1. Welcome of visitors and Introductions (Sanders)—Agenda attached

Voting members present: Neal Anderson, Mark Aschheim, Ozzie Bayrak, Robert Barnes, Zdeněk Bažant, D.J. Belarbi, Evan Bentz, Hakim Bouadi, Michael Collins, Walter Dilger, Marc Eberhard, Robert Frosch, Gary Greene, Neil Hawkins, Tom Hsu, Gary Klein, Dan Kuchma, John Ma, Adolfo Matamoros, Denis Mitchell, Carlos Ospina, Karl Reineck, David Sanders, Raj Valluvan, Jim Wight

Voting members not present: Adebar, R. Anderson, Brown, Darwin, French, Mo, Pantazopoulou, Polak, Ramirez

Informed Absence by Voting Members: Bonacci

Associate members present: Marvin Criswell, Neil Hammill, Paul Kourajian, Lawrence Novak, Ralph Oesterle, Sean Sullivan, Widianto

Visitors: Luis Fargier, Stephen Foster, Clinton Hoffman, Don Logan, Fabio Matta, Michael Murphy, Hani Nassif (TAC Contact), Daniel Reider, Carin Roberts-Wollmann, Ted Sherwood, Robin Tuchscherer

2. General Announcements (Sanders)

Chairman Sanders called the meeting to order. Attendees introduced themselves.

3. Review of Agenda (Sanders)

Agenda is attached.

4. Approval of Minutes of Fall 2007 ACI-ASCE 445 Meeting held in Puerto Rico (Sanders)

The minutes for the previous meeting were approved (Valluvan, Kuchma).

5. Ballot Items

a) Reapproval of Recent Approaches to Shear Design of Structural Concrete (ACI 445R-99) (Sanders)

The ACI 445R report was balloted for reapproval this year. The ballot passed with the following vote totals: 24 Affirmative, 3 Affirmative with Comment, 1 Abstain, and 7 Not Returned. Sanders thanked those who took the time to vote and admonished those that did not. Sanders reviewed the comments. Specific comments will be considered during the next attempt to update the document. Sanders will submit the ballot results to TAC for consideration.

b) Curved-Bar Node (Klein)

The purpose of this ballot was to get feedback on a proposal that Klein plans to submit to ACI 318. Therefore, the primary goal is not to achieve approval of the ballot in this committee. Nineteen affirmative ballots (8 with comments) were returned. There were 5 negative votes, with 3 abstentions and 8 ballots not returned. Klein thanked ACI 445 for their input, and stated that he would update the proposal to reflect the comments received (prior to submission to ACI 318). Klein plans to circulate a revised proposal along with a summary of his responses to the ballot comments. Klein noted the four main areas of comment and led a brief discussion of each:

- Definition of a curved bar node
• Language in Ch. 12 commentary
• Development and reliability of Equations A-7 and A-8
• Development of tie force difference through node

A brief discussion ensued regarding whether another ballot cycle is warranted prior to submission of the proposal to ACI 318. Most agreed that this was not necessary.

c) **Torsion Report** (Belarbi)
Sanders stated that he was pleased with the input from the committee. There were a total of 25 Affirmative votes (15 with comments), 2 Negatives, 1 Abstain, and 7 ballots were not returned. Belarbi has met with the negative voters. There have been substantial changes to deal with the comments of all voters. It is hoped that the document will go to TAC for approval before the Fall 2008 convention.

Belarbi reported that there were 517 comments (including those from two associate members). The comments were subdivided as follows: 38 PN, 101 P, 377 E, and 1 S. All PNs were addressed before the end of the subcommittee meeting on March 30, 2008. Seventy-eight P and E comments are yet to be addressed. Belarbi noted that the comments have greatly improved the document.

The subcommittee will attempt to address all remaining comments by May 15. French will then perform an editorial review by June 15. If another ballot is necessary, it will be sent to committee by July 1 with a due date of August 15. New comments would be addressed by September 30. The document should be submitted to TAC for review by October 1, 2008. Belarbi thanked the committee for their hard work on the document.

Kuchma asked how the need for a new ballot would be determined. Sanders noted that multiple ballots (each on specific portions of the document) may be requested.

6. **ACI 318-E Actions**

There was no report on ACI 318-E activities.

7. **Subcommittee Reports**

a) **445-A Strut and Tie** (Reineck)
Minutes of the subcommittee meeting are attached. Reineck reported that the subcommittee meeting was well attended. The main topic was the presentation of examples of design using strut-and-tie models (STM). There are presently ten to twelve examples. Some are still in the working stages. Reineck proposed that the subcommittee apply for a technical session at the Fall 2009 convention. This will provide enough time to develop an SP.

In the subcommittee meeting, Robin Tuchscherer presented research findings from the University of Texas about the inability to take advantage of increased bearing capacity at triaxially stressed nodes when using ACI 318 Appendix A design provisions.

Wight advised Reineck that now is the best time to submit proposals to ACI 318 subcommittees. Now is the time that the subcommittees are shaping their agendas for the next code cycle.

b) **445-B Seismic Shear** (Eberhard)
Eberhard was reappointed as subcommittee chair prior to the meeting. He reported the following subcommittee activities:

• Development of a report on evaluation of shear strength and deformation models for beam-columns,
• Support of the ACI 369 review of ASCE 41 document, and
Development of a database of structural wall test results.

The subcommittee plans to have presentations about the beam-column model evaluations at the next subcommittee meeting. They will then move toward preparing a report for ballot.

c) **445-C Slab Shear** (Ospina for Hawkins)

Minutes of the subcommittee meeting are attached. The meeting focused on the first of a series of punching shear databanks: *Punching Shear Test Databank 1: Concentric Punching of RC Slabs without Shear Reinforcement at Interior Columns*. Ospina presented a summary of progress on the “collected” and “selected” versions of this databank. A copy of his presentation slides is included with the subcommittee minutes.

A PDF archive of the papers from which the databank values were collected is ready to be posted on the committee website.

The subcommittee is working on two approaches to the databank. The first is an ACI 445- endorsed “selected databank” that remains after employing strict data-elimination criteria (DEC). The second is a “collected databank”, which includes all of the collected test results in a spreadsheet form that is flexible enough to allow for user-defined DEC.

The following data elimination criteria (DEC) have been agreed upon by the subcommittee:

- Minimum slab thickness of 100 mm
- $f'_{c}$ of at least 15 MPa
- $a/d$ of at least 3
- $\rho$ not exceeding 4 percent
- slab reinforcement consists of deformed reinforcing bars
- slab reinforcement adequately anchored (checking is still in progress)
- no flexural or bond failures (checking is still in progress)

Ospina then described the planned upcoming work related to the databank(s). The collected databank should be ready for release in the summer of 2008. The committee needs to establish a protocol for downloading the databank. An “optimistic” release date for the selected databank (after application of DEC) is fall 2008. An internal review/endorsement process needs to be established before the databanks are released. The databank task group plans to submit paper to the *ACI Structural Journal* describing the databanks and their development. They will next begin a databank on punching of prestressed slabs.

Sanders invited comments/questions regarding the work of the subcommittee on this databank. Kuchma asked about defining the internal review/endorsement process: is there a history on how this has been handled? Sanders stated that he thought the committee would be asked to vote to sanction the data elimination criteria (DEC).

Kuchma asked who is responsible for checking individual databank values? Ospina responded that all values have been double- or triple-checked thus far.

Wight suggested that the full committee needs to endorse the release of the database. Then everyone would have a period of time to review the database prior to a vote to approve the database. Sanders noted that this is similar to the document review process.

Mitchell asked if the eliminated data would be available. Mitchell and Eberhard each noted that various people like to evaluate the data in a variety of ways: why limit their options? Ospina clarified that both the collected and selected databanks would be accessible.

Sanders noted that it would be good if the various database collectors in the full committee would work together to establish common methods of dealing with certain issues (such as cube strength versus cylinder strength).
Sanders suggested that the subcommittee write a document about the compilation of the databank and the related decisions that were made. This document can be evaluated by the committee.

Frosch recommended that the databank be left as a sortable entity, and that the committee focus on making recommendations about how to filter or sort the material for specific types of evaluations.

d) **445-D Beam Database** (Reineck)
   This is a new subcommittee with the purpose of compiling a database that can be used for evaluating code proposals on beam shear.

   Reineck noted that the long-term goal is to merge this database with related databases that have been compiled. The subcommittee needs to check the sorting criteria. Some controversial issues have been identified that still need to be discussed. The subcommittee will develop a mission statement.

e) **445-E Torsion** (Belarbi)
   Belarbi reported that the subcommittee meeting was focused on modifying the state-of-the-art torsion report to address the negative votes and comments generated by the recently completed ballot. More information on this topic is reported under Ballot Items above.

   Belarbi reported that a technical session has been requested in St. Louis (Fall 2008) to include presentations related to the development of the torsion report. Six or seven speakers are expected.

   Belarbi also noted that the subcommittee’s bibliography of references (including abstracts) on torsion has been updated by a variety of committee members over time. Sanders will discuss distribution options with TAC.

   Belarbi stated that the subcommittee will reevaluate its mission after completion of the torsion report.

f) **445-F Beam Database** (Sanders)
   This subcommittee (formerly devoted to beam shear) is now effectively a placeholder because of the establishment of the new Subcommittee D. Sanders suggested that Subcommittee F be devoted to revising the ACI 318R-99 report (see Ballot Items above).

g) **Ad hoc committee on prestressed concrete shear issues** (Matamoros)
   Matamoros reported that the group had a meeting and discussed some possible provisions for increasing the strength of end regions in pretensioned members. This meeting specifically focused on an apparent need to limit the contribution of vertical reinforcement that can be assumed when designing to resist shear in these end regions. The subcommittee’s task is made difficult by a paucity of relevant test data.

   The committee reviewed some example calculations for inverted-T design performed by Kourajian using the current working proposal. The method would require a significant amount of additional bonded horizontal reinforcement in the end regions of these members. The group also plans to look at the ramifications of current AASHTO provisions on this topic.

   Matamoros asked ACI 445 for contribution of any relevant test data, especially for members with a short distance from the end of the member to the face of the support.

   The second part of ad hoc committee meeting was devoted to hollow-core slab test results. Results from an ongoing study at the University of Minnesota were reviewed. The ad hoc committee looks forward to the publication of these results and related conclusions.

   Matamoros noted that there are many hollow-core test results from a study completed in Denmark, but more information is needed about the support conditions in these tests—
particularly regarding the length of strand embedment relative to the supports. Matamoros asked ACI 445 for any photographs or other information that may be known about these tests.

Sanders asked what the next move would be if the group reached a proposal with which they were comfortable. Matamoros responded that this is really a decision for the chairs of ACI 445 and ACI 423 (Prestressed Concrete). Sanders suggested that they submit such a proposal to both committees simultaneously. The ballot results can be evaluated to determine whether the proposal is ready for submission to ACI 318.

Hawkins mentioned some inverted-T tests that he and Sharon Wood performed. The results are not published. He will provide them to Matamoros.

8. **Future Directions and Code Reorganization** (Sanders)

Sanders reported that the ACI 318 Code released in 2011 will incorporate only minor changes relative to the new ACI 318-08. However, a major reorganization of the ACI 318 Code is planned for 2014. This is a good time to provide input for that process.

9. **Technical Sessions**

Spring 2008 (Los Angeles), 9:00–12:00, April 1, 2008, *Size Effect in Shear*, moderated by D. Kuchma (see list of presentations on attached agenda)

Structures Congress, April 24–26, 2008 (Vancouver), *Recent Advances in Shear Design for Reinforced Concrete*, moderated by Adam Lubell (see list of presentations on attached agenda)

Fall 2008 (St. Louis), November 2–6, 2008, State-of-the-art report on torsion

Fall 2009 (New Orleans), Examples for design with strut-and-tie models

Structures Congress, 2009 (Austin)

Proposals for technical sessions at future ACI conventions are welcome. Future convention dates/locations:

- Spring 2009 (San Antonio), March 15–19
- Fall 2009 (New Orleans), November 8–12
- Spring 2010 (Chicago), March 21–25
- Fall 2010 (Pittsburgh), October 24–28
- Spring 2011 (Tampa), April 3–7

10. **Technical Presentations**

Gary Klein gave a brief presentation: “Slender Spandrel Beams Revisited: Design for Shear and Torsion”. The focus was on observations resulting from an in-progress, PCI-sponsored research study on spandrel beams. One goal of the research is to investigate the need for closed ties for torsion resistance. Closed ties present significant fabrication difficulties for pretensioned spandrel beams. He noted that the presented ideas were preliminary, and he invited input from the group prior to implementation of the results by PCI.

Slender spandrel beams, such as those primarily used in parking garages to support double-T beams, tend to act more like plates in torsion—rather than the “compact” sections that more closely conform to the tube analogy currently incorporated in ACI 318 torsion design provisions. By decomposing the spandrel torsion into plate-bending (skew) and twisting components acting on a plane inclined at 45
degrees to the member cross section, the orthogonal, in-plane reinforcement can be proportioned to provide adequate strength without the need for out-of-plane reinforcement.

11. Leadership Change (Sanders)

Sanders will become chair of the Technical Activities Committee (TAC) at the end of the Spring 2008 convention. Therefore, he is stepping down as chair of ACI-ASCE 445; Dan Kuchma will serve as the new committee chair. Sanders thanked committee and subcommittee officers as well as all the members for their hard and productive work during his term as chair.

12. Adjournment

Meeting adjourned at 5:04 p.m.

Minutes submitted by Robert Barnes on October 27, 2008.
AGENDA –Spring 2008 MEETING
ACI 445 – SHEAR AND TORSION
LOS ANGELES, CALIFORNIA
March 30 to April 3, 2008

Meetings
445 Shear & Torsion Main Committee, Monday, 31st, 2p-6p, Encino
445-A-Strut & Tie, Sunday, 30th, 10:30a-1:30p, Penthouse 1923
445-B-Seismic Shear, Sun 8a-11a, Century Suite 602
445-C -Punching Shear, Sunday, 30th, 1p-3p, Penthouse 1915
445-D-Database, Monday, 31st,10a-12p, Century Suite
445-E-Torsion, Sunday, 30th, 3p-5p, Penthouse 1923

423-445 Adhoc Grp on Shear in Prestress Conc, Sunday, 3p-5p, Penthouse 1915

318-E Shear & Torsion, Wednesday, 8:30a-1p, Governors 1

1. Introductions (Sanders)

2. Approval of the Minutes –Fall 2008 ACI 445 Meeting held in Puerto Rico (Sanders) (Posted on 445 Website)

3. Ballots
a) Torsion – Issued 1/11, Due 2/26
b) Curved-Bar Node – Issued 1/14, Due 3/11
c) Re-approval of Recent Approaches to Shear Design of Structural Concrete – Issued 2/27, Due 3/28

4. ACI 318-E Actions (Ramirez - Wood)

5. Subcommittee reports
   445-A Strut and Tie (Reineck)
   445-B Seismic Shear (Sanders)
   445-C Slab Shear (Hawkins)
   445-D Beam Database (Reineck)
   445-E Torsion (Belarbi)
   445-F Beam Shear (Sanders)

   Ad hoc committee on prestressed concrete shear issues (Matamoros)

6. Future Directions and Code Reorganization (Sanders)

7. Technical Sessions

Size Effect (Los Angeles), D. Kuchma
1) Experimental Evidence: Size effect in Members with and without Shear Reinforcement (Evan Bentz, Associate Professor)
2) Explanation 1: Size Effect due to Reduction in Interface Shear Transfer Resistance (Michael P. Collins, University Professor and Bahen-Tanenbaum Professor)
3) Explanation 2: Size Effect Predicted by Fracture Mechanics (Zdenek Bazant, McCormick School Professor and Walter P. Murphy Professor)
4) Other Explanations for the Size Effect in Shear (Karl-Heinz Reineck, Professor)
5) How National Codes Account for the Size Effect in Shear (Daniel Kuchma, Assistant Professor)
6) Accounting for the Size Effect in ACI318 (Julio Ramirez, Professor)
7) Open Time for Discussion

Structures Congress, April 24-26, 2008 (Vancouver), Adam Lubell
Session: Bridge & Transportation Structures -- Recent Advances in Shear Design for Reinforced Concrete
1) Effect of Flexural Ductility on Shear Capacity, Rachel Howser, A. Laskar, Y.L. Mo (Presenter)
2) One-Way Shear in Wide Concrete Beams with Narrow Supports, Adam Lubell (Presenter) Evan Bentz, Michael Collins
3) Recent Changes to Concrete Shear Strength Provisions for AASHTO-LRFD Bridge Design Specification, Neil Hawkins (Presenter), Daniel Kuchma
4) Size and Scale Effects on the Shear Strength of Concrete Beams, Lesley Sneed (Presenter), Julio Ramirez

Design Examples for STM (St. Louis), K. Reineck Torsion (St. Louis), DJ Belarbi
Spring 2009 (San Antonio), Fall 2009 (New Orleans), Spring 2010 (Chicago), Fall 2010 (Pittsburgh), Spring 2011 (Tampa)

8. Other Business

9. Presentations
Possible design approaches for shear and torsion in slender spandrel beams, Sami Rizkalla and Gary Klein

Technical Presentations (10 Minutes) - Please let me know if you are interested

Please note that subcommittee meetings are scheduled prior to the 445 main committee meeting. All members are welcome and encouraged to attend.
Minutes of the meeting in Los Angeles, CA of ACI 445-A: Strut-and-tie models

Sunday 30 March 2008, 10.30 - 13.30 h

Attendants: 13 members; 7 guests

Members: Karl -H. Reineck (Ch.), Bob Anderson, Robbie Barnes, Ozzy Bayrak, Attila Beres, Hakim Bouadi, Sergio Brena, Gary Klein, Dan Kuchma, Larry Novak, Guillermo Santana, Sean Sullivan, Fernando Yánez

Visitors: Dan Gruman, Nasim Moghaddasi, Larbi Sennour, Miriam Toledo, Robin Tuchscherer, Koray Tureyen, Jigin Yuan

Agenda

1 Approval of agenda: the approval was given after welcomes and introductions.

2 Approval of minutes of the meeting in Puerto Rico: the approval was given.

3 Further examples for the use of strut-and-tie models

3.1 Presentation of examples
Reineck presented the current list of examples proposed for the upcoming Special Publication. (See the end of this document for a summary of that list.)

Specific discussion regarding each example as follows:

1 Diaphragm for Segmental Box Girder, Bob Anderson
   • Anderson said that he was working on the further development of this example. He mentioned that he was finding different interpretations of where to locate the application of shear forces to the web. Reineck said he would review the example and offer advice.

2 Diaphragm for Extradosed Cable Stayed Bridge, Bob Anderson
   • Anderson presented example. Reineck believed application of loads should be at the bottom of the diaphragm and 100% should be lifted up.

3 End-regions of Pretensioned Members, Dan Kuchma
   • No discussion.

4 Propped Cantilever, Dan Kuchma
   • Kuchma presented Strut-and-Tie model studies that were both externally and internally indeterminate. Based upon the work thus far, Kuchma stated that he felt designing for first yield was too conservative. He felt picking the plastic capacity was more realistic.
• It was suggested:
  o Sensitivity analysis could be done.
  o Provide better description of design process.
  o Study the fixity condition at the right support better.
  o Potentially break the example into Parts 1, 2 and 3 to avoid mixing topic.

5 Link beam - Coupling beam, Asif Wahidi, Hakim Bouadi
  • Bouadi stated that example had not been progressed very far.

6 Hammerhead bent cap / Hammerhead Pier, Michael Brown, Oguzhan Bayrak
  • No discussion.

7 Continuous Bent Cap, Michael Brown, Oguzhan Bayrak
  • No discussion.

8 Grade Beam, Bob Anderson
  • Reineck stated that there was some conservatism in the model by not giving a percentage of the load to the indirect load path.

9 Art Institute Shear Wall Gary Klein
  • It was felt that this is still a good example. … needs more work.

10 Dapped-end T-beam with Curved Bar Node Gary Klein
  • Overall progress has been made with this example as it was recently presented as a code change.

11 Stepped Slender Beam Adam Lubell
  • Example was presented by Karl.

12 Transfer Girder Design Wall Adam Lubell
  • Example was presented by Karl.

13 Pile Cap with Tension Piles Ozughan Bayrak
  • It was felt that this is still a good example. … needs more work.

14 Hanging Roof of Airport Hakim Bouadi
  • It was felt that this is still a good example. … needs more work.

15 Bridge Strengthening with External PT Katrin Habel
  • No discussion.

16 Case Studies of Improper Reinforcement Details Denis Mitchel
  • Added after the meeting.
3.2 Session + SP

- Reineck: Upcoming milestones
  - Final drafts (More or less done) all examples Fall, 2008.
  - Internal review of currently (more or less done) examples by Fall, 2008.
  - SP published by Fall, 2009 (New Orleans convention)

- Novak volunteered to be co-editor of the Strut-and-Tie example document.

- Reineck: All Strut-and-Tie examples should be presented in dual units.

- Reineck: The notation “compression strut” and “tension tie” is superfluous. Just use “strut” and “tie”.

- Novak: Reference should be made to 2008 ACI in examples.

- Reineck: The Special Publication should include discussion of phi for Strut and Tie analysis versus phi for normal B-Region design. Klein agreed that this topic should be on the table. Kuchma also mentioned that Vc term is neglected in Strut-and-Tie analysis.

- Current Status of examples
  - More or less done: 5
  - Pending: 7
  - Dropped: ?

3.3 Other Topics

  No discussion.

4 Changes and amendments to Appendix A of ACI 318-02 – State of Work

4.1 Maximum limits for shear in App. A may exceed that defined in Ch. 11

  No discussion.

4.2 STM for point load near support; hanging-up reinforcement

  No discussion.

4.3 Triaxially stressed CCC-node and bearing stress acc. to ACI 318, 10.17

  No discussion.
5 Database for deep beams
Bayrak suggested that this topic go the newly formed “D-Group”. Reineck and Kuchma agreed.

6 Strut-and-tie models for earthquake design

6.1 State of Work
No discussion.

6.1 Future Work
No discussion.

7 Membership No discussion

8 Next meeting No discussion

9 Research Presentations
Tuchscherer presented new research from the University of Texas studying the compression strength of bearing regions.

10 Other items None
**ACI 445-A: Further examples for the design with strut-and-tie models**

**List of contents**

<table>
<thead>
<tr>
<th>#</th>
<th>Title; contents</th>
<th>Author(s)</th>
<th>Status</th>
<th>Reviewer (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Diaphragm for Segmental Box Girder</td>
<td>Bob Anderson</td>
<td>Draft Okt 04</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Diaphragm for Extradosed Cable Stayed Bridge - real world application of the &quot;indirect support&quot; problem.</td>
<td>Bob Anderson</td>
<td>final paper 30.03.2008</td>
<td>Lawrence Novak Evan Bentz</td>
</tr>
<tr>
<td>3</td>
<td>End-Regions of Pretensioned Members</td>
<td>Dan Kuchma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Propped Cantilever</td>
<td>Dan Kuchma</td>
<td>final paper 30.03.2008</td>
<td>KHR Attila</td>
</tr>
<tr>
<td>5</td>
<td>Hospital: Link beam</td>
<td>Asif Wahidi</td>
<td>Apr 07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) coupling beam (normal case)</td>
<td>Hakim Bouadi</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Upper shear limit of ch. 11 exceeded</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Hammerhead Bent Cap / Hammerhead Pier</td>
<td>Michael Brown</td>
<td>final paper Oct. 2007</td>
<td>Bob Anderson</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oguzhan Bayrak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Continuous Cap</td>
<td>Michael Brown</td>
<td>final paper Oct. 2007</td>
<td>Sergio Brena</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oguzhan Bayrak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Cantilever Grade Beam</td>
<td>Bob Anderson</td>
<td>final paper 30.03.2008</td>
<td>Dan Kuchma</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Art Institute Shear Wall</td>
<td>Gary Klein</td>
<td>draft 1 Apr 07</td>
<td>Evan Bentz</td>
</tr>
</tbody>
</table>
### ACI 445-A: Further examples for the design with strut-and-tie models

#### List of contents

<table>
<thead>
<tr>
<th>#</th>
<th>Title; contents</th>
<th>Author(s)</th>
<th>Status</th>
<th>Reviewer (s) (from 445-A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Dapped-end T-beam with curved bar node</td>
<td>Gary Klein</td>
<td>April 2007</td>
<td>Yanez</td>
</tr>
<tr>
<td>11</td>
<td>Stepped slender beam draft 1 (deferred: if time?) Cazaly Hanger ????</td>
<td>Adam Lubell</td>
<td>draft 1 Apr 07</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Transfer Girder Design</td>
<td>Adam Lubell</td>
<td>draft 1 Apr 07</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Pile Cap with Tension Piles</td>
<td>Ozughan Bayrak</td>
<td>Task sheet Apr 07</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Hanging Roof of Airport: Shear Wall with Anchorage of Cables</td>
<td>Hakim Bouadi</td>
<td>Task sheet Apr 07</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Bridge Strengthening with External Post-Tensioning</td>
<td>Katrin Habel Adam Lubell</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Case Studies of Improper Reinforcement Details</td>
<td>Denis Mitchell</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Present:

MINUTES

1. At the request of Chair Hawkins (absent), the subcommittee meeting was chaired by Carlos E. Ospina.
2. The agenda consisted of a single item: Presentation of progress report on Punching Shear Databank by Ospina on behalf of the punching shear databank Task Group (Ospina, Birkle, Widianto, Smith).

Presentation on Punching Shear Test Databank Progress Work

Ospina presented progress work on the punching shear test result databank examining concentric punching shear tests of slabs without shear reinforcement at interior column locations, including the development of a PDF paper archive for free public access through the internet. A copy of the slide show is attached to these minutes.

Ospina reported the PDF archive is ready to be posted in the Committee webpage. PDF file downloading protocol to be defined. A list of unavailable references will be sent to committee members to attempt getting copies of this work.

The presentation touched base on the status of the “Collected” databank, the development of Data Elimination Criteria (DEC) for the “Selected” databank, and the drafting of the databank user’s guide. The DECs are intended to eliminate doubtful test results. Ospina noted that the spreadsheet programming will be made flexible enough so that the databank user is able to select his/her own DECs. Nevertheless, the official “Selected” databank will be based on a list of DECs recommended by the main ACI 445 committee. A list of DECs was put on the table for discussion (see slide show for details). The DECs were agreed upon by sub-committee members.

Next Meeting
Next ACI 445C meeting to be held in St. Louis, Missouri, on Sunday, Nov. 2, 2008.

Adjournment
Meeting was adjourned at 2:45 pm.

Minutes submitted by C.E. Ospina to main ACI 445 on Sept. 25, 2008.
Overview

- Punching Shear Databank Recap
- PDF Paper Archive
- Punching Shear Test Databank No. 1
  - Collected Data
  - Databank User's Guide Overview
  - Histograms
  - Data Sorting and Data Elimination Criteria
- Timetables

Punching Shear Databank Recap

- Directions given in Atlanta to proceed with "collected" and "selected" test result databanks. Selected databank necessary to establish "undisputed" test data.
- Directions given in Puerto Rico (445C) on Data Elimination Criteria (DEC).
- Collected databank ready. Copyright issues sorted out except DAfS.
- PDF archive ready. Copyright issues sorted out except DAfS.

Collected Databank

- 532 tests of isolated slabs added to date.
  - Still Wanted references:
    - Kinnunen, Nylander & Tolf (1983) (KTH)
    - Nylander & Sundquist (1972) (KTH)
    - Schaidt, Ladner & Rossli (1970) (EMPA)
    - Hahn & Chefdeville (1951) (France)
    - Graf (1933) (DAfS)

Collected Databank

- Mostly tests of isolated slab specimens with orthogonal reinforcement. Wide variety of loading set-ups.
- Slabs with restrained edges:
  - Low in-plane restraint: OK
  - High in-plane restraint: Tossed
- No tests on footings added yet.
- Multispan slab system tests not considered.
**Reference Overview**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Year</th>
<th>Tests</th>
<th>Variables</th>
<th>Comments</th>
</tr>
</thead>
</table>

**Data and Notation**

- **Test Set-up**
- **Specimen Geometry:**
  - Slab Shape
  - Slab Restraints
  - Shape of Support/Loading Array
  - Shape of column/loaded area
- **Material Properties**
  - Concrete
  - Reinforcement
- **Mode of Failure reported by researcher**

**Data and Notation: Test Set-up**

- SS-CL: Slab Supported on all edges, Column Loaded
- SSC-CL: Slab on Supports in Circular Pattern, Column Loaded
- SSO-CL: Slab Supported on Opposite Sides, Column Loaded
- CS-CL-SR: Column Supported, Column Loaded, Slab Reacted Against
- CS-CL-SL: Column Supported, Column Loaded, Slab Loaded
- CS-SL: Column Supported, Slab Loaded
- CS-SLO: Column Supported, Slab Loaded on Opposite Sides

**Data and Notation**

- **Slab Concrete Compressive Strength**
  - CY: Cylinder
  - CU: Cube
  - Cylinder or cube size also reported
  - e.g. CU120, CY150x300
  - Strength reported either at testing time or at 28 days
  - Additional ancillary test results included, if reported
  - Observation added to note absence of specimen size/testing time data
Data and Notation

- Slab reinforcement anchorage conditions
  - S: Straight bars
  - H: Hooked bars
  - SP: Bars with Steel Plates at ends
  - NR: Not reported
- Bar diameter and bar area
- Effective depth in x and y directions ($d_x$, $d_y$)
- Slab reinforcement spacing
  - U: Uniform
  - N: Non-uniform (defined as string array, see dwg)
    - $S_x$: Reinforcement spacing along x direction
    - $S_y$: Reinforcement spacing along y direction
- Reinforcement ratio only if reported by researcher

Data and Notation

- Mode of failure, as observed by researcher
  - P: Punching Failure
  - F: Flexural Failure
  - FP: Flexural Punching
  - DP: Ductile Punching
  - B: Bond Failure

Observations

Data Evaluation Histograms

Slab Edge Restraint

Concrete Compressive Strength

Slab Thickness
Preliminary (Unofficial) Overview of Test Result Trends using Collected Data

Evaluation in light of ACI 318 Punching Shear Design Rules
Two-stage process:
- Post-processing of collected data
- Data selection based on Data Elimination Criteria (DEC)

DEC: Two Avenues
- ACI 445-Endorsed Selected Databank
  - Strict DEC
- Spreadsheet flexible enough to allow user to select the collected data he/she needs
  - Flexible DEC (up to the user)

### Data Post-processing
- Slab concrete compressive strength:
  - Take 150x300 cylinder strength as reference value.

<table>
<thead>
<tr>
<th>Reference Specimen</th>
<th>Specimen Shape</th>
<th>Size (mm x mm)</th>
<th>Uncertainty Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinders</td>
<td>150 x 300</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 x 200</td>
<td>0.97</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 x 300</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>120 x 300</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>120 x 120</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td>130 x 130</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>200 x 200</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Cubes</td>
<td>120 x 360</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 x 100</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td></td>
<td>120 x 120</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td>150 x 150</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td></td>
<td>150 x 300</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 x 100 x 500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>120 x 120 x 240</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>200 x 200 x 540</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Data Post-processing
- Slab concrete compressive strength at testing time:
  - Weber:
    \[ f_{\text{t}}(t) = f_{\text{c}}(t) e^{\left(\frac{1.40}{1.40} - \frac{1.40}{t}\right)} \]
  - CEB/FIB MC90:
    \[ f_{\text{t}}(t) = \beta_{\text{c}}(t) f_{\text{c}} \]
    \[ \beta_{\text{c}}(t) = e^{t \left(1 - \frac{28}{t}\right)} \]

### Data Post-processing
- Slab reinforcement ratio:
  \[ \rho_{x,y} = \frac{A_{\text{m}}}{s_{x,y} d_{x,y}} \]
  \[ \rho_{\text{ave}} = \frac{\rho_{x} + \rho_{y}}{2} \]

- Different formulations being examined
- For non-uniform slab reinforcement spacing, evaluate \( \rho \) within 3d from each column face

### Data Post-processing
- Slab Failure Mode (fib Bull 12):
  - Pure flexural failure: \( \frac{V_{\text{a,not}}}{V_{\text{a,flex}}} > 1.15 \)
  - Punching failure:
    \[ \frac{V_{\text{a,not}}}{V_{\text{a,flex}}} < 1.15 \]
    \[ 0.95 < \frac{V_{\text{a,not}}}{V_{\text{a,flex}}} < 1.15 \] (flexural punching)
    \[ \frac{V_{\text{a,not}}}{V_{\text{a,flex}}} < 0.95 \] (brittle punching)
### Data Post-processing

- Yield line capacities (adapted from CEB/FIP Bull. 168):

  ![Yield line capacities diagram](image)

### Data Elimination Criteria (ACI 445C)

- Minimum slab thickness = 100 mm
- $f_c' > 15$ MPa
- $a/d > 3$
- $\rho_{\max} = 4\%$
- Slab reinforcement anchorage check (in progress)
  - Check development length beyond column face
  - Examine concrete splitting effect on bond
- Discard slabs with flexural and bond failures (in progress)
- Discard slabs with smooth (undeformed) reinforcing bars

### Data Elimination Criteria

<table>
<thead>
<tr>
<th>Type</th>
<th>f'c [MPa]</th>
<th>Rebar ( a/d )</th>
<th>c/d</th>
<th>h [mm]</th>
<th>( \rho ) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>20</td>
<td>3</td>
<td>0</td>
<td>100</td>
<td>0.003</td>
</tr>
<tr>
<td>max</td>
<td>40</td>
<td>8</td>
<td>2</td>
<td>400</td>
<td>0.050</td>
</tr>
</tbody>
</table>

### Data Selection Criteria

<table>
<thead>
<tr>
<th>Type</th>
<th>f'c [MPa]</th>
<th>Rebar ( a/d )</th>
<th>c/d</th>
<th>h [mm]</th>
<th>( \rho ) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>20</td>
<td>3</td>
<td>0</td>
<td>100</td>
<td>0.003</td>
</tr>
<tr>
<td>max</td>
<td>40</td>
<td>8</td>
<td>2</td>
<td>400</td>
<td>0.050</td>
</tr>
</tbody>
</table>

### Results

<table>
<thead>
<tr>
<th>f'c [MPa]</th>
<th>Rebar ( a/d )</th>
<th>c/d</th>
<th>h [mm]</th>
<th>( \rho ) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>20</td>
<td>3</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>max</td>
<td>40</td>
<td>8</td>
<td>2</td>
<td>400</td>
</tr>
</tbody>
</table>

- **Number of Specimens**
  - ALL: 100
  - Selected: 50

### Concrete Strength (MPa) vs. Number of Specimens

- **Reinforcement Ratio [%]**
  - Below 10: 0
  - 10 to 15: 20
  - 15 to 20: 40
  - 20 to 25: 60
  - 25 to 30: 80
  - 30 to 35: 100
  - 35 to 40: ALL
  - Above 40: Selected
Results

<table>
<thead>
<tr>
<th>Type</th>
<th>$f'$ [MPa]</th>
<th>$c/d$</th>
<th>$h$ [mm]</th>
<th>$\rho$ [-]</th>
<th>$d$ [mm]</th>
<th>$f'$ [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>min</td>
<td>20</td>
<td>0.5</td>
<td>0.3</td>
<td>100</td>
<td>0.003</td>
<td>F</td>
</tr>
<tr>
<td>max</td>
<td>40</td>
<td>0.8</td>
<td>2</td>
<td>400</td>
<td>0.050</td>
<td>B</td>
</tr>
</tbody>
</table>

Data Selection Criteria

Timetable

- PDF Paper archive ready. Databank post-processing progress so advanced it is OK to release the PDFs any time.
- Define internal review/endorsement process by ACI 445 before databanks are released
- Collected databank release (tentative): Summer 2008
- Selected databank release (tentative): Fall 2008
- TG to submit paper to ACI Str Journal, Late 2008
- Work to begin on Prestressed Concrete Slabs Databank