<td>Older Action Items:</td>
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<tr>
<td>1.2</td>
<td>Checklists</td>
<td>Provide updated / new checklists</td>
<td>Cloutier</td>
<td>Asap</td>
</tr>
<tr>
<td>1.3</td>
<td>Suitability of SCC testing for grouts</td>
<td>Prepare a research proposal</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>1.4</td>
<td>Cement specification</td>
<td>Revisions to section 3.3.4 and a new section 4.4.10</td>
<td>Kelley</td>
<td>Received 4/28/15</td>
</tr>
<tr>
<td>1.8</td>
<td>Grout robustness</td>
<td>Specification language for robustness</td>
<td>Hamilton</td>
<td>Asap</td>
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<tr>
<td>1.9</td>
<td>Pressurizing / flushing</td>
<td>Provide specification language for pressurizing during grouting and flushing of tendons</td>
<td>Cloutier</td>
<td>Received 5/19/15</td>
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## Agenda Item

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<tr>
<td><strong>A. General</strong></td>
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<tr>
<td>A.1 Call to Order</td>
<td>A.1</td>
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<tr>
<td>A.2 Introductions</td>
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<td>A.3 Committee Roster Changes</td>
<td>A.3</td>
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<td>A.4 PTI Antitrust Policy (Exhibit A.4)</td>
<td>A.4</td>
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<tr>
<td><strong>B. Agenda &amp; Minutes</strong></td>
<td>B.1 Agenda changes:</td>
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<tr>
<td>B.1 Approval of Agenda</td>
<td></td>
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<tr>
<td>B.2 Approval of Minutes (Meeting ballot)</td>
<td>A minimum of 9 voting members is required for a meeting ballot.</td>
</tr>
<tr>
<td>B.2.1 Meeting Minutes from 4/26/15, distributed on 7/26/15</td>
<td>B.2.1 Vote on approval of Meeting Minutes from 4/26/15:</td>
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<tr>
<td></td>
<td>Motion / Second: Name / Name</td>
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<td></td>
<td>Result: 0-0-0 (Y-N-A)</td>
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<tr>
<td>B.2.2 Meeting Minutes from</td>
<td>B.2.1 Vote on approval of Meeting Minutes from 11/1/15:</td>
</tr>
<tr>
<td>Agenda Item</td>
<td>Expected Outcome / Actions Taken</td>
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<td>-------------------</td>
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<tr>
<td>11/1/15</td>
<td>Motion / Second: Name / Name Result: 0-0-0 (Y-N-A)</td>
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**C. Actions Taken Between Meetings**

C.1 Letter Ballots (none)

C.2 Web Meetings (none)

**P. Presentations**

**1. Action Item 1: Specification Update Items**

1.1 Revision Items
1.1.1 ASTM C1090 TG discussion (Exhibit 1.1.1) 1.1.1 ASTM C1090 discussion

1.1.2 Grout repair 1.1.2

1.1.3 Pressurizing / flushing (Exhibit 1.1.3) 1.1.3

1.1.4 Cement Specification 1.1.4

1.1.5 Grout robustness 1.1.5

1.1.6 Other items needing discussion before ballot 1.1.6

**D. New Business**

D.1 List Title D.1

D.2 List Title D.2

**E. Next Meeting**

E.1 ASBI Convention – Sunday, November 6, 2016 at the Westin Long Beach, CA, 8:00 am – 12:00 pm E.1

E.2 Web Meetings E.2
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<td>F. Adjourn</td>
<td>F.</td>
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### AGENDA / MINUTES EXHIBITS

<table>
<thead>
<tr>
<th>Exhibit #</th>
<th>Subject</th>
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<tr>
<td>A.4</td>
<td>PTI Anti-Trust Policy</td>
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<tr>
<td>1.1.1</td>
<td>ASTM C1090 discussion</td>
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<tr>
<td>1.1.3</td>
<td>Pressurizing / flushing</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.
Use of ASTM C1090 Test for Evaluation of Post-Tension Grout

The evaluation of post-tensioned grouts in accordance with PTI M55.1-12 includes testing for volume change, or dimensional stability, in accordance with ASTM C1090 Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout. The test is performed by placing freshly mixed flowing or plastic grout into a steel cylinder, covering with a glass plate within 4 minutes of batching, weighting and then clamping the glass plate in place for 24 hours, and making subsequent sample height readings over a period of 28 days. The criteria for volume change per Section 4.4.4 of PTI M55.1-12 are the following:

- “The vertical height change shall be 0.0% to less than +0.1% at 24 hours”.
- “The maximum change in height shall be no greater than +0.2% at 28 days”.

The commentary to Section 4.4.4 of PTI M55.1-12 states that “A value of 0.0% indicates that the grout cannot have settlement shrinkage within 24 hours based on this ASTM test method. This condition is very similar to a duct, where no positive post-hardening vertical height can occur in a duct. A limit of +0.2% at 28 days safeguards against potentially delayed expansion that can occur from some post-hardening ‘nonshrink’ grouts.”

The performance and acceptance criteria for non-shrink grouts can be traced back to Corps of Engineers CRD-C 621 Corps of Engineers Specification for Nonshrink Grout. The 1982 version of this document includes a description and schematic of the volume change test procedure which ultimately was adopted as ASTM C1090. The 1991 version of CRD-C 621 includes three categories for nonshrink grout: A (Prehardening Volume Controlled Type), B (Post Hardening Volume Controlled Type), and C (Combination Volume Controlled Type). These same three categories, with identical text and acceptance criteria, are included in the 1999 version of ASTM C1107 Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink). PTI is apparently attempting, for good reason, to apply the constraints for nonshrink grout Type B to products that in actuality perform as Type A or Type C. It should be noted that paragraph 1.4 of CRD-C 621-82A states “This specification does not cover . . . grouts for use in bonded posttensioned Prestressed concrete. . . .” Note that the current version of C1107 no longer references grouts by type.

Another ASTM test, C827 Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens of Cementitious Mixtures, is used to assess a grout’s relative ability to fill a cavity prior to hardening. Per PTI M55.1-12, “grout materials capable of producing early positive height changes are associated with reduced chloride ion penetration resistance and bond of the grout; therefore, these materials are discouraged for use in post-tension grout applications”. We assume this statement is based on the previous and outdated use of aluminum powder to produce expansion. There are other/better expansion mechanisms available today that may be appropriate.

While ASTM C1090 and C827 are performed using different sample geometries and test protocols, some aspects of both tests are meaningful in characterizing a grout’s performance in post tensioning applications. The test procedure for ASTM C1090 appears to be incomplete for its current use primarily due to the lack of available information obtained from the time the glass plate is installed at 4 minutes, to the time of glass plate removal at 24 hours. Any post-hardening expansion or shrinkage that occurs prior to 24 hours is thus undetected. Further, any expansion or shrinkage that occurs after 4 minutes time up until setting is also not directly measured. For a grout product to meet the current minimum 24 hour
requirement of 0.0% height change, either the material must remain completely volumetrically stable, or exert some positive expansive pressure resulting in net expansion following release of the glass retainer plate.

For the purposes of PTI evaluation of grouts, an improvement on the existing ASTM C1090 test procedure would be to delay placement of the glass plate until the grout has reached initial set. Note that measures would be needed to protect the specimens from moisture loss before placement of the glass plate. To assess the pre-hardening expansion or shrinkage, the C1090 test could be performed as is, but with removing the glass plate immediately after placement and making initial measurements. The difficulty here is measuring a still plastic/fluid grout with a micrometer. Readings could then be performed when the grout reaches initial set. Possibly the C1090 test could be performed without the glass plate altogether; however, care would need to be exercised to not penetrate the sample surface during making initial readings and measures are needed to prevent moisture loss. Acceptance criteria would need to be developed for these additional grout ages and conditions, but the allowable expansion prior to hardening should likely be less than the 4.0 percent limit using the C827 test procedure referenced within ASTM C1107.

A more appropriate test method for assessing volume stability, both early age and longterm, would be similar to that included in the ASCE Journal of Materials for Civil Engineering titled “Dimensional Stability of Grout-Type Materials Used as Connections between Prefabricated Concrete Elements.” The test is a modification of ASTM C1090 that generally includes using a laser for making initial measurements of the grout top surface pre-hardening. The top surface is open to the environment similar to the ASTM C827 test. Alternatively, a LDVT may be installed for these purposes. As before, additional acceptance criteria may be needed related to pre-hardening expansion.

Significance and Use of Test Methods

**Per ASTM 827:** 4.1 *This test method provides a means for comparing the relative shrinkage or expansion of cementitious mixtures. It is particularly applicable to grouting, patching, and form-filling operations where the objective is to completely fill a cavity or other defined space with a freshly mixed cementitious mixture that will continue to fill the same space at time of hardening. It would be appropriate to use this test method as a basis for prescribing mixtures having restricted or specified volume change before the mixture becomes hard.*

**Per ASTM C1090:** 4.1 *This test method is intended to provide a means of assessing the ability of a hydraulic-cement grout to retain a stable volume during the stipulated testing period of 28 days, provided that the tendency to change height does not include the effects of drying caused by evaporation, uptake of moisture, carbonation, or exposure to temperatures outside the range 23.0 ± 2.0 °C (73 ± 3 °F)*

Precision and Bias of Test Methods

**ASTM C827:** 13.1 Precision—*The single-operator standard deviation for sand/cement mixtures has been found to be 0.12 % (Note 8) change in height. Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 0.34 % change in height.*
13.2 The single-operator standard deviation for cement paste has been found to be 0.43 % (Note 8) change in height. Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 1.22 % change in height. NOTE 8—These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670. Data were from tests of specimens 4 in. in height.

13.3 Bias—This test method has no bias because the value of the change in height can only be defined in terms of a test method.

ASTM C1090: 12.1 Precision—Based on an analysis of results of cooperative tests of three materials tested at two consistencies, stored at two storage conditions, it was concluded that separate precision statements are needed for flowable and fluid mixtures.

12.1.1 Flowable Mixtures—The single-operator standard deviation has been found to be 0.07 % (Note 9). This does not vary with test age (up to 28 days) or with expansion (over the range from 0.02 to 0.43 %). Therefore, results from two properly conducted tests by the same operator on the same material should not differ by more than 0.196 % (Note 9).

12.1.1.1 The multilaboratory standard deviation has been found to be 0.08 % (Note 9). This does not vary with test age (up to 28 days) or with expansion (over the range from 0.02 to 0.43 %). Therefore, results of two properly conducted tests on the same material in two laboratories should not differ by more than 0.216 % (Note 9).

12.1.2 Fluid Mixtures—The single-operator standard deviation has been found to be 0.11 % (Note 9). This does not vary with test age (up to 28 days) or with expansion (over the range from 0.11 to 0.33 %). Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 0.3255 % (Note 9).

12.1.2.1 The multilaboratory standard deviation has been found to be 0.11 % (Note 9). This does not vary with test age (up to 28 days) or with expansion (up to 0.43 %). Therefore, results of two properly conducted tests on the same material in two laboratories should not differ by more than 0.30 % (Note 9).

NOTE 9—These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670.

12.2 Bias—No statement on bias is being made because there is no accepted reference material suitable for determining the bias in this test method.

Validity of Current PTI Expansion/Shrinkage Limits

ASTM C1090 - Are the spec limits of 0.0% to 0.1% at 24 hours and 0.0% to 0.2% at 28 days valid given the precision of the C1090 test procedure?

Assuming a normal distribution of net expansion/shrinkage values for ASTM C1090 testing for fluid consistencies - the multi & single operator variations are the same (0.11%). Assuming a “true” average expansion of + 0.10% (i.e. tested at 28 days), then the same criteria typically used for concrete compression testing per ASTM C39 would imply the following:

- Approximately 1% chance of failure would occur with a z-value (x-mean/σ) = 2.33. Therefore, a failing “shrinkage value” would be -0.156%, and a failing “expansion value” would be +0.356%.
-similarly, assuming a 1% of 3 consecutive failing results equates to an individual z-value of 1.34 (closer to 10% failure fractile). Based on this, a failing “shrinkage value” would be -.047%, and a failing “expansion value would be +0.247%.

Therefore, assuming the second criteria (z-value of 1.34) from above, if the lab performed the test multiple times on separate samples, then statistically speaking, a test sample could come in as low as -0.04% shrinkage 3 times in a row, and be indistinguishable from the true average result of +0.10%.

Based using the existing PTI criteria, the precision statement of the C1090 testing, and assuming a target 28-day net expansion of 0.10%, the portion of samples failing in shrinkage (<0.00%) would be approximately 19.1% and the portion of samples failing in excessive expansion (>0.20%) would also be 19.1%. So nearly 40% of samples that are statistically equal to the average of 0.10% could fail the test criteria as stated. The preferred ratio of commonly accepted failures would be about 1/2 to 1/4 of that value (this is where some debate comes in). The bottom line is that the PTI specification criteria are much too strict for the precision of the C1090 test method.

The only way this test can be useful is if you require many sequential tests, and apply a criteria to the average result of all of those tests. The second challenging aspect is how much shrinkage (if any) is allowable, and how much expansion is too much. You’d really have to shift the “true” average value that you are targeting a 28-day expansion up from +0.10% to say +0.15%. Then if you applied the ongoing average of 3 criteria as stated above, you could conclude that now only about 1% of 0.00% net expansion/shrinkage results would be statistically different from the true average of +0.15%. You’d have to be willing to live with net 28-day expansion of up to 0.30% then (average of 3 consecutive test results). If this is too much, then the test would be impractical.

The 24-hour criteria is even more challenging to make relevant. 0.00% to +0.10% is an extremely tight range. The upper end would likely have to go up to around +0.20% with the same parameters as listed above. Then a 24-hour result of -0.05% shrinkage may still meet the 0.00% at 28 days; however, both criteria would have to be enforced in concert.

ASTM C827 - If we used the C827 method, what would be good limits to propose?

The same situation applies for the C827 test procedure - if you assume the grout is a “cement/sand” mixture which was probably historically true, then the test precision values are similar (slightly wider) than that for C1090. If you use the “cement paste” mixture values, then the results are nearly 4 times as great.

Modified C1090 per ASCE Paper - What about the proposed test in the ASCE article? Note that it is primarily concerned with shrinkage.

The precision appears to be similar to the existing C1090 procedure. One notable exception to the relevance of the stated criteria is the fact that the modified test procedure allows some early age (unconfined) expansion of the grout, both prior to setting, and post-hardening but before 24 hours, which is not allowed (or detected) with the current C1090 test procedure. Therefore, when using the modified test procedure, the measured volume change of an ideally designed PT grout, when measured at 24 hours and 28 days, could very well be nearly identical. The acceptance criteria for 24 hours and 28
days should both be increased somewhat from what PTI currently allows. This would allow an enforceable, and potentially relevant, acceptance criteria with precision in mind (assuming an average of 3 tests).

A proposed set of acceptance criteria would be as follows:

- Net expansion (positive), when measured both at 24 hours and 28 days must be:

\[ x \geq 0.00\%, \quad x \leq 0.30\% \]

For reference, the following comparison of the fib, EN 447 and PTI expansion limits is presented:

Fib: -2% to 5%
EN447: -1% to 5%
PTI: 0.0% to 0.1%