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american concrete institute

To: ACI 355 Committee Members December 8, 1997

From: Richard Wollmershauser, Chairman
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Subject: ACI 355 Committee Advisory Letter Ballot on CB-30

Enclosed is an advisory ballot of the latest version of CB-30 which is being balloted in ACI 318 Subcommittee B. Included are:

1) the reason Statement which give some detailed background (4 pages);
2) the draft Code dated 12/1/97 (14 pages);
3) the draft Commentary dated 12/1/97 (12 pages);
4) eight sample problems; and
5) four graphs which compare different allowable tension service loads.

I am requesting that all ACI 355 member consider this ballot, vote, and return the ballot along with any comments. Please key your comments to the exact paragraph number, such as 23.4.1. You may also give the page and line number if it will help clarify your comments. If you can, please e-mail me your summary comments so that I can assemble them electronically. If you want an electronic ballot page, I can e-mail it to you. Just let me know.

Please observe the deadline of January 9, 1998 to have the document to me. I will prepare a summary of the comments for forwarding to Jack Breen.

With regard to the two ballots that you currently have for the ACI 355 provisional standards, I would like to setup a Committee meeting to discuss the results and resolve any negatives in late January. My first choice would be Thursday January 22, 1998 in Orlando, the day after the end of the World of Concrete. Other possibilities would be over the weekend of January 17 (possibly in Orlando) or the weekend of January 24. Other locations would be Dallas, Chicago, Atlanta. Any feedback in the next week would be helpful - fax or e-mail.

If you have any questions, please call or e-mail me.

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ACI 355 committee correspondence

C11

CB-30 — CHAPTER 23

FASTENING TO CONCRETE

REASON STATEMENT*

Introduction

The ACI 318 Building Code has been silent in the area of fastening to concrete although designers and constructors have frequent applications in this area. Earlier areas of application of cast-in-place anchor bolts and inserts for columns and machinery, joinery of precast members and support of vital utility systems have now been greatly augmented with the increased use of post-installed fasteners, particularly in the areas of repair and strengthening. The only formal ACI design provisions for fasteners are the pioneering Appendix B to the ACI 349 Code for the design of nuclear-related structures. That important document developed design recommendations for embedments and attachments for nuclear-related structures emphasizing ductility in failure modes and basing concrete breakout capacity on a 45-degree cone. The use of the circular surfaces from the 45-degree cones made manual computations complex for groups of fasteners. PCI subsequently adapted the 45-degree cone into 45-degree prisms for group effects and the PCI handbooks have included substantial tables based on the modified 45-degree cone and prism. Model codes such as the Uniform Building Code have included expressions for concrete fasteners for very simple cases, and the ICBO evaluation service has developed a number of tests for evaluating the performance of fasteners to concrete. The proposed IBC has provisions for cast-in-place anchors and some provisions for post-installed fasteners for attachments. In general the expressions and procedures found in the model codes have greatly lagged developments in the fastener industry and in field applications.

In 1970 ACI TAC formed ACI Committee 355 — Anchorage to Concrete — with the specific charge of developing design procedures for cast-in-place anchor bolts and inserts, as well as other post-installed devices for anchorage to concrete. Committee 355 has greatly stimulated research and dissemination of knowledge in the field but historically was in disagreement over code-type recommendations. ASTM had developed standards for testing fastenings to concrete but did not have comprehensive standards for evaluating the performance of a wide range of fasteners.

In the last decade a very comprehensive research program was undertaken at the University of Stuttgart which consolidated and greatly expanded the database of fastening tests and the general knowledge in the area. Major US research programs supported by the power and highway industries spurred testing and development. PCI supported several studies on connections of interest to precasters while NRC- and NSF-supported seismic retrofit research programs added further technical data. All of this research served as a catalyst for substantial activity within CEB (Comite Euro-International du Beton) in development of comprehensive provisions for design of fastenings to concrete. Eight members of ACI

* This reason statement contains substantial additional information for 318 voters. A condensed reason statement will be developed at a later date for reballot by 318 and for submittal to TAC when CB-30 is adopted.

procedure highly transparent and more user-friendly. Fuller details and comparisons are given in Commentary Ref. 4. ACI Structural Journal article by "Fuchs & Breen"

Current Proposal

anchors currently excluded

At this stage of development specialty inserts, adhesive anchors and direct fasteners (powder or pneumatic actuated nails) are excluded from the provisions. However, ACI 355 and the ACI 318 B Task Force are jointly working on adhesive anchor provisions in similar format and it is hoped that they can be added in a future revision.

The approach depends on parallel development of two ASTM Standards on "Performance of Anchors in Cracked and Uncracked Concrete Elements" and "Performance of Anchors in Uncracked Concrete Elements." Such standards are well under development and have been balloted several times. They are going to be processed within ACI as provisional standards to give a backup in case the ASTM clock runs too long. These would only be for a three year interim. The ASTM Committee has furnished 318 B with copies of the current draft of the proposed ASTM Standards. They are included in this ballot package. They have been revised and are currently under ballot. They should be adopted in time for main 318 committee balloting and direct reference in the 2001 Code. These apply to both cast-in-situ and post-installed fasteners. The proposed ϕ factors in our document are varied for three categories of anchors according to the performance of different types of post-installed fasteners. They reflect the variability in installation safety as found in the ASTM tests. They specifically provide for fasteners in uncracked concrete and in cracks with widths similar to those envisioned with the current ACI 318 expressions for reinforcement distribution. These procedures indirectly consider specific crack widths.

A series of trial designs are included with the ballot package for comparison with current practices. The proposed chapter is less conservative than typical manufacturers recommendations and current UBC values. Without supplementary reinforcement, it is more conservative than some of the PCI design Handbook approaches. However, cast-in-place fasteners as generally envisioned in the PCI Handbook often have additional confining reinforcement to allow very low values of edge distances and minimum spacings to be utilized in the often congested connection area. Section 23.11 waives the minimum spacing, edge distance and thickness provisions if adequate supplementary reinforcement to control splitting is provided. In addition, a new Section 23.4.4 has been added to clearly indicate that the effect of a supplementary reinforcement added to confine or restrain the concrete breakout can be used in a design model which has been verified by tests. In new additions to R23.4.4 considerable detail is provided for design and evaluation of the contribution of such supplementary reinforcement. Several example problems show the contribution of such reinforcement.

The new provisions fill a major void in ACI 318. Their inclusion has been encouraged by building officials, consultants and many fastening manufacturers. Together with the parallel development of the ASTM performance standards, they should promote uniform safety, prevent fastener abuses, and the optional use of the CCD provisions gives designers a transparent, user-friendly model for unusual applications.

Ballot History

These provisions were formally balloted twice by Sub B during the 1995 Code cycle after substantial subcommittee discussion during their formation. The first Sub B ballot had three negative ballots and the text was significantly rewritten. The second Sub B ballot had no negatives and one abstention. The

Committee 355 participated actively in the CEB work. Committee 355 and Committee 349 Sub B have been very aware of the CEB developments. Very comprehensive design guides have been published by CEB and are in preparation in ACI 355 based on these general procedures.

With support of the German equivalent of our National Science Foundation, one of the Stuttgart scholars (Dr. Werner Fuchs, as a post-doctoral fellow at The University of Texas at Austin) assembled a comprehensive data bank of all available US and European tests. This database was made available to ACI 355 and all interested parties.

318-B Task Force

A special task force was set up within ACI 318 Sub B and charged with development of a new chapter on Fastening to Concrete. The development of such a chapter was reported to and strongly endorsed by ACI 318. Working with Dr. Fuchs and Dr. Eligehausen, Chairman of the CEB Committee, a revised form of the earlier Stuttgart "κ method" was developed (with substantial input from 318-B) based on a simplified rectangular prism model for both single fasteners and fastener groups (Concrete Capacity Design or CCD approach). ACI Structural Journal papers (Refs. 4 and 9 in the ballot Commentary) were published to compare the ACI 349 45-degree cone and the CCD approaches. The comparisons indicated that the CCD method gave good results over the full range of applications. While the ACI 349 procedure had very much the equivalent accuracy in some ranges, it was very unconservative in other ranges, particularly with group effects, and the geometry of intersecting circles was much more complex in group applications. Later comparisons with the PCI recommendations showed that, when put on the same load and resistance factor basis, there was equivalent accuracy for many single anchors but the PCI procedures were also very unconservative when compared to the group test results if supplementary reinforcement is not present. In particular the Stuttgart research results pointed out the highly damaging effect of concrete cracking on the tensile capacity of fasteners. The design procedures presented in CB 30 specifically differentiate between fasteners in cracked concrete and those in uncracked concrete applications. The ACI 318 B Task Force, and ultimately both ACI 355 (by a 12-1 vote) and ACI 349 sub B (by a 7-1 vote), expressed clear preferences for design procedures based on the CCD model.

However, recognizing that widely accepted procedures such as the ACI 349 model and the PCI model can give satisfactory results in certain ranges, the ACI 318 Sub B Task Force developed the proposal with a first level performance statement (Sections 23.4.1 to 23.4.5) that would allow any "design models which result in substantial agreement with results of comprehensive tests" to be used. This is the exact nature of the Code wording of Chapter 10 which permits various types of stress blocks to be used if a designers does not care to use the rectangular stress block in flexure. This generalized wording allows current procedures like the ACI 348 Sub B or PCI techniques to be used in applicable ranges if desired. This will be particularly helpful in the near future as clearly one does not have to reevaluate all existing fastenings. This provision also allows users of post-installed fasteners to use test results "for design by test" as long as they are interpreted to give the 5% fractile values and not the mean. The Code and Commentary indicates the level of accuracy required to make sure conservative design expressions are used. The CCD design equations given in the Code texts are the 5% fractile limits defined as 1.645 or the one-sided 95% tolerance limit with 90% confidence. These provide ample conservatism. The Code then sets out in Sections 23.6 and 23.7 "deemed to satisfy" procedures based on the Concrete Capacity Design procedures. Groups of fasteners are handled by rectangular failure surfaces rather than the intersecting circles which made the ACI 349 procedure more cumbersome. This approach makes the

principal concern of the abstaining voter was that the material should be introduced as a Code Appendix rather than a Code chapter in view of its length and because it was a very new approach. Minor editorial changes were made and the material was submitted for main committee ballot on LB-93-5 Item 5. This ballot item was huge in that it included not only the Code, Commentary, draft ASTM standards and design examples included with this ballot item, but it also included the full text of Refs. (4) and (9) which have subsequently been reviewed, published and discussed in the ACI Structural Journal. This information overload and the bulk of such an item as a new chapter coming in the very last ballot stage of the 1995 Code caused severe doubt with many voters who protested it was "too much, too late." During the ballot stage, Dan Jenny sent a letter to all 318 members expressing severe reservations on behalf of PCI and pointing out major discrepancies between PCI procedures and CB-30, especially for groups. Dan's letter was very persuasive and the Committee voted overwhelmingly to disapprove CB-30 for the 95 Code. Many negative voters indicated it should not be dropped. During the subsequent discussions at the special 318 summer meeting outside Chicago, it was indicated that 318 wanted to continue with CB-30 but only after several steps were taken:

1. Discussions were held with PCI to resolve differences where possible;
2. The proposed ASTM standards were essentially adopted by ASTM;
3. Refs. (4) and (9) were published in the ACI Journal for open discussion;
4. CB-30 was revised as necessary to meet the specific objections raised in LB-93-5.

These conditions were met and the revised proposal was reballoted by the reconstituted Sub B. Extensive negatives and Yes w/reservation votes were cast. All votes were carefully examined and a completely reformated CB-30 was developed. Significant changes to CB30 were outlined in five pages headed *"CB-30 Significant Changes"* distributed to ACI 318 Sub B as part of the November 1, 1996 Revision to CB 30. In particular, higher ϕ values and guideline commentary rules were added to reflect increased ductility with addition of supplementary reinforcement. Specialty inserts were excluded from the scope.

All comments by voters from ACI 318 Sub B and the parallel vote within ACI 355 were examined and most were addressed by change or clarification. We have now discussed this substantially and made many changes. We are ready to revote at the Sub B level.