American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331 USA
+1.248.848.3700
www.concrete.org

Meeting Agenda

435 Deflection of Concrete Building Structures

Fall 2021 Virtual Convention (Atlanta, GA)

October 18, 2021 6:00 PM – 9:00 PM EDT

Mission: *Develop and report information on the deflection of concrete building structures.*

1. **Administrative [5 min]**
    - 1.1. **Review & approve minutes from Spring Virtual Convention (Baltimore, MD), 3/29/2021 [Exhibit 1]**
    - 1.2. **Membership update**
2. **Planning and Discussion [45 min – 1 hour]**
    - 2.1. **ACI 435R Report on Deflection of Prestressed Concrete Structures document**
        - 2.1.1. **Updates from chapter authors (+/- 5 minutes per chapter)**
    - 2.2. **Presentation by Drs. Ghali & Gayed (abstract attached)**
3. **New Business [15 min]**
    - 3.1. **Future Technical Sessions**
        - 3.1.1. **Mini-session on 435R-20**
    - 3.2. **Other new business**
        - 3.2.1. **Fate of PRC 435.8-85: Observed Deflections of Reinforced Concrete Slab Systems, and Causes of Large Deflections**
4. **Adjournment**

Exhibits

Exhibit 1 Meeting minutes from Spring 2021 Virtual Convention (Baltimore, MD), 3/29/2021

Exhibit 2 Presentation abstract by Drs. Ghali & Gayed

American Concrete Institute

ACI Committee 435

Deflection of Concrete Building Structures

Spring 2021 Meeting Minutes - *Draft*

Virtual Meeting

29 March 2021
6:00 - 7:30pm EDT
GoTo Meeting

ADMINISTRATIVE

Attendance

Members in Attendance: Dylan Freytag (Chair), David Shook (Secretary), Ziad El Aghoury, Peter Bischoff, Allan Bommer, Jared Brewe, Donald Carroll, Norbert Delatte, Mamdouh El-Badry, Brock Hedegaard, Ricardo Henoch, Eric Musselman, Hani Nassif, Adi Obeidah,Debrethann Orsak, Mahmoud Taha

Visitors in attendance: Carlos Baeza, Jason Bray, Scot Campbell, Jordan Carrette, Alessandro Fantilli, Allan Figueroa, Karl Gullerud, Shady Gomaa, Diana Largaespada, Alex Meucci, Sabrina Muller, Carlos Vasquez

Voting members not present: Eamonn Connolly (regrets), Ramez Gayed, Amin Ghali(regrets), Shawn Gross, Adam Knaack, Young Hak Lee, Adam Lubell (regrets), Faris Malhas, Clay Naito

TAC Contact: Barzin Mobasher (present)

Introductions

Attendance taken. Visiting member introductions.

Prior Meeting Minutes

Minutes from Fall 2020 virtual meeting previously posted on ACI website and distributed. Two corrections noted.

1. Update Young Hak Lee to reflect ‘regrets’.
2. Revise Allen Bommer as a reviewer of in-progress document Chapter 7.

Mahmoud Taha, motion to approve. Brock Hedegaard second. Minutes approved without objection.

Committee Membership

1. Consulting members voluntarily stepping down: none
2. New voting members: none

PLANNING AND DISCUSSION

Update on 435R-20 Report on Deflection of Nonprestressed Concrete Structures

1. Document has been published by ACI. Many members have a hard copy. Current and prior committee members are thanked for their hard work and dedication to this important document.

Update on 435R-XY Report on Deflection of Prestressed Concrete Structures

1. **Chapter 1 & 2 Introduction & Notation** (Shook) - Draft has been finished. Will be posted for the ballot soon after convention.
2. **Chapter 3 Prestressing reinforcement** (Musselman) - Draft is in progress and will be ballotted before Spring 2021.
3. **Chapter 4 General approach to deformation considerations curvature and deflections** (Nassif) - Nassif and students did several studies related to I_eff for prestressed members. They observed that by removing the precompression moment favorable results are found. They believe this approach is good for service level conditions, but not ultimate conditions. Chapter development work is on-going.
4. **Chapter 5 Short-term deflection and camber evaluation in prestressed beams** (Nassif) - Peter and Hani to meet and discuss next steps. Draft will be shared with the committee.
5. **Chapter 6 - Long-term deflection and camber evaluation in prestressed beams** (Bischoff, Naito) - Peter and the chapter team had a productive meeting since last Fall. They agreed to use a multiplier method for long-term deflections. Hani told the committee that the age-adjusted (incremental) approach was described in the past 435 document, but used a different name. Shook suggested the upcoming document notify

the reader of this. Shook/Henoch offered to run analysis on a project where survey information is available to 'try out' approach when it is further developed.

6. **Chapter 7 Deflections and camber evaluation of two-way prestressed slabs** (Saarkinen, Shook/Henoch) - Shook reported that a meeting occurred since the Fall 2020 meeting with a consensus that the chapter be focused on guidance for practicing engineers. Focus will be on commonly used software and best practices, but will avoid being a user guide or textbook.

7. **Appendix** - Not discussed

   Discussion regarding the potential inclusion of methods of controlling deflection in the in-progress prestressed document was raised by Mamdouh El-Badry. Committee decided the content is important and some portions related to prestressed design could be added to the in-progress document. Broader approaches would be incorporated into a future document.

New business

1. ACI 435R-20 mini session - Musselman, Bischoff & Freytag
   a. Freytag to make a request to ACI for Fall 2021.
2. Recent publications
   a. Bishoff - Rational Approach for Computing Long-Term Deflection of Reinforced Concrete in ACI Structural Journal Volume 118 Issue 2
3. Scott Campbell from NRMCA visited and notified the committee of on-going research at University of Washington in collaboration with Dr. Lehman and Dr. Lowes regarding maximum spacing of reinforcement in concrete walls. ACI 318 currently limits spacing to 18" maximum and their research may change this for concrete walls in low-seismic / low-wind load environments. Committee notes the need to consider shrinkage cracks and out of plane flexure in tilt-up for example.

Next Meeting

Fall 2021 convention.
ACI has not determined if this will be entirely in-person, hybrid, or entirely virtual. Committee members have heard it may be hybrid for sessions but committees are likely in-person only. Some members expressed concern about attending in-person due to government or personal considerations. 435 may hold a virtual meeting ahead of the convention if notable conflicts with in-person requirements occur.

Adjourn

Motion to adjourn by Nassif, second by Mahmoud Taha, and no objections.

American Concrete Institute

American Concrete Institute

ACI 435R-XY - Approved Table of Contents for Report on Deflection of Prestressed Concrete Members TAC

American Concrete Institute

Raw notes - to be removed

Agenda

- Attached

Fall 2020 Meeting Minutes

- Fall 2020: Add Young Hak Lee Regrets
- Change Allan Bommer (reviewer) - shows question mark
- Move to vote: Mamoud, Second: Brock

Administrative

- Regrets: Amin Gali, Adam Labell, Ramez,
- Karl Gullerud (Bentley/Ram Concept)
- Scott Campbell - wants to talk about deflection of thin tilt up
- Consider intermediate online meeting ahead of Fall 2021 if online is not available to those who cannot attend due to COVID.

Planning and Discussion

- ACI 435-20 published. Documents in hand by several members.
- Chapter Updates
    - Chapter 1 (Shook) - Start ballot after Spring 21 convention
    - Chapter 2 (Shook) - Start ballot after Spring 21 convention
    - Chapter 3 (Musselman) - Start ballot after Spring 21 convention. A material chapter mostly.
    - Chapter 4 (Nassif) - Hani and student did several studies and found Ieff for prestressed. If you take out decompression moment you get very good results. Good for service conditions, not ultimate.
    - Chapter 5 (Nassif) - Nassif/Bischoff to meet and discuss next steps. Draft will be shared with Mamdough El-Badry/Amin/Ramez.
    - Chapter 6 (Bischoff/Naito) - Had meeting. Precast/pretensioned use the multiplier method. Peter request Brock join the discussion. Shook offered to run examples when data is closer to finished.
    - Chapter 7 (Saarkinen, Shook/Henoch, Allen[reviewer]) - Direction will be practicing engineer focused content which helps bridge the 435 content into practice with commonly used software. Distribute Ch 7 Ramez slides.

American Concrete Institute

Future Technical Session - ACI 435 RC Document Mini-Session

- Dylan will make request to ACI.
- Eric, Peter, Andy S. - potential presenters
- In person seems likely, TBD with ACI. Maybe keep online for sessions, but not committee meetings.

New Business

- Peter/Clay - Partial prestressing PY Lin Award (congrats!). Also, Peter has new ACI paper.
- Hani - Long term deflection (Brock). Not called age-adjusted modulus, but it's in their document. Effective modulus plus extra factor on it (Peter). Incremental approach where creep affects cracking and vice-versa (age-adjusted). Total (effective). Say when it's best to use effective (total) or incremental (age-adjusted) in Chapter 6.
- Mamdouh El-Badry asked if we could include 'control of deflections' in the PT document. Shook/Dylan said maybe, but shouldn't hold up schedule of PT. Perhaps we work it in within the context of the approved TAC content.
- Scott Campbell - NRMCA - on-going research project with Univ. of Wash. Max rebar spacing in walls (18"). Lightly reinforced walls where out of plan. 3-4 story low seismic - why do we need 18" spacing? In some low seismic/low wind it is not needed for strength. Even with two curtain of steel - doesn't o much until you get to high deformations/drifts. 6" to 8" walls (slender).
    - Shrinkage cracks.
    - Out of plan deflection (Peter) - tilt up

October 2, 2021

Presentation at ACI 345 virtual meeting, Fall 2021

Immediate and Long-Term Deflection Control

R.B. Gayed and A. Ghali, associate member and voting member of ACI Committee 435

The assumption that plane cross sections remain plane, combined with fundamental compatibility and equilibrium principles adequately predict immediate and long-term deflections of concrete beams and two-way slabs, subjected to gravity load and prestressing. Calculations require reliable time-dependent parameters of concrete, including: elasticity modulus, creep coefficient, shrinkage strain, tensile strength, and relaxation of prestressing reinforcement[1]. Equation 1 adopts the assumption that plane cross sections of beams remain plane, and complies with compatibility and equilibrium principles. The use of the properties of the transformed section ensures that the strain in concrete is compatible with that in adjacent bonded reinforcement. Multiplying strain with E gives stress, whose resultants are equal to N and M, satisfying equilibrium. The strain parameters ε_O and ψ are axial strain and curvature, respectively; O is a reference point on principal y-axis. Equation 1 gives the strain distribution of a beam cross section subjected to normal force, N combined with bending moment, M:

$$\varepsilon_O = N/(E\,A) \quad ; \quad \psi = M/(E\,I) \tag{1}$$

Equation 1 applies when O is at the centroid of the transformed section. E is age-adjusted elasticity modulus for concrete. The transformed section properties A and I are area and moment of inertial about principal x-axis, passing through O. Superposition of strain parameters as algebraic sum is possible when O is selected at a fixed point, employing B, A and I; where B is the first moment of transformed section area about x-axis; a substitute equation[2] applies when O is not at the centroid of the transformed section. The substitute equation applies for the immediate values of ε_O and ψ at loading time t_0 and for the change in their values in the period $(t - t_0)$, with t being the end of the service life of the member. Geometry relation gives displacements from ε_O and ψ. A selected post-tensioning level controls the deflection at a tolerable value.

Appendix B of ACI 345R-95 gives the substitute equation. Chapter 6 of Gayed and Ghali, 2022[3] applies and demonstrates the procedure to post-tensioned beams and two-way slabs.

References

1. ACI 209.2R-08, 2008, *Guide for Modeling and Calculation of Shrinkage and Creep in*

Hardened Concrete, American Concrete Institute, Farmington Hills, MI, 48 pp.

2. ACI 435R-95, 2000, *Control of Deflection in Concrete Structures*, American Concrete Institute, Farmington Hills, MI, 77 pp.
3. Gayed, R.B. and Ghali, A., 2022, *Structural Analysis Fundamentals*, CRC Press, Taylor & Francis Group, 1st Edition, ISBN 9780367252618, 654 pp.