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POST-TENSIONING—CODES VERSUS PRACTICE—A NEED FOR TRAINED ENGINEERING PROFESSIONALS

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POST-TENSIONING INSTITUTE ®

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INTRODUCTION

Typically, in a design-bid-build project, the structural engineer of record (SEOR) designs all structural aspects of the project. However, lately, in addition to delegating secondary structural elements in a design-build, design-assist, integrated project delivery, or fast-track environment, the SEOR may opt to delegate design responsibilities of even primary structural components such as floor systems to specialty design engineers (SDEs). The reasons that may affect this design delegation are many and varied—possibly due to construction cost; competitive design fees, hectic design and construction schedules; and most unfortunately, lack of competency in a particular structural system, such as post-tensioning (PT). Although there can be many economic and business reasons that can impact the decision on whether to delegate the design of certain structural components, lack of competency should not be the determining factor. If the decision is based on the lack of competency, then in addition to questioning the engineer's technical competency as the SEOR for that particular building, one would question their engineering ethics, as well. As a more professionally responsible solution, the engineer would be better served to acquire the necessary design competence and expertise and it should be addressed properly on how to gain the competency and expertise in the field of interest. This paper focuses on the reasons behind this lack of competency in post-tensioning design expertise within the United States and how to improve our knowledge and design skills using this time-tested, post-tensioning technology and to be able to gain confidence performing this task, rather than delegating to specialty engineers. The role of PTI and post-secondary, college engineering programs are discussed on how they can take a more active role in bringing this required competency and expertise by conducting seminars, sponsoring research activities, and introducing prestressed concrete as a core subject in civil engineering curricula.

PRIMARY STRUCTURAL COMPONENTS AND PRIME PROFESSIONAL

The Council of American Structural Engineers' (CASE) national guidelines define the primary structural system as: "the completed combination of elements which serve to support the building's self-weight, the applicable live load which is based upon the occupancy and use of the spaces, the environmental loads such as wind, seismic, and thermal".[1] This discussion will focus on the state of Florida and by extension to other states and regions. According to Florida Administrative Code (FAC) #61G15-31.001, the Engineer of Record for a structure is responsible for all structural aspects of the design of the structure, including the design of all of the structure's systems and components. The FAC #61G15-30.002 defines a prime professional as a Florida professional engineer or a duly qualified engineering corporation or partnership who is engaged by the client to provide any planning, design, coordination, arrangement, and permitting for the project and for construction observations in connection with any engineering project, service, or creative work. The prime professional engineer may also be an Engineer of Record on the same project. A delegated engineer is a Florida professional engineer who undertakes a specialty service and provides services or creative work (delegated engineering document) regarding a portion of the engineering project. The delegated engineer is the Engineer of Record for that portion of the engineering project.

CODE REQUIREMENTS

The legal implication of delegation of engineering is excluded in this review. However, a review is made with respect to the local building codes, regulations, and professional licensure requirements and its limits on delegation of design elements. Surprisingly, some of the engineering boards—for example, the Florida Board of Professional Engineers (FBPE)—align with the market trend and industry practices. ACI 318-11, Section 1.2[2] (and ACI 318-14, Section 26.10.1.(a)[3]) and by reference International Building Code (IBC) require that contract documents shall show "magnitude and location of prestressing forces"; similarly, the South Florida Building Code, 1999 Broward County Edition[4] Section 2510.2 (a) states, "the structural construction documents shall show the magnitude and location of all prestressing forces and all design assumptions." This implies that the SEOR shall design the primary structural floor system and provide the magnitude of the final effective PT forces, including the tendon profile, arrangement of banded and distributed tendons, and all the structural assumptions in the analysis arriving at the final design. An SEOR cannot provide this information without performing an actual analysis and design of the post-tensioning floor system. This was reflected in the earlier Florida Administrative Code Chapter 61g15-31 responsibility rules of professional engineers concerning the design of structures, as amended on 9/28/10 (FBPE), which requires that if the Engineer of Record elects to delegate the responsibility for preparation of calculations, then calculations shall also be submitted by the delegated engineer, which show sufficient information to confirm that the number and size of tendons provided are adequate to provide the prestressing forces shown on the structural engineering documents. Although delegated, it is only a second verification of the SEOR's PT design, not a complete design from scratch or a value engineering exercise.

On the other hand, the local building department may require the PT design by the SEOR. For example, the City of Miami Building Department requires a post-tensioning shop drawing affidavit by the EOR to certify that the shop drawings for the post-tensioned cables are in conformance with the SEOR's design. The affidavit explicitly gives a clarification on what it means by conformance. It defines that conformance means that all applied post-tensioning loads, mild reinforcement, and shear reinforcement are in accordance with the SEOR's design drawings. How can the SEOR give a certificate of conformance affidavit if he/she did not perform the analysis and design and provide information to the specialty engineer to follow?

CURRENT TREND

Although many structural engineering firms fully design post-tensioned floor systems and provide PT forces and other relevant information on the contract documents, oftentimes, other structural engineering firms acting as the SEOR will delegate the design of the PT floor system to the SDEs. There are other instances in which choosing an efficient structural system such as a post-tensioned floor system would have resulted in significant economic and performance advantages, but the SEOR may choose not to delegate the floor system design to a specialty post-tension expert but instead go with a conventionally reinforced concrete floor system due to limited expertise and competency and unwillingness to risk delegating this design to a specialty engineer.

Common reasons for delegating the post-tensioned floor system to specialty engineers:

- Lack of competency: One of the primary reasons attributed to the lack of competency is the deficient U.S. educational system, leading to a lack of diversely educated engineers. Very few universities teach prestressed concrete design, and even fewer have a course covering the topic of post-tensioning. Another interesting aspect is that even within those universities that include a prestressed concrete design course, there is question of how effective the course material is delivered.[5]
- Reduced cost and time of the primary professional engineer if the system design is performed by the specialty engineer.
- Strangely, a misconception that the liability and responsibility can be divested by delegating design responsibilities,[6] contrary to many professional engineering board's requirements and statutory obligations.

ROLE OF LICENSING BOARDS AND PROFESSIONAL INSTITUTIONS

Licensing boards, however, rather than addressing the deficiency, amend the duties and responsibilities of the SEOR to reflect the industry practices, the latest being the Florida Board of Professional Engineers (FBPE). Per FAC #61g15-31.004, design of cast-in-place post-tensioned concrete structural systems, as amended on 2-28-16,[7] if the Engineer of Record (EOR) elects to delegate the responsibility for preparation of calculations, then calculations shall be submitted by the delegated engineer showing sufficient information to document that the number and size of tendons provided are adequate to carry all loads shown on the structural engineering documents. This is a total change from its earlier code, which required the EOR to provide PT forces. Now it requires only to provide design specifications and not a complete system design that would provide the required PT forces in the contract documents. This implies that the SEOR is not required to provide any PT design, but rather to provide design assumptions and intent such that the specialty engineer can perform an analysis and design of the PT floor system. This is a huge shift and a complete change in the way the SEOR is obligated to perform their duties. However, the code maintains its stand that it is the responsibility of the EOR for the structure to review the post-tensioning system installation drawings and the effect of post-tensioning on other parts of the structure. The duties and responsibilities of the specialty engineer who will now become the EOR for his/her design is out of purview of this discussion.

Apart from delegating cast-in-place, post-tensioned concrete structural systems, other major delegated design components of structures are: 1) prefabricated wood trusses; 2) precast and prestressed concrete components; 3) open web steel joists and joist girders; 4) pre-engineered structures; 5) foundations; and 6) structural steel connections.

Stand taken by other professional organizations

Although delegation of steel connections to a specialty engineer has been practiced since the 1960s,[8] the American Institute of Steel Construction (AISC) Code of Standard Practice – 2010 #3.1.2 - (COSP, AISC 303-10) included a provision for delegation of connection design as an option for the owner's designated representative for design (that is, SEOR), namely:

1. Provide complete connection design;
2. Connections be selected or completed by an experienced steel detailer (probably using tables from the AISC manual); or
3. Delegated to a licensed professional engineer working for the fabricator.

The third provision was introduced only in 2010. However, it is worth noting that the delegation is only for connections, not the entire flooring system. The structural design drawings shall clearly show per specification [3.1] (a) the size, section, material grade and location of all members. Even if the connection design is delegated, the requirement of Section 3.1.1 (on providing complete details of bracing, column stiffeners, web reinforcement, openings, etc.) and Section 4.4 (on review and approval of connection design and shop drawings) shall apply. The SEOR should think twice to delegate the design of primary structural steel members, such as columns and beams, to a specialty engineer, as it would make him/her irrelevant to the project, but not so if the primary structural system is a post-tensioned floor slab. Strange indeed.

The Steel Joist Institute (SJI) 2010 *Code of Standard Practice for Steel Joists and Joist Girders* states that the SEOR shall "calculate and provide the magnitude and location of all joists and joist girder loads." The term "all" implies a level of completeness that might not be achievable by the SEOR.[9]

ADVANTAGES AND RISKS

The advantage in delegation is that in most of the instances, the vendor firm, which generally specializes in that specific field, possesses sufficient knowledge and design skills to provide an efficient design. Delegating engineering design responsibility to a subcontractor providing post-tensioning materials and accessories will often provide efficiency and enhance the quality of the design, reduced project cost, and completion time.[10] The SEOR can delegate design duties to others only if the SEOR's contractual duties include delegated tasks, not just because the SEOR lacks the engineering skills or competency in a particular system—for example, post-tensioning. One needs to keep in mind that the delegation does not relieve the SEOR from his/her contractual liability of the performance of the delegated engineering task. Most importantly, if the SEOR cannot fully understand the structural system and its impact on the overall structural system, he/she cannot deliver an efficient final product to the client and thus risks losing his/her credibility in the marketplace.

LACK OF TRAINED ENGINEERS

To address the issue of lack of trained professionals in the prestressed concrete and post-tensioning technology, we need to review the current state of the U.S. educational system in terms of failure to embrace and teach new engineering technological concepts, such as prestressed/post-tensioned concrete, although modern prestressing technology has existed for over 100 years. There are presently approximately 3000 degree-granting institutions that exist in the United States,[11] out of which 363 schools offer accredited bachelor's (4-year) degrees in engineering,[12] and only 221 of these schools have civil engineering curricula. It is estimated[5] that the number of schools that have structural engineering programs and teach prestressed concrete design is between 20 and 30; presumably even fewer institutions have any detailed discussion specifically on post-tensioning. Despite this lack of trained engineers, within both the building and bridge industries, prestressing technology is routinely and actively promoted by both government and private entities for its diverse positive attributes, such as cost-effectiveness, durability, constructibility, reduced self-weight, and ability to be manipulated into almost infinite shapes and geometries. So there is an ever-increasing demand for the trained PT design professionals, and the educational institutions have the opportunity to take advantage of this need.

CONCLUSIONS

There is nothing wrong with delegating the design of post-tensioning to a specialty engineer, and in one aspect it provides an efficient and economical design from the expertise of the specialty engineer. However, the specialty engineer will not have the complete knowledge and information of the entire building structural system. Additionally, the primary structural engineer (SEOR) is still responsible for the entire building structural system and the behavior of the structure as a whole due to various systems acting in tandem, including the effect of post-tensioning on the structure, and hence, he/she must be professionally competent to understand and review the post-tensioning technology and approve the design presented by the specialty engineer. To bring in this competency, as an institution, PTI should:

- Increase its participation in education through funding professorships, research, and doing more design seminars for practicing engineers.
- Sponsor "professor's seminars"[5] similar to PCA seminars.
- Take an initiative to convince the universities through ABET, NCEES, and other such organizations of the urgency to include prestressed concrete design, including post-tensioning, as a fundamental design topic as part of a typical undergraduate structural engineering curriculum.
- Advocate including prestressed concrete as a core course requirement for licensure examination qualification.

Well-trained engineers provide the best possible solutions, which includes more efficient and optimized PT design for successful project development and outcome. Both the structural engineering firms and vendors benefit from well-trained engineers from the universities with an added advantage of expertise in the competitive market place. If we do not educate the future engineers and current practicing engineers on post-tensioned structural systems and do not willingly embrace and employ this innovative, economical, time-saving, and, more importantly, sustainable structural system in our projects, we do a disservice to the society and to our profession and ultimately risk becoming irrelevant.[6]

REFERENCES

1. Hatem, D. J., and Tuller, M. P., "Structural Design Delegation," *STRUCTURE*, Nov. 2009, pp. 32-33.

2. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI-318-11) and Commentary," American Concrete Institute, Farmington Hills, MI, 2011, 503 pp.

3. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)," American Concrete Institute, Farmington Hills, MI, 2014, 520 pp.

4. "South Florida Building Code, 1999 Broward County Edition," Broward County Board of Rules and Appeals, Plantation, FL, 1999, 780 pp.

5. Bondy, K. B., "The State of Post-Tensioned Concrete Education," *Concrete International*, V. 36, No. 10, Oct. 2014, pp. 32-36.

6. DeStefano, J., "Delegating Design Responsibility," *STRUCTURE*, July 2005, p. 40.

7. "Design of Cast-in-Place Post-Tensioned Concrete Structural Systems," Rulemaking Authority 471.033(2), 471.008 FS. Law Implemented 471.033(1)(g), (j) FS. History-New 1-26-93, Formerly 21H-31.004, Amended 9-28-10, 2-28-16.

8. Duncan, C. J., and Carter, C. J., "Connection Design Responsibility—How's It Been Going?" *Modern Steel Construction*, Mar. 2015, 3 pp.

9. CASE Guidelines Committee, "Delegated Design," *STRUCTURE*, Sept. 2013, pp. 50-52.

10. Circo, C. J., "When Specialty Designs Cause Building Disasters: Responsibility for Shared Architectural and Engineering Services,", *Nebraska Law Review*, V. 84, No. 1, 2005, 86 pp.

11. NCES, "Fast Facts: Educational Institutions," National Center for Education Statistics, Washington, DC, https://nces.ed.gov/fastfacts/display.asp?id=84.

12. Dedicated Engineers, "A Quick Guide to Colleges Offering Engineering Degrees," Feb. 2007, http://www.dedicatedengineers.org/Resources/Quick_Reference_Guide_Complete.pdf.

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