FALL 2007 MEETING
ACI 408 - BOND AND DEVELOPMENT OF REINFORCEMENT
Sunday, October 14th, 2007
8:00-11:00 a.m.
Salon 2 Room
El Conquistador Resort and Spa, Fajardo, Puerto Rico

In Attendance:
Adolfo Matamores (Chair)  David Johnson
M. Keith Thompson (Secretary)  Guillermo Riveros
JoAnn Browning  Scott Graham
David Darwin  Robert Frosch
Tess Ahlborn  Carl Peterson
Robert Barnes  Jean-Jacques Braun
Neil Hawkins  Lou Colarusso
James Cox  John Silva
Thomas Kang  LeRoy Lutz
Kenneth Luttrell

Excused:
James M. LaFave  Anthony Felder
Ted Mize  Leroy Caldwell
William Zehrt  Steve Holdsworth
A. Koray Tureyen  Conrad Paulson
Rolf Eligehausen

Visiting:
Oan Chul Choi  Professor of Architectural Engineering
Soongsil University
Seoul, Korea
occhoi@ssu.ac.kr

Kyong Min Choi  Soongsil University
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Marusang1@empal.com

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Bohwan Oh  Daewoo E&C
South Korea
82-19-441-9975
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1. Welcome

2. Introductions

3. Approval of minutes from Spring 2007 meeting in Atlanta, GA

Moved: K. Thompson
Seconded: R. Frosch
Approved by the committee.

4. Membership Changes

The table below summarizes membership changes:

<table>
<thead>
<tr>
<th>Name</th>
<th>Level</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christian Dahl</td>
<td>Voting</td>
<td>Headed Reinforcement Corp.</td>
</tr>
<tr>
<td>Jean-Jacques Braun</td>
<td>Voting</td>
<td>Dextra Manufacturing</td>
</tr>
<tr>
<td>William H. Zehrt, Jr.</td>
<td>Voting</td>
<td>Dept. of Defense</td>
</tr>
<tr>
<td>Louis J. Colarusso</td>
<td>Voting</td>
<td>Erico, Inc.</td>
</tr>
<tr>
<td>Scott K. Graham</td>
<td>Voting</td>
<td>Wiss, Janney, Elstner</td>
</tr>
<tr>
<td>James L. Caldwell</td>
<td>Voting</td>
<td>Dayton Superior</td>
</tr>
<tr>
<td>Alvin C. Ericson</td>
<td>Voting</td>
<td>Consultant</td>
</tr>
<tr>
<td>Steven E. Holdsworth</td>
<td>Voting</td>
<td>Barpslice Products</td>
</tr>
<tr>
<td>James Bret Turley</td>
<td>Associate</td>
<td>Simpson Strong Tie</td>
</tr>
<tr>
<td>Bruce Ireland</td>
<td>Associate</td>
<td>Danley Construction</td>
</tr>
<tr>
<td>Theodore A. Mize</td>
<td>Associate</td>
<td>Ivy Steel &amp; Wire</td>
</tr>
<tr>
<td>Ken W. Williamson</td>
<td>Associate</td>
<td>Nucor</td>
</tr>
<tr>
<td>Domingo J. Carreira</td>
<td>Associate</td>
<td>Consulting Engineer</td>
</tr>
<tr>
<td>Kent A. Harries</td>
<td>Associate</td>
<td>Univ. of Pittsburgh</td>
</tr>
<tr>
<td>Melvyn Precious</td>
<td>Consulting</td>
<td>Preshcon Industries</td>
</tr>
<tr>
<td>Allen Hulshizer</td>
<td>Consulting</td>
<td>Consultant</td>
</tr>
<tr>
<td>Brian Gerber</td>
<td>Consulting</td>
<td>ICC-ES</td>
</tr>
<tr>
<td>Kenneth A. Luttrell</td>
<td>Consulting</td>
<td>CYS Structural Engineers, Inc.</td>
</tr>
<tr>
<td>William C. Gallenz</td>
<td>Consulting</td>
<td>Reinforcement Solutions, Inc.</td>
</tr>
<tr>
<td>Richard A. Ramsey</td>
<td>Consulting</td>
<td>Ramsey &amp; Assoc.</td>
</tr>
</tbody>
</table>

The new membership is due mostly to the re-organization of 408 responsibilities to include headed bars and couplers formally dealt with by committee 439. The 408
committee welcomes the new members and looks forward to having the viewpoints of more practitioners and producers in its membership.

5. **Joint Committees – Consideration of becoming joint ACI/ASCE committee.**

**Update, resolution from TAC.**

The resolution was balloted and approved by the 408 committee before the substantial membership changes that occurred with reorganization of 439 and 408 responsibilities. TAC discussed the resolution during their summer meeting and has asked 408 to wait because of the significant changes in membership. TAC feels that the issues involved with the resolution need to be discussed for the new members.

Adolfo will present an update to TAC during this convention with the viewpoints of the new members who attended this meeting. The advantages of joint committee status are:

- ACI committee documents cannot be published in the ACI journals, however, they can be published in the ASCE journals. They would still be published in the Manual of Concrete Practice. Thus, there is a publishing advantage because of this.
- Administratively, there would be few significant changes that would affect 408. 408 would operate under the rules of ACI because they will be the major sponsor.
- Joint committee status would require some 408 meetings to be held at ASCE conventions, however, the 408 membership already contains several members who attend those conventions and this should not present any problems. In fact, it will be a benefit because it will provide more opportunity for work to get done during the year.

John Silva moved for a vote of to reaffirm the change of becoming a dual committee. Seconded by JoAnn Browning and Tess Alborn. Approved by the committee.

6. **Request to modify mission statement assigned by TAC.**

**Update, resolution from TAC.**

*Title and mission statement adopted by TAC in Atlanta*

Title: ACI 408 Development and Splicing of Deformed Bars

Mission

Develop and report information on bond, development, and splicing of deformed bars, and anchorage of headed bars.

*Title and mission statement for committee 408 prior to Atlanta*

Title: Bond and Development of Reinforcement
Mission
Develop and report information on analysis and design of concrete structures as influenced by bond, development, and anchorage of reinforcement.

Title and mission submitted to TAC in response to committee discussion in Atlanta
Title: Bond and Development of Reinforcement
Mission
Develop and report information on analysis and design of concrete structures as influenced by bond, development, and anchorage of reinforcement.

Currently, 408 is operating under the first title and mission statement. As with item 6, TAC requested that the committee wait for perhaps 2 more meetings before adopting a new title and mission statement. This would be to allow time for the membership changes to stabilize in 408 and for all the new members to provide input which may affect the desired mission statement or 408.

Discussion:
- David Darwin suggested that 408 has been the best committee to deal with headed bars even before the change in mission statement occurred (because of 408’s membership and prior activities).
- Lou Collarusso suggested that the committee should adopt the changes quickly to justify activity for headed bars for which much active research and current code development are occurring.
- Would the committee be responsible for technical criteria? No. The committee would determine performance criteria; ASTM would deal with technical performance criteria.
- Should the word “splicing” be included in the title? No, the title should only use broad terms and avoid wordiness. In the mission statement? Yes, it is appropriate.

John Silva moved for the committee to respectfully ask TAC to reconsider the change in the mission statement. Seconded by David Darwin. Approved by the committee.

Neil Hawkins moved for the word “splicing” to be included in the mission statement. Seconded by Robbie Barnes. Approved by the committee.

David Johnson affirmed that TAC’s primary concern is for the new members to have time for worthwhile consideration of the new mission statement and its responsibilities before a change is made. How would document production be affected? How would the joint membership with ASCE work?
David Darwin suggested two new web ballots (one for the mission statement and another for the change to joint status) could satisfy the TAC’s desire for communication. Adolfo will implement these ballots.

7. **Ballot results “Splice and Development Length of High Relative Rib Area Reinforcing Bars in Tension (ACI 408.3-01) and Commentary (ACI 408.3R-01),” Adolfo Matamoros.**

The document was reviewed by TAC during their summer meeting. The document was balloted after addressing comments by TAC (the use of the words “code” and “specification” rather than the preferred word “guide”).

There was confusion with the 408 ballots because the initial set of TAC comments had a clerical error which was not discovered until after the first ballot had been initiated. A second ballot was required.

The primary issue with the document now appears to be the membership status of the committee at the time the document was balloted and how it will be listed in the front matter (the listing of the committee secretary primarily). The listing of names can treated as an editorial issue and will not require a new ballot.

There were three negative votes in the ballot:

**Negative from Steve Holdsworth** – definition of lightweight aggregate. A definition was added in response to TAC comments which matches closely with ACI 318-05 (a limiting value of 115 pcf). The definition does not match ACI 116R-00. What definition should be used?

- Neil Hawkins suggested that the 115 pcf definition may be outdated, reflecting old practices of lightweight concrete.
- The $\lambda$ factor tends to be applied universally and is tied to the 115 pcf definition, but may not be appropriate for many applications. A density-specific factor may be required for high-relative rib area bars.
- David Darwin suggested that the new provisions for high relative rib area bars should not be available for use with lightweight concrete. There is no research that supports the use of a lightweight aggregate factor or even suggests what the behavior of high relative rib area bars is in lightweight aggregate.
- Because the $\lambda$ factor is taken from 318-05, the definition should match 318-05.

As a response to TAC, a statement will be added in the document that the provisions apply only for normal weight concrete (Section 1.6 of the Scope). An explanation will be added in the commentary. The change will be re-balloted.

**Negative from John Silva** – (1) Change in the title to use the word “guide;” (2) Lightweight aggregate definition; (3) Editorial change to eqn. (A-1) sum of gaps divided by “per” (which stands for perimeter). Should this be changed to “p”?
Item (1) – The matter has been discussed. “Guide” is acceptable.
Item (2) – The lightweight aggregate definition will be handled by the change listed as a response to Steve Holdsworth’s comment.
Item (3) - The “per” will be changed to “$p_{bar}$."

**Negative from Robert Frosch** – (1) Removal of class C splices because section 4.4 has been removed and all subsequent references to section 4.4; (2) The reason for the use of $\omega_c = 1.0$ is not clear. More explanation seems necessary to address the TAC comment. Why is there a limit on $\omega_c$? ; (3) Robert suggested that the entire collection of TAC responses should be re-balloted due to the confusion over TAC comments and because many deletions of sections will occur.

Item (1) – changes will be made.
Item (2) – Robert will work with Dave and LeRoy to develop a statement for inclusion that will provide a satisfactory discussion.
Item (3) – A re-ballot of negative comment responses will be conducted. Other comments from Robert can be addressed with editorial changes and do not require re-balloting.


JoAnn provided an update. The document should go out for ballot in November or earlier.

9. **Update in changes to Chapter 12 of ACI 318.**

There was no time for this update.

10. **Development length of D45 wire.**

There was no time for this discussion.

11. **Update of “Mechanical Reinforcing Bar Anchorage (ACI 439.4R-XX),” Keith Thompson.**

Keith provided a brief update. A short list of changes is attached at the end of the minutes. It is hoped to have the document ready to ballot by the end of the calendar year. The following items need to be addressed: (1) the front matte needs to be updated to reflect the new status as a 408 document; (2) updated specifications from 318-08 need to be determined and inserted; (3) updated specifications from ASTM A970-07 need to be determined and inserted; (4) proper language to describe the application of ICC-ES AC347 needs to be determined and inserted (Keith will contact an ICC representative and determine what that body would prefer).

There was no time for this update.


There was no time for this update.

14. Technical Session Requests

- Post-Installed Reinforcing Bars: Design and Qualification Considerations
  
  *John Silva provided an update:*
  The session is set for Los Angeles, and is a half day session. A Monday presentation was requested.

  Description and Objective: Discuss various aspects of design and behavior including qualification requirements, quality control, installation, detailing, and design for adverse conditions.

  Five presenters: John Silva, Rolf Eligehausen, Neil Anderson, and two others.

- Sessions Honoring David Darwin, St. Louis

15. Research Presentations

- Mechanical Splices and Anchorages, J.J. Braun, Dextra

- Splices of Deformed Bars in Compression, Sung Chul Chun, Daewoo Ltd., Korea

  *Dr. Chun was able to present briefly. The committee thanks him for his time and work.*

- Crack Modeling, Jim Cox

- Bond Strength of Highly Confined Bars in Steel Plate Concrete Wall Structures, Oan Chul Choi, Soongsil University, Korea

  *Dr. Choi was able to present briefly. The committee thanks him for his time and work.*

16. Other Business

None.

17. Next Meeting
There will be a meeting at the spring convention in Los Angeles.

18. Adjournment

Attachments:

(1) Bond Strength of Highly Confined Bars in Steel Plate Concrete Wall Structures, Oan Chul Choi, Soongsil University, Korea

Bond Strength of Highly Confined Bars in Steel Plate Concrete Wall Structures

Oan Chul Choi  
Soongsil University, Seoul, Korea, occhoi@ssu.ac.kr

ABSTRACT

Steel plate concrete (SC) is a useful and effective structural system for walls and floors of large scale buildings such as nuclear power plants. SC composite wall system consists of two steel plates with vertical ribs, headed studs welded to steel plates and tie bars to connect two plates forming a sandwich. Since there is no need for form work or reinforcing bar placement, the construction period may reduce approximately by 50%.

Bond tests were performed to evaluate the anchoring system between SC wall and foundation mat. Key parameters are bar diameter of the reinforcing steel, spacing, cover, embedded length and material strengths. The test bars are highly confined by tie bars used to connect two plates, headed studs, shear bars or the vertical rib on steel plates, and each component of confinement details plays a key role to increase bond strength.

This paper presents the results of the large scale bond test with 26 specimens. Bond behavior of the composite wall anchor system differs from that of spliced beam specimens. Most specimens split and later the bars were pulled out. The test specimens with reinforcing steel highly confined by tie bars and headed studs failed by splitting with minimum unloaded slips. A design equation is proposed to determine the development length of the anchored bars in SC composite wall system considering the key variables including the confinement details.
(2) Update of “Mechanical Reinforcing Bar Anchorage (ACI 439.4R-XX),” Keith Thompson

Update of “Mechanical Reinforcing Bar Anchorage (ACI 408.4R-XX)”

Keith Thompson

Changes made in response to ballot results from Spring 2007 meeting.

**General Changes:**
- “Headed Anchor” has been changed to “Headed End” throughout the document. Uses of the word “anchorage” or “anchor” are being modified to avoid confusion with ACI 318 Appendix D.
- Formatting changes.
- Photos have been reformatted to decrease the file size.
- Comments on the text supplied by reviewers have been addressed.

**New Organization:**
- Front Matter
  
  *Needs to be updated to reflect the current committee. Do we rename the document with a 408 number? How do we acknowledge the work of the 439 committee?*

- Chapter 1 “Introduction”
  *No significant changes.*

- Chapter 2 “Fundamentals of Behavior”
  *This is a new chapter. Material in this chapter provides a broad overview of the failure types associated with headed bars with photos and drawings to illustrate concepts.*

- Chapter 3 “Head Types”
  *This is a new chapter. In order to deal with the problems that headed devices with sleeves may present, this chapter was created to discuss the potential problems. The matter presented in it is mostly conceptual and thus debatable. A table was created to present various head types and equations that should be used to calculate net head area (Thank you JJ. for this table.) The inclusion of this table makes the dimensional lines on the head type figures (formally in Chapter 4) unnecessary.*

- Chapter 4 “List of Notation”
  *Formally Chapter 2. No significant changes.*

- Chapter 5 “Historical Development”
  *Formally Chapter 3. No significant changes.*
Chapter 6 “Types of Headed End Devices”
Formally Chapter 4. Dimensional lines on drawings have been removed. The table
of dimensional data has been removed. The document will no longer report
dimensional data because it is too hard to keep the information current. Photos of
products have been inserted. The following companies have sent products to K.
Thompson to be photographed and inserted:

- Bar Splice Swage Device
- Griptec Extruded Coupler Device
- Bar Splice NC-Threaded Bar Device
- Zap Griplok Shear Screw and Wedge Head Device
- Lenton Terminator Tapered Threaded Bar Device
- DSI All-Thread Bar Device
- Bartec Upsized Threaded Bar Device
- Preshcon Threaded Bar Device (What category of device is this?)

Chapter 7 “Previous Research”
Formally Chapter 5. New figures related to the CCT node tests and lap splice tests
of M.K. Thompson have been added. Minor corrections to the content.

There is ongoing research on headed bars occurring. Additional results could be
included depending on the timeline expected for completion of this document.

Chapter 8 “Qualification Tests”
Formally Chapter 6. The description of ASTM A970 was shortened to one section.
The current summary reflects the 2004 version of A970 and needs to be checked
against the 2006 version. A section on ICC-ES AC 347 was added (these are not
standards – they are used for evaluation reports). All figures have been redrawn
for clarity.

Chapter 9 “Uses of Headed Reinforcement”
Formally Chapter 7. Should we include a summary of ACI 318-08 provisions that
affect headed bar design?

Chapter 10 “Summary”
Formally Chapter 8. No significant changes.

Chapter 11 “References”
Formally Chapter 9. When revisions of the body are completed, the references
need to be checked to make sure they reflect the latest standards.
408.2R Update — Items added

*State-of-the-art report on bond under cyclic loads*

- Chapter 2 – Bond and anchorage
  - FRP to increase confinement and bond strength
  - FRP rods
  - Engineered cementitious composites
- Chapter 3 – Bond behavior under cyclic loads
  - Debonding longitudinal reinforcement in shear span to increase ductility or reduce torsion
- Chapter 4 – Anchorage under high cycle fatigue
  - Updated references – splice tests
- Chapter 6 – Analytical bond models
  - Updated recent constitutive bond models
  - Behavior of frame elements including bond-slip behavior
  - Bond modeling to evaluate existing structures with short lap splices
  - Modeling high-cycle fatigue loading

Chapter 7 – Design and Analysis Approaches

- High Cycle
  - ACI 215
  - AASHTO
- Low Cycle
  - ACI 318
  - ACI 352
  - New Zealand
  - CEB
  - Eurocode 8
  - AIJ
  - AASHTO
  - FEMA 310
  - FEMA 358
Chapter 7 – Design and Analysis Approaches – High Cycle

• 408 Recommendations – 1992
  – ACI 215 stress range with upper limit
  \[ f_r = 23.4 - 0.33 f_{min} < 21 \text{ ksi} \]
  – Assuming the anchorage lengths of ACI 318-89, the allowable bond stress range for bars between #3 and #11 at service loads is:
  \[ \sigma_b = 2.8 \sqrt{f'_c / d_b} < 280 \text{ psi} \]

Chapter 7 – Design and Analysis Approaches – High Cycle

• 408 Recommendations – 20XX
  – ACI 215 stress range with upper limit
  \[ f_r = 23.4 - 0.33 f_{min} < 21 \text{ ksi} \]
  – Assuming the anchorage lengths of ACI 318-08,
  \[ u = 1.6 \sqrt{f'_c} < 300 \text{ psi (No. 6 bars and smaller)} \]
  \[ u = 1.3 \sqrt{f'_c} < 300 \text{ psi (No. 7 bars and larger)} \]

Chapter 7 – Design and Analysis Approaches – Low Cycle

• 408 Recommendations – 1992 – similar ACI 352
  1) For straight anchorages and splices with a cover of at least 1.5 \( d_b \):
  \[ l_s = (1860 d_b) / \sqrt{f'_c} > 20 d_b \]
  For \( f'_c \) of 3800 or greater, \( l_s \) may conservatively be taken as 30 \( d_w \).

Barring further research, all the modification factors currently in the code can be applied.
Chapter 7 – Design and Analysis Approaches – Low Cycle

• 408 Recommendations – 1992

2) For hooked bar anchorages:

\[ l_{bd} > 1800d_b / \sqrt{f_c} \]

3) For beam-column joints in structural frames, the ACI-ASCE 352 provisions discussed above should be applied.

Chapter 7 – Design and Analysis Approaches – Low Cycle

• 408 Recommendations – 20XX – ACI 352

1) For hooked anchorages in exterior joints (terminating within the joint):

\[ l_h = \frac{\alpha f_y d_y}{75 \sqrt{f_c}} \text{ psi} \]

2) For headed reinforcement in exterior joints (terminating within the joint):

\[ l_h = 0.75 \left( \frac{\alpha f_y d_y}{75 \sqrt{f_c}} \right) \geq 8d_y \text{ or } 6\text{ in (psi)} \]

Chapter 7 – Design and Analysis Approaches – Low Cycle

• 408 Recommendations – 20XX – ACI 352

3) Straight anchorages terminating in exterior joints (terminating within the joint) are not recommended

4) For straight anchorages the following recommendations are made:

In construction with columns wider than beams, all straight beam and column bars passing through the joint should be selected such that:

\[ \frac{h_{(beam)}}{d_b (beam bars)} \geq 20, \frac{f_y}{60,000} \geq 20 \text{ and } \frac{h_{(column bars)}}{d_b (column bars)} \geq 20, \frac{f_y}{60,000} \geq 20 \]
Chapter 7 – Design and Analysis
Approaches – Low Cycle

• 408 Recommendations? – 20XX – ACI 352

For wide-beam construction, beam longitudinal reinforcement passing outside the joint core should be selected such that:

\[
\frac{h_{\text{min}}}{d_{b} (beam~bars)} \geq 20 \quad \frac{f_{y}}{60,000} \geq 20
\]

and

\[
\frac{h_{\text{min}}}{d_{c} (column~bars)} \geq 24 \quad \frac{f_{y}}{60,000} \geq 24
\]

Chapter 7 – Design and Analysis
Approaches – Low Cycle

• 408 Recommendations? – 20XX – ACI 318

ACI Committee 318 (Building Code Requirements for Structural Concrete) –

Mechanical or welded splices, no lap splices except center half of member as tension lap splice with transverse reinforcement.

Chapter 7 – Design and Analysis
Approaches – Low Cycle

• 408 Recommendations? – 20XX – ACI 318

ACI Committee 318 (Building Code Requirements for Structural Concrete) –

For joints of special moment frames, the development length of No. 3 through No. 11 bars in tension a standard 90 degree hook shall not be less than the largest of 8d, 6 in., and:

\[
l_{d} = \frac{f_{y} d}{26 \sqrt{f'_{c}}}
\]

Bars cast with lightweight aggregate must have a standard \(l_{d}\) not less than the largest of 10d, 7.5 in, and 1.25 times the value defined above.
Chapter 7 – Design and Analysis Approaches – Low Cycle

• 408 Recommendations? – 20XX – ACI 318
  ACI Committee 318 (Building Code Requirements for Structural Concrete) –

For straight bars cast with more with no more than 12 in. of concrete cast below the bar, the requirements described above are multiplied by 2.5. For bars cast with more than 12 in. of concrete below the bar, the value for standard hook development length is multiplied by 3.25. Factors described for bars under static loading with epoxy coating apply.

Chapter 7 – Design and Analysis Approaches – Low Cycle

• 408 Recommendations? – 20XX
  1) For hooked bar anchorages and straight bar anchorages and splices, the provisions provided by ACI 318-08 are adequate.

  2) For beam-column joints in structural frames, the ACI-ASCE 352 provisions discussed above should be applied.