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Structural Engineers Association of Colorado

White Paper on:
Recommended Practices for Specifying and Delegating Responsibilities for Precast Concrete Building Structures in Colorado

Prepared by the Precast Concrete Committee

Precast Concrete Committee
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This document does not replace, and is not to be used as an adjunct, to the current "Guide for Consulting Structural Engineering Services in Colorado", PCI publications, or Case Guideline – 962B.

The following is a discussion of the current responsibilities and common issues that arise during the design and construction of precast concrete structures in Colorado.

This paper was prepared by the SEAC Precast Concrete Committee, a coalition of Structural Engineers and Precast Specialty Engineers, dedicated to improving the precast concrete construction industry. The intent of this paper is to propose suggestions for improving the working relationship between Engineers of Record and Precasters.

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1. Introduction

The purpose of this document is to describe the recommended practice of the working relationship between Engineers of Record and Precasters, in Colorado. Described within is the process of delegated design for precast concrete structures, identify the responsibilities of Engineers of Record and Precasters. The timing, content, and review of precast submittals are discussed, along with common construction errors, toppings, camber, tolerances, interfaces with other structural elements, construction loads, stability during construction, and building-information models. This document stresses that close collaboration between the Engineer of Record and the Precaster is important for successful projects.

Other documents have addressed some of the issues contained herein, but none of these referenced documents fully address the relationship between the Engineer of Record and the Precaster.

Reference documents include:

1. *A Guide for Consulting Structural Engineering Services in Colorado*, Second Edition, 2004, Structural Engineers Association of Colorado
2. *CASE Guideline – 962-B: National Practice Guidelines for Specialty Structural Engineers*, 2009, Council of American Structural Engineers
3. *Design and Construction Responsibilities for Architectural Precast Concrete*, Precast/Prestressed Concrete Institute (DN-28)
4. *Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products (MNL-117)*, Fourth Edition, 2013, Precast/Prestressed Concrete Institute (PCI)

The SEAC Guide has a short list of submittal items related to precast concrete. Section 7 discusses services relative to performance specified elements, but only generally considers the responsibilities of the Engineer of Record, and does not discuss the responsibilities of the Precaster.

CASE 962-B discusses general requirements for specialty structural engineers, and contains a short list of specific recommendations for precast structures, but does not discuss the important relationship and collaboration between the Engineer of Record and the Precaster.

The two PCI documents contain very similar content. These publications contain the most comprehensive description of the responsibilities of the Engineer of Record and the Precaster, but do not provide the significant detail on several topics discussed in this white paper. It is recommended that this document be reviewed by Engineers of Record and Precasters.

2. Terminology

AOR – Architect of Record

ASI – Architect's Supplemental Instructions

BIM – Building Information Modeling or building information model

CDs – Construction Documents (drawings and specifications)

CIP – Cast-in-place

CLC – Code Loading Criteria

CMAR – Construction Manager at Risk

CMGC – Construction Manager/General Contractor

DBB – Design, Bid, Build

DD – Design Documents (Design drawings and General Notes)

Design Team – The group of licensed design professionals responsible for the design of the project, which can include AOR,EOR, and others

EOR – Engineer of Record

GC – General Contractor

NCR – Non-conformance Report

Precaster – Precast Manufacturer, Precast Specialty Engineer (PSE), and Erector (Precaster used throughout document refers to all the precast entities as a whole)

PSE – Precast Specialty Engineer (a member of the precast team)

PSF – pounds per square foot

RFI – Request for Information

3. Definition of Delegated Design for Precast Concrete Structures

Delegated design is a unique situation in the construction industry that requires the collaboration of an Engineer of Record (EOR) and a Precaster to provide the engineering design of a structure with precast components. The EOR delegates the design of the primary precast concrete structural system or precast structural elements of the structure to the Precaster. Submittals of design documents to the design team (EOR and AOR) and the General Contractor (GC) by the Precaster are reviewed for general conformance to the design intent. Below are specific notes on delegated design.

1. Depending on the scope of services, the EOR may choose to designate responsibility of designing precast concrete primary structural systems, structural elements, or both to a Precaster. Responsibilities should be clearly defined in the Contract Documents (CDs).
2. The EOR may choose to specify and require means & methods items which are specifically excluded from the EOR's scope of work.
3. There is no legal contract between the EOR and Precaster.

4. The EOR's design documents should provide ample information for the Precaster to complete his or her portion of the design; recommended items are listed in EOR Responsibilities, Section 4.
5. Items that should be included or considered in the Precaster's design documents are outlined in Precaster's Responsibilities, Section 5.
6. Authority for design items should correspond to contractual and licensure responsibilities.
7. The Precaster will submit precast concrete design documents for review by the design team. The documents prepared by the Precaster should be reviewed by the EOR according to the process outlined in Section 7, Review of Delegated Design and Comment Resolution.

4. Responsibilities of the Engineer of Record

The EOR for a project is responsible for defining which structural elements are performance specified and to be designed by the Precaster. The EOR will define criteria for the design of the structure, including loads, serviceability requirements, material and durability requirements, and other performance requirements (see list below). The EOR will provide a complete design of the foundation systems and will design and define the lateral force resisting system. The lateral force resisting system design should include the distribution of load to precast elements to be designed by the Precaster, the design of the floor and roof diaphragms, including topping thickness and reinforcement, or should provide required design forces for pre-topped systems (see Section 9). Early collaboration between the EOR and the Precaster is encouraged to facilitate the development of these systems. If the EOR has assumed the use of temporary shoring in design and it is critical to the construction sequence, the EOR's drawings should clearly indicate locations where temporary shoring is required. The EOR will review submittals from the Precaster (see Section 6) and will perform site observations.

Project definition by the Design Team:

1. Building geometry
    a. Building grid
    b. Column layout
    c. Wall layout, panel joint locations, and openings
    d. Member sizes
    e. Expansion joint locations
    f. Slopes, drain locations
    g. Clear heights
    h. Floor elevations
    i. Bearing pad locations
2. Insulated wall panel insulation thickness or thermal performance requirements – composite or non-composite, wythe connectors
3. Details of Precast interfaces with other materials
4. Indicate required fabricator and erector qualifications and certifications.
5. Submittal requirements, indicating what content is required to be signed and sealed.
6. Precast supplier qualification requirements.

Design criteria to be defined by the EOR:

1. Design standards
    a. Indicate governing building code, including amendments.
    b. Other design standards not referenced by the governing building code
2. Loads
    a. Live loads (distributed and concentrated) with description or key plan which indicates where various live loads apply. Indicate whether live loads are reducible.
    b. Snow loads
        i. Ground snow load (PSF)
        ii. Roof snow load (PSF)
            1. Uniform (PSF)
            2. Drifting and sliding with diagrams and magnitudes
        iii. Snow storage area loads and locations
    c. Superimposed dead loads
        i. Magnitude and locations
    d. Topping thickness
        i. Assumed average topping thickness
    e. Wind loads applied to the precast system
        i. Wind speed (3-sec gust) and exposure
        ii. Component and cladding loads
            1. Locations, effective area, and pressures
        iii. Specific loads applied to each precast element in the lateral force resisting system
    f. Seismic loads applied to the precast system
        i. Spectral acceleration values
        ii. Site class
        iii. Response modification factor
        iv. Specific loads applied to each precast element in the lateral force resisting system
    g. Construction loads (if applicable)
    h. Thermal loads
    i. Future loads from building vertical or horizontal expansion, where applicable
    j. Special loads and requirements
        i. Blast resistance
        ii. Progressive collapse
        iii. Fire rating
    k. Define loads where elements not designed by Precaster are connected to precast
    l. Where precast loads are supported by the structure designed by the EOR, indicate location of loading and maximum permissible applied loads. The EOR should consider consequences of eccentricities.
3. Serviceability requirements for all precast elements.
    a. Deflection
    b. Vibration, where required.
    c. Camber, if limited, refer to Section 9.

4. Material and durability requirements
    a. Cast-in-place concrete mix design requirements, including topping slabs.
    b. Reinforcement types, grades and finishes
    c. Steel types, grades and finishes
    d. Masonry grades
    e. Welding
    f. Grout materials
    g. Bearing pads (often delegated to precaster)
5. Construction stability requirements for atypical conditions
6. Special erection procedures or sequences, where necessary

5. Responsibilities of the Precaster

The responsibilities of the Precaster Including detailed calculations, drawings, and support for means and methods during the construction process, are outlined below.

1. Provide specific member design and connection designs for the specified project criteria, as well as considerations for manufacturing, handling, storage, hauling, and erection.
2. Prepare submittals as indicated in Section 6, indicating how delegated design requirements have been achieved. Calculations should:
    a. Document a complete load path to foundations or supporting elements
    b. Use sound engineering judgment
    c. Provide loading diagrams
    d. Be sufficiently documented and clear, so that a 3rd party can follow
    e. Indicate loads from precast on elements designed by EOR
    f. Indicate member camber
    g. Identify controlling load combinations and members
    h. Have clear graphical design summaries
3. If the delegated design responsibilities include calculation of floor/roof diaphragm forces, foundation loads, or both, the results should be included on the drawings. Note this is not typical in Colorado.
4. The Precaster should select methods of handling, storage, shipping and erecting precast components, design lifting hardware; and additional reinforcement if required.
5. Include considerations for interface connections between precast and structural components of other materials.
6. The Precaster should communicate and seek solutions for issues that may be encountered, including deviations from the EOR's design intent.
    a) Do not make assumptions; request additional information and clarifications using communication channels appropriate for the project procurement method
    b) Report discrepancies in the construction documents to the design team for resolution among the respective disciplines
    c) Report spatial conflicts
    d) Propose alternative solutions

6. Timing (phasing) and Content of Precast Concrete Specialty Design Submittals

The timing and content of submittals are critical to the successful completion of a precast concrete project. Furthermore, it is crucial that all involved parties understand the expectations of all involved parties. Typically the involved parties including the Engineer of Record (EOR), Architect (AOR), Owner, General Contractor (GC) and Governing Building Official/ Authority Having Jurisdiction (AHJ). Each of these parties may have different expectations of what is expected for both the content and timing of the precast concrete specialty design submittals. Generally the content of precast concrete specialty design submittals can be divided into three tiers: with Tier 1 includes the most typical submitted information, Tier 2 consists of supplementary information and calculations less commonly required, and Tier 3 contains project specific supplementary information that is only included in submittals when requested:

Tier 1:

1. Project loading and design criteria
    a) Reference design codes and standards including project specific requirements
    b) Design loading criteria as described in Section 4
    c) Material properties
        i) Concrete compressive strengths
        ii) Unit weight of concrete
        iii) Steel reinforcement grades
        iv) Pre-stressing strand grades
        v) Welded wire reinforcement grades
        vi) Structural steel grades
2. Structural calculations for precast elements and connections
3. Erection drawings
    a) Plan
    b) Elevations
    c) Sections (without reinforcement detailing)
    d) Interfaces with other precast elements
    e) Interfaces with non-precast elements
    f) Locations of connections and magnitude of loads applied by precast to the non-precast elements
    g) Miscellaneous supplied steel drawings (such as plate drawings)

Tier 2:

4. Specialty calculations
    a) Fire resistance
    b) Thermal loads
    c) Blast resistance
    d) Progressive collapse
    e) Vibration
5. Materials

a) Concrete mix designs in accordance with project specifications
b) Mill certificates for reinforcement and structural steel

6. Architectural
   a) Appearance, including samples
   b) Finish
   c) Dimensional requirements
7. Construction stability
   a) Shoring and bracing plan
   b) Calculations

Tier 3:

8. Precast supplier qualification certificates
9. Piece drawings (including reinforcing layout)

The required timing of the submittals can have a significant impact on the cost and schedule of the project. It is in the best interest of the project overall to set forth reasonable expectations for the content and timing of submission for all required submittals in order to avoid multiple submittal revisions. It is important for each party to keep in mind the typical order of operations for all other parties. Below is a list of a typical order of operations on a conventional design, bid, build (DBB) project for precast suppliers and EORs.

Precaster:

1. Project request received
2. Conceptual layout drawings
3. Initial cost estimate
4. Award of project
5. Final EOR design documents received
6. Code Loading Criteria (CLC) submitted by Precaster and approved by EOR, see Section 6 Tier 1, item 1
7. Perform initial calculations
8. Revise conceptual drawings
9. Submit drawings and calculations for review by EOR
10. Revise drawings and calculations based on EOR comments
11. Create production drawings (piece drawings with reinforcement layout)
12. Submit For-Construction drawings (including erection drawings and production drawings)
13. Begin manufacturing process
14. Revise items as necessary during construction, such as those identified in non-conformance reports (NCR)
15. Complete manufacturing process
16. Issue As-Built Drawings, when required.

Engineer of Record:

1. Issue initial bid drawings
2. Receive bids

3. Complete contract documents
4. Issue drawings for construction
5. Review shop drawings and submittals
6. Project construction administration/construction phase services (RFI's, progress meetings, punch list)
7. Issue letter of general conformance and as-built Drawings, if required

Some common concerns for the timing of the submittals which should be considered at the onset of the project are as follows:

1. Precast manufacturers generally do not want to spend time or money working on submittals until the project is awarded, but are generally willing to assist with pre-construction concept designs.
2. Design changes should generally not be handled through the submittal process and subsequent revisions
3. Having the precast manufacturer provide submittals out of the optimum workflow for the manufacture of the products increases the effort associated with submittals and often results in multiple revisions
4. Having the precaster submit items prior to the EOR's completion of the final design often results in multiple revisions
5. The Authority Having Jurisdiction requesting to see precast concrete submittals at the time of permit requires special attention for design-build projects, and projects where a precaster is not awarded the project early

The content and timing of precast specialty design submittals are critical to the successful completion of a precast concrete project. Special attention should be given to developing reasonable expectations for the timing and content of these submittals.

7. Review of Delegated Design and Comment Resolution

A pre-design meeting should be scheduled well in advance of the start of the precast design, to review:

1. Loading design criteria
2. Special details
3. Site access
4. Structural depth
5. Precast member geometry and dimensions
6. Connections between precast elements
7. Locations and types of connections when connecting to non-precast elements designed by the EOR
8. Schedule of submittals
9. Trade coordination information
10. Project sequencing that effect design
11. Contact information
12. Information and communication procedures
13. Review of Precaster's question log

14. Clarification of ambiguities or special conditions

The EOR, Architect, Precaster, should all attend this meeting. Other trades may participate as needed. Many of the delegated design questions can be answered in this meeting. The Precaster should create a summary of questions in the form of a question log prior to attending this Pre-design meeting. Meeting minutes including action items should be distributed to all the attendees.

The review of the submittals by the Design Team and the EOR is for general conformance with the design intent of the Construction Documents (CDs). Questions and/or clarifications requested by the Precaster should be clouded on the submittal.

During submittal review, the EOR should identify and mark items not compliant with the CDs on the submittal to be returned to the Precaster. The Precaster should review the marked up comments and revise the delegated engineering submittal as required. If the Precaster questions or does not agree with the marked up comments, the Precaster should ask the EOR for additional clarification; a meeting in person may be warranted at this point.

Submittal comments are not an acceptable method for making changes to the CDs. If errors or omissions are found to exist in the CDs that are discovered by the EOR during the submittal review process, a formal change to the CDs should be generated. The method of documenting the change is to be determined by the Design Team and Contractor and is usually done by addendum, Architect's Supplemental Instructions (ASI), or other method.

8. Resolution of Issues During Construction

Issues arising during construction, after the submittal process as described in Section 6 is complete, can be problematic as no contractual relationship between the EOR and Precaster exists. It is essential that the design responsibilities between the EOR and the Precaster be clearly assigned and that the scope of services is carefully defined for all parties before the delegated engineering submittal process is started. Issues can arise due to regional variances and differing expectations. It is essential that both parties recognize that the success of the project is in their best interest even when there is no direct contractual obligation.

When issues occur, the following hierarchy of resolution methods are recommended:

1. Fully informed all parties of the issue through a phone call or email.
2. Identify a solution.
3. Identify who is responsible for designing and reviewing the repair.
4. Provide documentation of the solution such as a confirming RFI.

Issues may arise between the Precaster and the Contractor as a result of construction errors. Typical examples include:

- Misplacement of embedded material by other trades to be utilized by the Precaster, such as dowels or NMB sleeves
- Missing or misaligned embeds or blockouts

The Contractor has the final responsibility for the coordination of all trades on the project. The Precaster should ask to review the recommended repair to verify that it is acceptable for the final installation of the precast members. For example, precast erection may require welding to anchors, but if those anchors are installed using adhesives, welding may not be advisable as the heat may melt the adhesive. It is important that the Precaster allows the Contractor to coordinate the resolution and that the Precaster not become an unauthorized project manager for the Contractor.

9. CIP Topping Design and Camber

When a Precaster is awarded a project during the design phase, the Precaster and EOR should work collaboratively to define the lateral load force resisting system and cast-in-place (CIP) topping thickness required for precast composite action, vertical loading, and fire resistance. When a Precaster has not been selected during the design phase, the EOR should consult a Precaster for guidance and collaboration.

As a key component of the lateral force resisting system, the concrete topping thickness and reinforcement should be designed and documented by the EOR. The Precaster will design connections from the horizontal diaphragm system to the precast elements for the horizontal shear at the interface between the topping and precast elements in the lateral force resisting system.

The EOR will provide a complete topping slab design, including reinforcement, considering:

1. Diaphragm shear
2. Vertical loading
3. Chords
4. Collectors
5. Fire resistance

Delegating topping slab design to the Precaster is not appropriate. The EOR is responsible for design of the complete lateral force resisting system.

The EOR and the Design team will define the topping thickness, flatness, slopes, washes, and drainage. Multi-span conditions, such as those at cantilevers and balconies, are common sources of slope issues that should be considered. The EOR will define whether the topping is uniform thickness following the cambered precast profile, or if the topping thickness varies to make the floor level. EORs should recognize that varying topping thickness can affect both floor-to-floor height and the superimposed dead load imposed on the supporting floor members. Varying topping thickness and washes can also affect parapet heights.

The EOR will define joint types and joint locations in the topping. The EOR should consider if tooled or sawcut joints are acceptable, and how joints between precast elements will be sealed to prevent concrete from leaking through the joints during topping placement.

When a pre-topped system is used, the EOR should define the diaphragm shear forces, chord forces, and collector forces. The Precaster will design the precast elements and connections for the forces provided by the EOR. Slopes and washes should also be defined by the Design Team.

The Precaster is responsible for defining precast camber. Camber varies naturally between precast pieces. This phenomenon is due to creep during storage of the precast and other factors beyond the control of the Precaster. If a floor is to be placed flat by using a varying topping thickness, the variation in camber will affect the thickness of the topping, thus affecting gravity design of the structure, topping volume, and floor-to-floor height. The Precaster should discuss these issues with the Design Team and Contractor.

10. Tolerances for Precast Products and Interface Connections to Components of Other Materials

Coordination between the EOR, Precaster, and other trades should be carried out in order to develop an understanding of the tolerances and connections to be used.

Tolerances:

The EOR should specify applicable dimensional and placement tolerances for the precast components and other structures that adjoin precast components. Tolerances indicated in reference documents, such as PCI MNL-116, PCI MNL-117, ACI 301, and AISC 303 often differ at interfaces. The EOR should indicate in the CDs which tolerances should be used when industry guidelines differ, and at special conditions. Suggested tolerances to be specified include:

1. Precast material tolerances
2. Precast member dimensional tolerances
3. Connection and joint size tolerances
4. Other interface tolerances

The Precaster and EOR should coordinate project specific tolerances as needed, prior to issuing CDs when possible. In some cases, more or less stringent tolerances may be required to facilitate the interface with other systems.

Connections of components:

The EOR should include conceptual details of precast and structure interfaces in the CDs. If the project is in the early stages of design the Precaster should be engaged to offer guidance of appropriate connections. Details provided by the EOR should indicate:

1. Connection geometry indicating support locations
2. Anchor and connection types
3. How tolerances and clearances are accommodated
4. Permissible locations for connections to non-precast elements and the direction of loading

The Precaster should submit complete details and calculations of the precast system and interface with components not designed by the Precaster, per Section 6. Interface issues discovered by the Precaster between precast and other systems should be communicated to the EOR.

11. Loads and Stability during Construction

It is critical that the EOR, Precaster, and Contractor work together in the preconstruction stage to plan for construction sequencing and loading to maintain stability throughout the duration of construction. The discretized nature of precast systems and the absence of a completed lateral load resisting system, and its connections, during erection create inherent instability. To ensure the success of this phase of construction some suggested responsibilities are as follows:

Engineer of Record Responsibilities:

1. Per Section 4, if the EOR has assumed the use of temporary shoring that is critical to the construction sequence, these locations should be indicated in the CDs.
2. Indicate in the CDs which aspects of the construction stability plan are requested for review, if desired.

Precaster Responsibilities:

1. Means, methods, techniques, sequences, and procedures unless they have been specified by the EOR in the CDs.
2. Where required by the CDs, documentation showing structural stability in accordance with plans and specifications.
3. In erection drawings, include component handling and bracing/stability information (unless otherwise contained in a developed erection plan).

Contractor Responsibilities:

1. Temporary loading
    a) Equipment used for construction
    b) Stockpiling of materials
    c) Scaffolding
2. Construction sequence or deviation from the communicated construction sequence

Examples requiring close collaboration:

- Retaining walls interfacing with the precast structure that may have a specific backfilling sequence
- Composite construction where temporary shoring was assumed in the design (communicate assumptions by EOR to contractor)
- Shoring of structures elevated above precast structures

12. BIM and Collaboration

The implementation of Building Information Modeling for total-precast structures is a still developing topic. For the sake of this paper we provide current practices in Colorado. On projects where the Precaster is brought on early, either the Precaster provides the precast building information model and the EOR models the foundation and other structures, or the EOR can provide the overall structural model including the precast. For partial-precast structures, it is more likely that the EOR will provide an overall model.

Since models are not used to manufacture precast products, the Precaster does not gain significant value from Building Information Modeling, and it is often not a required part of their scope of work as it is not relied upon to manufacture precast product. It is current practice for a Precaster in this locale to generate a model only when required by the CDs. When a model is required or developed it is best practice for the Precaster to coordinate with all other models (architectural and structural) and to bring attention to any conflicts found.

If a precast contractor is awarded a project early, before design has begun, such as could occur with Design-Build, CMGC, or CMAR contracting methods, the Precaster is a collaborative part of the design team. In this case, the Precaster and EOR should work collaboratively to define the precast structural system, including design criteria, floors, roofs, walls, columns, topping, foundation loads, and the lateral load force resisting system. The Precaster should define required precast dimension such as depth, width, thickness, and overall geometry for overall coordination with the EOR. An open dialogue between the EOR and the Precaster is beneficial and essential for a successful project.

When a precast contractor is not awarded project early, but instead bids a project after completion of bid documents, the EOR is encouraged to work with a Precaster during design for guidance and collaboration. Many precast organizations are willing to assist EORs in the development and planning of structural systems. As a precast contractor is not under contract in this delivery system, the EOR develops a Building Information Model for non-precast and precast structural elements. After the project is awarded, the precast design is based strictly on the construction documents prepared by the EOR. Refer to Section 6 for content of precast design submittals.

As the industry evolves and precast producers begin to develop production drawings directly from the model, it is likely that the Precaster will develop the precast model independently. This model can potentially be used to for collaboration and coordination. If discrepancies are found between models, they will be resolved by the contractor through input from the parties involved.