

# Codification of PRESSS Structural Systems



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*A PCI-initiated proposal containing requirements for non-emulative design of special precast concrete shear walls has recently been approved for inclusion in the 2003 edition of NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures. This article provides background to this significant development and looks into the future.*

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Code provisions for non-emulative design of special precast concrete shear walls have been lacking for many years. However, a recent PCI-initiated proposal has been approved (subject to ratification by member organizations of the Building Seismic Safety Council) for inclusion in the 2003 edition of NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures.<sup>1</sup> But first, some background information on this important subject is needed.

For regions of high seismicity, Section 21.2.1.5 of ACI 318-02<sup>2</sup> permits the use of structural systems that do not meet the relevant prescriptive requirements of Chapter 21 if certain “experimental evidence and analysis” are provided. ACI Standard T1.1-01,<sup>3</sup>

“Acceptance Criteria for Moment Frames Based on Structural Testing,” defines the minimum evidence required when attempting to validate the use of strong column-weak beam moment frames in accordance with that section.

Among the subjects covered by ACI T1.1-01 are requirements for procedures that should be used to design frame modules for acceptance testing; configurations for those modules; test methods; test reports; and criteria for determining satisfactory performance. That standard should be used when attempting to validate the wide variety of frames possible by using precast elements, precast prestressed elements, precast elements post-tensioned together, and combinations of such elements.

Any combination of these elements can result in deformation, strength, energy, absorption, and ductility characteristics different from those for monolithic reinforced concrete construction.

Before acceptance testing, ACI T1.1-01 requires that a design procedure be developed for prototype moment frames having the generic form for which acceptance is sought and that the design procedure be used to proportion the test modules. Provisional Standard ACI T1.2-XX<sup>4</sup> defines the design procedure to be used for one specific type of moment frame (the so-called hybrid frame, in which features of post-tensioned and precast concrete construction are combined) that does not satisfy the requirements of Chapter 21 of ACI 318-02, but that

can be validated for use in regions of high seismicity under ACI T1.1-01.

The moment frame uses precast concrete beams that are post-tensioned to precast or cast-in-place concrete columns. Energy dissipation for earthquake excitation is primarily provided by reinforcing bars grouted into ducts located in the columns and in the top and bottom of the beams in the beam-column joint region.

One key feature of this system is that those reinforcing bars are deliberately debonded in the beam for a specified length measured from the interface between the precast beam and column. A second key feature is that the post-tensioning force allows the columns to be built without the corbels normally found in precast concrete construction. Friction induced by the post-tensioning force transfers the shear between the beam and the column.

Following the development of ACI T1.2-XX, validation testing in conformance with ACI T1.1-01 was done at the University of Washington, Seattle, where one interior, one exterior and one corner beam-column joint were tested. There was prior validation testing done at NIST.<sup>5</sup> The design procedure used for the prototype moment frame, which was represented by the NIST specimens, was substantially similar to the procedure of ACI T1.2-XX. All the validation testing enabled Charles Pankow Builders Ltd. to get approval for use of the Hybrid Post-Tensioned Precast Frame in a recently completed 39-story building.<sup>6</sup>

Special moment frames constructed using precast concrete and not emulating special moment frames of cast-in-place concrete are specifically permitted by ACI 318-02, provided they satisfy the requirements of ACI T1.1-01.

## CODIFICATION GOALS

At a meeting of the PRESSS Advisory Group on May 30, 2001, it was decided to pursue the codification process for two structural systems selected out of the five that were used in the PRESSS five-story building test:<sup>7</sup> the Pretensioned Precast Frame System and the Precast Shear Wall System. Another structural system used in

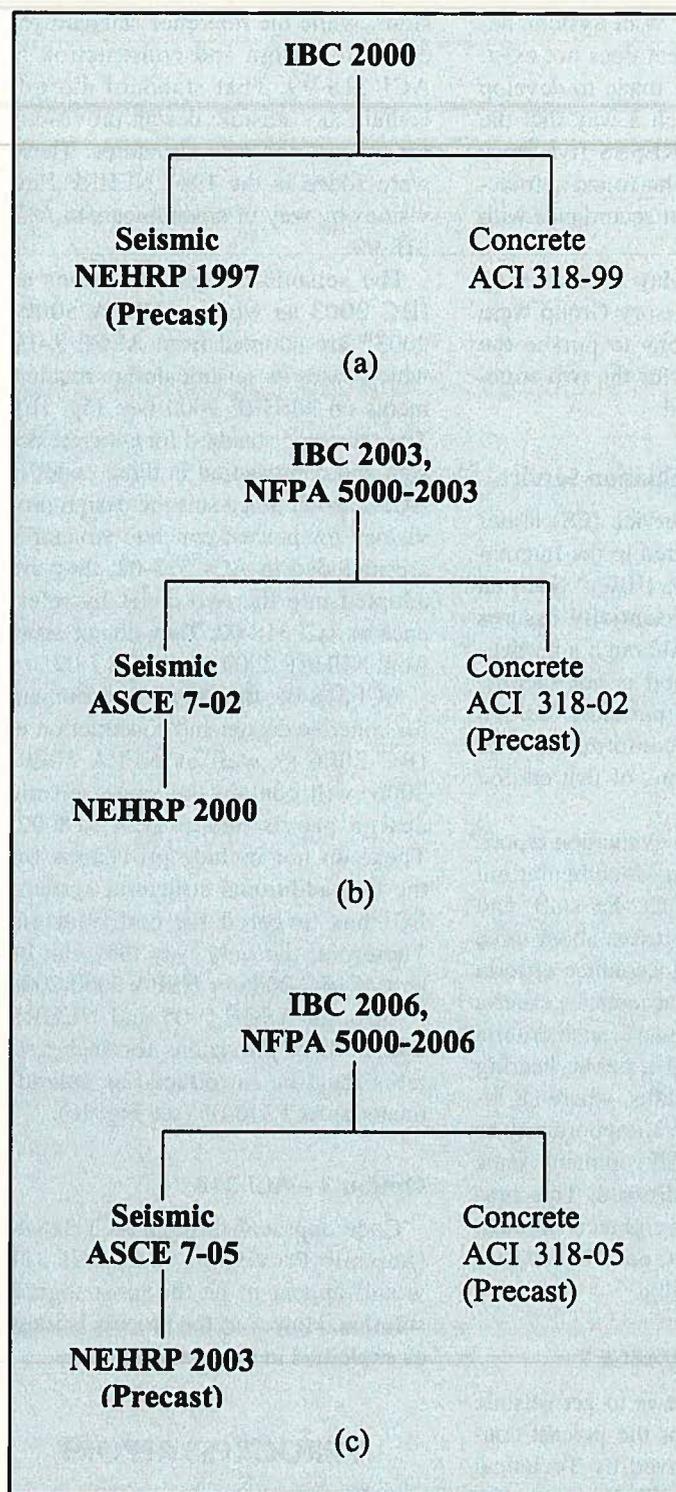


Fig. 1. Seismic design provisions for precast concrete structures in model building codes.

the PRESSS five-story building test, the Hybrid Post-Tensioned Precast Frame discussed above, has essentially already been codified as indicated in the preceding section. It was recognized early on that to satisfy the codification goals, three separate documents would have to be developed by the PCI consultants Neil M. Hawkins and S.K. Ghosh.

These documents are:

1. The equivalent of ACI T1.2-XX for the Pretensioned Precast Frame System. It will be checked and verified that the design of pretensioned frames in the PRESSS five-story building test followed ACI T1.1-01.
2. The equivalent of ACI T1.2-XX for the Precast Shear Wall System.
3. The equivalent of ACI T1.1-01

for the Precast Shear Wall System, because such a document does not exist. Attempts were to be made to develop this document in such a way that the shear wall in the PRESSS five-story building test would be found retroactively to have been in accordance with this document.

Discussed at the May 2001 meeting of the PRESSS Advisory Group were three possible options to pursue the codification process for the two structural systems selected.

### Option 1 – ICC Evaluation Service

ICC Evaluation Service (ES) issues Evaluation Reports tied to the International Building Code (IBC).<sup>8</sup> Such an evaluation report essentially assures code enforcers that although a particular product or method is not specifically addressed in a particular edition of the IBC, it is in conformance with the relevant provisions of that edition of the IBC.

Application for an evaluation report, including supporting documentation, is reviewed by the ICC-ES staff, and the approval process takes about three months if no new acceptance criteria are required. If new acceptance criteria are found to be necessary, such criteria must be presented at a public hearing held every three months, where all interested parties have an opportunity to comment on them. All comments must be satisfactorily addressed. This process can take up to eighteen months. An evaluation report, once issued, has to be renewed annually.

### Option 2 – NEHRP/ASCE 7

The objective here is to get seismic design provisions for the precast concrete systems approved by Technical Subcommittee No. 4 (TS4) on concrete and the Provisions Update Committee (PUC) of the Building Seismic Safety Council (BSSC) for inclusion in the 2003 NEHRP Provisions. The 2003 Provisions will form the basis of seismic design requirements in ASCE 7-05,<sup>9</sup> which will then be adopted by reference in the 2006 edition of the IBC.

Fig. 1a explains that the seismic design provisions for precast concrete structures in the 2000 IBC came directly from the 1997 NEHRP Provi-

sions, while the reference standard for concrete design and construction is ACI 318-99. That standard did not contain any seismic design provisions for precast concrete structures. These were added in the 1997 NEHRP Provisions by way of amendments to ACI 318-99.

The seismic design provisions of IBC 2003 as well as NFPA 5000-2003<sup>10</sup> are adopted from ASCE 7-02, which bases its seismic design requirements on NEHRP 2000 (see Fig. 1b). The reference standard for concrete design and construction in those codes is ACI 318-02. Since seismic design provisions for precast concrete structures are included in ACI 318-02, they are adopted into the two codes by reference to ACI 318-02. They do not come from NEHRP 2000 via ASCE 7-02.

ACI 318-05, the reference document for concrete design and construction in IBC 2006 as well as NFPA 5000-2006, will contain the same seismic design provisions as ACI 318-02. These do not include provisions for the two additional structural systems PCI has targeted for codification. Therefore, the only way they can be part of IBC 2006 or NFPA 5000-2006 is through ASCE 7-05 and NEHRP 2003, where provisions for such systems must be introduced as amendments to ACI 318-05 (see Fig. 1c).

### Option 3 – ACI 318

Code approval through ACI 318-H (Seismic Provisions) and ACI 318 would appear to be the most logical solution. However, the process is long, as explained in the next section.

## A PROGRESS REPORT

A Proposed Provisional Standard and Commentary titled “Acceptance Criteria for Special Structural Walls Based on Validation Testing” was developed by Neil Hawkins and S.K. Ghosh in early 2003.<sup>11</sup> This document proposes the minimum experimental evidence that can be deemed adequate to attempt to validate, in regions of high seismic risk or in structures assigned to high seismic performance or design categories, the use of structural walls (shear walls), including coupled

walls, for Bearing Wall and Building Frame Systems (Section 9 of ASCE 7-02) not satisfying fully the prescriptive requirements of Chapter 21 of ACI 318-02.

The document consists of both a Provisional Standard and a Commentary that is not part of the Provisional Standard. The document has been written in such a form that its various parts can be adopted directly into Sections 21.0, 21.1, and 21.2.1 of ACI 318-02 and the corresponding sections of ACI 318R-02. Among the subjects covered are requirements for procedures that shall be used to design test modules; configurations for these modules; test methods; test reports; and determination of satisfactory performance.

Input on the above document was received at a PCI Review Group meeting at PCI Headquarters on January 31, 2003. A modified version, dated February 3, 2003, which accommodated the input, was presented at a meeting of BSSC TS4 in Portland, Oregon, on February 8, 2003. A letter ballot of the Technical Subcommittee was subsequently conducted. Further modifications were made in response to several valuable comments from Joe Maffei, a member of TS4.

The modified document was then balloted by the BSSC Provisions Update Committee ahead of their meeting in San Diego on June 15-17, 2003. The proposal did draw a large number of negative votes on that letter ballot. Neil Hawkins devoted considerable time and energy responding to every negative comment that was submitted. Then Neil Hawkins, S. K. Ghosh and Jim Messersmith of the Portland Cement Association (PCA), working together, made further significant adjustments to the proposal at the PUC meeting itself.

Jack Moehle, chair of ACI 318-H and a member of the PUC, and Jim Harris, chair of ASCE 7 and a member of ACI 318 as well as the PUC, were supportive of the modified package. With that support, the PCI-initiated proposal to permit non-emulative design of special precast concrete shear walls, using a modified version of “Acceptance Criteria for Special Structural Walls Based on Validation

Testing,” was approved by the PUC for inclusion in the 2003 edition of the NEHRP Provisions. This code approval is a significant milestone. The PUC approval is subject to ratification by member organizations of the BSSC. A letter ballot to member organizations (including PCI) should go out at the beginning of August.

The next forum where the proposal must be taken is the ASCE 7 Seismic Task Committee (STC). The BSSC proposal will have to be rewritten to fit the ASCE 7 format and other requirements. The deadline for this submission is July 20, 2003. Approval by the STC of ASCE 7 is far from automatic. However, the authors are optimistic on the outcome.

Once such approval is obtained, the proposal goes on a letter ballot to the entire 90-member ASCE 7 committee. If the proposal is approved on that ballot, it becomes part of ASCE 7-05, which then will be adopted by reference by IBC 2006 as well as NFPA 5000-2006.

## FUTURE COURSE

If one follows the path that led to the inclusion of non-emulative special moment frames in ACI 318-02, an Innovation Task Group (ITG) will have to be formed within ACI to develop a provisional standard similar to ACI

T1.1-01 for precast shear wall systems. PCI, in fact, has requested the formation of such an ITG. A task group appointed by ACI’s TTTC (Technology Transfer Committee of the Technical Activities Committee), chaired by Dick White, has returned a positive recommendation concerning the formation of ITG 5, which will be charged with standardizing the proposed “Acceptance Criteria for Special Structural Walls Based on Validation Testing” by Hawkins and Ghosh.

A letter ballot has gone out to the TTTC membership. Upon approval by the entire TTTC, the ITG formation will also have to be approved by the Technical Activities Committee (TAC) of ACI. TAC approval is expected by the Boston convention of ACI (September 27 to October 1, 2003). Hopefully, if all goes well, a provisional standard may be approved by the Standards Board of ACI by the fall of 2005 (this is the most optimistic scenario).

If the above transpires, it should be possible to have provisions included in ACI 318-08, which would permit non-emulative design of special precast shear walls using the provisional standard. If ACI 318-08 is missed, which can happen relatively easily, the provisions should make it into ACI 318-11. ACI 318-08 will be the reference document for IBC 2009 and ACI 318-11

for IBC 2012. Once the provisions go into ACI 318, they will be dropped from ASCE 7.

## CONCLUDING REMARKS

Requirements for non-emulative design of special precast concrete shear walls, including coupled walls, are expected to be included in the 2006 edition of the International Building Code by reference to ASCE 7-05, which will have its seismic design requirements based on the 2003 NEHRP Provisions. The precast shear wall provisions should appear in the NEHRP document as amendments to ACI 318-02.

A course is being pursued vigorously to have similar provisions included in ACI 318-08, the reference document for the 2009 IBC, or, failing that, in ACI 318-11, the reference document for the 2012 IBC. At that point in time the provisions will be dropped from ASCE 7. The codes will adopt them directly by reference to ACI 318.

The PRESSS testing program was concluded in 1999. IBC 2006 will represent a seven-year period required for codification of the precast shear wall system that was tested as part of that program. Codification would have taken 10 or 13 years if one had to wait until ACI 318-08 or ACI 318-11, respectively, would act.

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