What's new in the precast industry?

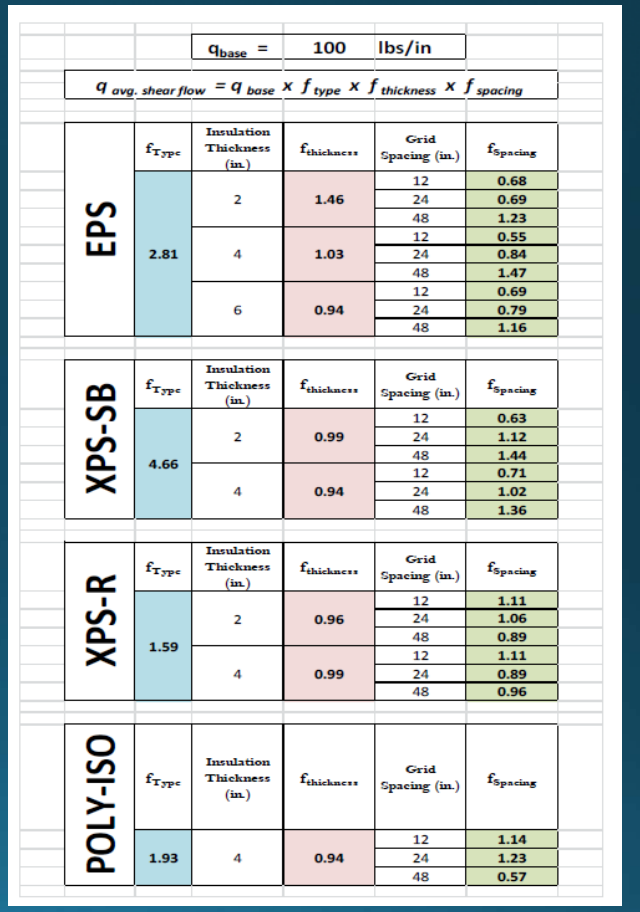
- Seismic provisions
  - Chapter 26
  - ASCE 7-16
- High – tech materials
- ACI 318-14
  - Plate-bending for spandrel beams
  - Updated

Innovative products

- Carbon-cast walls
- Carbon reinforced TT flanges
- UHPC

Composite Insulated Wall Panels C-Grid Design Approach

Shear Flow Design Equation



q_{base} = 100 lbs/in

$q_{avg.\ shear\ flow} = q_{base} \times f_{type} \times f_{thickness} \times f_{spacing}$

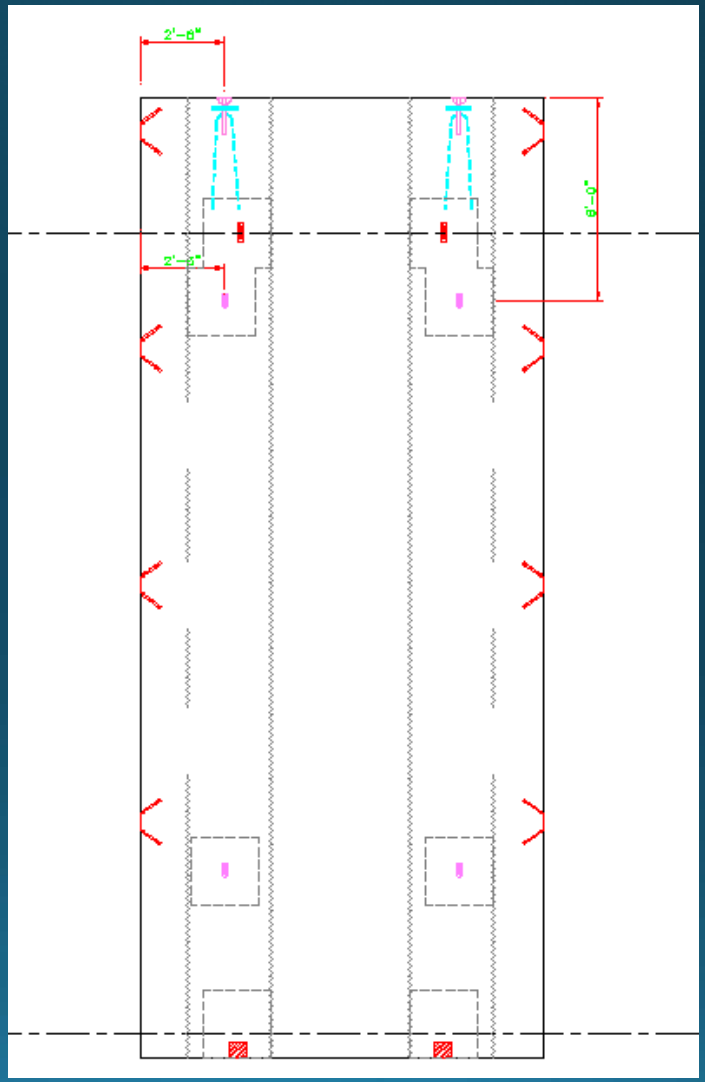
	f_{Type}	Insulation Thickness (in.)	$f_{thickness}$	Grid Spacing (in.)	$f_{Spacing}$
EPS	2.81	2	1.46	12	0.68
				24	0.69
				48	1.23
		4	1.03	12	0.55
				24	0.84
				48	1.47
		6	0.94	12	0.69
				24	0.79
				48	1.16

	f_{Type}	Insulation Thickness (in.)	$f_{thickness}$	Grid Spacing (in.)	$f_{Spacing}$
XPS-SB	4.66	2	0.99	12	0.63
				24	1.12
				48	1.44
		4	0.94	12	0.71
				24	1.02
				48	1.36

	f_{Type}	Insulation Thickness (in.)	$f_{thickness}$	Grid Spacing (in.)	$f_{Spacing}$
XPS-R	1.59	2	0.96	12	1.11
				24	1.06
				48	0.89
		4	0.99	12	1.11
				24	0.89
				48	0.96

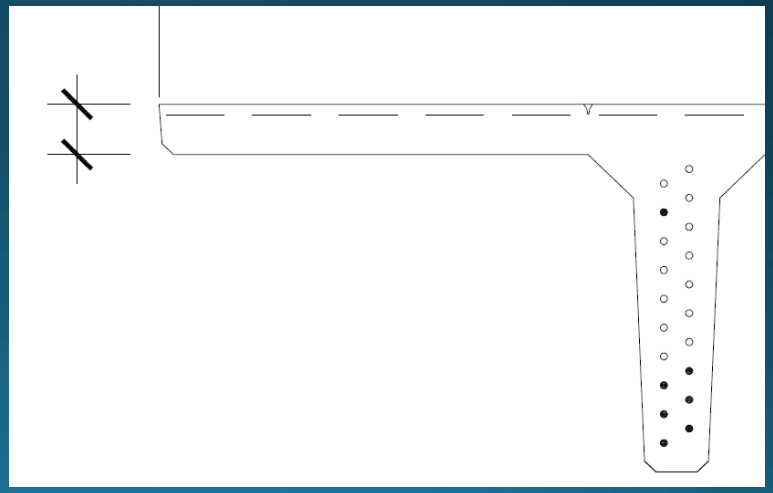
	f_{Type}	Insulation Thickness (in.)	$f_{thickness}$	Grid Spacing (in.)	$f_{Spacing}$
POLY-ISO	1.93	4	0.94	12	1.14
				24	1.23
				48	0.57

Grid Layout



Carbon-reinforced TT flange

- Non-corrosive reinforcing in parking garages
- Thinner sections with less cover requirement
- Lighter structures



How much detail should I provide on my drawings if each precaster has their own preferred connections?

Specialty Engineers/EOR

- Most precast concrete projects involve delegation of engineering design for some part of the structure
- The Structural Engineer of Record is engaged by an architect or owner and has a duty to the interests of that architect or owner.
- The Specialty Engineer for the Precast Concrete is engaged or employed by the precast concrete manufacturer and has a duty to the interests of that manufacturer

Precast Concrete

As SER, what part of the design of a precast/prestressed concrete project are you designing?

- Do you design the gravity and lateral force-resisting system, the components and the connections and only require submittal of shop drawings to verify that the intent of design has been understood and executed?
- Do you design the gravity and lateral force-resisting system, and the connections and only require submittal of calculations for the components and shop drawings to verify that the intent of design has been understood and executed?
- Do you design the gravity and lateral force-resisting system, and assign the design of precast components and connections to the Precast Specialty Engineer?

- Do you check only enough of the configuration and systems to develop a preliminary foundation design, and wait for the Precast Specialty Engineer to provide a completed design of the gravity and lateral force resisting system with foundation loads to complete the design?
- Do you only get involved to design the foundation after the Specialty Structural Engineer has done a complete design of the superstructure based on his foundation assumptions?

- CASE Guidelines implicitly assume that the role of the Structural Engineer of Record follows the 2nd or 3rd level of delegated design:
  - Designate elements to be designed by SSE's. Specify the type of element and position within the structural system. Specify the structural criteria for the SSE's design of the pre-engineered structural elements. Specify required submittals from the SSE for review.

- CASE Guidelines for the Specialty Engineer continue the same assumption.
  - SSE services may include structural steel connections, precast, prestressed concrete components and connections, post-tensioned members and connections, timber trusses, pre-engineered metal buildings, metal plate connected wood trusses, open web steel joists. In these cases, the SER may require that the SSE seal work resulting from the design of these items. In any case, these designs should be reviewed by the SER, since primary structural systems are usually included in the basic services of the SER, unless specifically exempt by contract.

- As applicable, SER's contract documents shall identify:
  - Scope of precast component designs to be delegated
  - Component configuration and acceptable/unacceptable connection locations with assumed/maximum forces
  - Schematic representations of components, connections and/or supporting conditions
  - Loading to be imposed on the elements or systems
    - Are they factored or service loads?
  - Performance requirements (e.g. deflection requirements, temperature considerations, corrosion and fire protection requirements, etc…)

- As applicable, the delegated design engineer shall provide fabrication and erection drawings, calculations, and concrete mix designs showing compliance with project contract documents.

Drawings shall Provide

- Reinforcing quantity & details
- Fully detailed bracing and connections
- Loads imposed on the supporting structure
- Location and magnitude of the building reactions on the foundation under all design conditions

Calculations shall

- Indicate design methodology (ASD or LRFD)
- Provide full design of all components, bracing and connections accounting for S&H, and erection
- Demonstrate performance of the overall system

- My Experience as both Structural Engineer of Record and Specialty Engineer for Precast/prestressed Concrete is very different from the practice and relationships assumed by the Guidelines
- My projects tend to be like the 4th bullet point and some are even like the 5th. None are like the 1st, except when I assume the role as both SER and SSE on a project.

- The Engineer of Record is the owner's representative, design Professional and agent
- The Specialty Structural Engineer is engaged by a subcontractor who has the job based on his low bid
  - The job of the SSE is to provide design for the lowest cost of construction that conforms to the drawings, specifications and building code.
  - The SSE get the project because he is either recognized as being very good at meeting the subcontractors objective, is himself a low bidder, or both.

- The Engineer of Record is the owner's representative, design Professional and agent
- The Specialty Structural Engineer is engaged by a subcontractor who has the job based on his low bid
  - If our responsibilities and priorities are clear, the relationship between SER and SSE should not be one of cooperation and not adversarial
  - Our goal is the best possible project for everyone

- The SER usually has months of work in schematic design, design development and contract drawings working with the architect, the Owner, and other design professionals to define the structural requirements for the project, coordinated with the requirements of all these others

- The SER, in most states, bears an overall responsibility for the structural performance of the building

- The SSE, based on special expertise, specialized design resources, and knowledge and procedures in the manufacture, erection, and performance of precast/prestressed concrete, is delegated responsibility for the design of part of the project.
- The SSE, in most states, is responsible for what he or she designs and draws, and not for structure not provided by the precast concrete manufacturer.
- The SSE must rely on the SER to provide the detailed criteria developed for the project prior to bid

What does the SSE for precast concrete need?

- Structural drawings that comply with the requirements of the IBC

1603.1 General. *Construction documents* shall show the size, section and relative locations of structural members with floor levels, column centers and offsets dimensioned. The design loads and other information pertinent to the structural design required by Sections 1603.1.1 through 1603.1.8 shall be indicated on the *construction documents*.

Structural requirements of the IBC

- 1603.1.1 Floor live load
- 1603.1.2 Roof live load
- 1603.1.3 Roof snow load data
- 1603.1.4 Wind design data
- 1603.1.5 Earthquake design data
- 1603.1.6 Geotechnical information
- 1607.1.7 Flood design data
- 1607.1.8 Special loads

- Checklist for Engineers of Record
  - Calculations:
    - General
    - Lateral Design
    - Connection Design
    - Component Design
  - Erection Drawings

- General
  - Is the criteria correct?
  - Are the stated assumptions correct?

Gravity & Lateral Design

- Is the LFRS correct and consistent with the foundation design?
- Are the seismic factors correct?
- Are the wind factors correct?
- Are the resulting base reactions consistent with the foundation design?

- Connection Design
  - Are structural integrity requirements met?
  - Are capacities of proprietary inserts interpreted correctly?
  - Is there a reasonable representation of the load paths that are considered?

- Component Design
  - Check cautions on computer printouts
    - If the computer output is not clear, ask
  - Shear/torsion of deep spandrels
  - Check that bilinear behavior for beam deflection with cracked sections calcs has been used
  - Have fire endurance ratings been satisfied for 3 end points?

Component Design

- Check that requirements for limited shear reinforcement in double-tees is satisfied
  - Simple span
  - Uniform loads
  - Class U or T flexural behavior

See March/April 2004 PCI Journal

Erection Drawings

- Are drawings clear and easy to follow?
- Are changes from contract drawings identified?
- Is the interface with the foundation drawings correct and coordinated?

Provide Answers to Questions

❖ Consider thermal movement capability

- Is an expansion joint necessary?

- Connections
  - Confirm that details are consistent with calculations.
  - Do not require excessive weld.
  - Confirm patching requirements.
  - Are material finishes correct?

ACI 318-14 Chapter 26

- **26.1.1** This chapter addresses (a) through (c):
  a. Design information that the licensed design professional shall specify in the construction documents, if applicable.
  b. Compliance requirements that the licensed design professional shall specify in the construction documents, if applicable.
  c. Inspection requirements that the licensed design professional shall specify in the construction documents, if applicable.

ACI 318-14 Chapter 26

- This chapter establishes the minimum requirements for information that must be included in the construction documents as applicable to the project. The requirements include information developed in the structural design that must be conveyed to the contractor, provisions directing the contractor on required quality, and inspection requirements to verify compliance with the construction documents.

- ACI 318-14 Chapter 26
  - This chapter is directed to the licensed design professional responsible for incorporating project requirements into the construction documents. The construction documents should contain all of the necessary design and construction requirements for the contractor to achieve compliance with the Code. It is not intended that the Contractor will need to read and interpret the Code.

ACI 318-14 Chapter 26

- It is recognized that there are situations, such as those in precast or post-tensioned structures, where design and detailing of portions of the Work are delegated to specialty contractors who may retain the services of a specialty engineer. Such specialty engineers should be licensed design professionals who are sufficiently knowledgeable in the design and construction of the structural items being delegated for design.

ACI 318-14 Chapter 26

- Does not place a requirement on the SSE to provide the design criteria for the project.
- The commentary suggests that the SSE needs to know only enough of the code to complete the design delegated to them.

What are the differences in detailing for precast in seismic design categories A to F?

- SDC A and B do not have seismic detailing requirements for precast concrete
- SDC C: Walls that are part of the LFRS must be intermediate precast concrete walls
- SDC C: Collectors and their connections to the LFRS must be designed for forces amplified by the Ω_o system overstrength factor.

What are the differences in detailing for precast in seismic design categories A to F?

- SDC D, E, and F require detailing for special seismic systems in accordance with Chapter 18
  - Moment frames: 18.2.3 through 18.2.8 and 18.9
  - Walls: 18.2.3 through 18.2.8 and 18.11

SDC D, E & F

- **18.9.2.1** Special moment frames with ductile connections constructed using precast concrete shall satisfy (a) through (c):

(a) Requirements of 18.6 through 18.8 for special moment frames constructed with cast-in-place concrete

(b) V_n for connections calculated according to 22.9 shall be at least $2V_e$, where V_e is in accordance with 18.6.5.1 or 18.7.6.1

(c) Mechanical splices of beam reinforcement shall be located not closer than $h/2$ from the joint face and shall satisfy 18.2.7

SDC D, E & F

- **18.9.2.2** Special moment frames with strong connections constructed using precast concrete shall satisfy (a) through (e):

(a) Requirements of 18.6 through 18.8 for special moment frames constructed with cast-in-place concrete

(b) Provision 18.6.2.1(a) shall apply to segments between locations where flexural yielding is intended to occur due to design displacements

(c) Design strength of the strong connection, ΦS_n, shall be at least S_e

(d) Primary longitudinal reinforcement shall be made continuous across connections and shall be developed outside both the strong connection and the plastic hinge region

(e) For column-to-column connections, ΦS_n shall be at least $1.4S_e$, ΦM_n shall be at least $0.4M_{pr}$ for the column within the story height, and ΦV_n shall be at least V_e in accordance with 18.7.6.1

SDC D, E & F

- **18.9.2.3** Special moment frames constructed using precast concrete and not satisfying 18.9.2.1 or 18.9.2.2 shall satisfy (a) through (c):

(a) ACI 374.1

(b) Details and materials used in the test specimens shall be representative of those used in the structure

(c) The design procedure used to proportion the test specimens shall define the mechanism by which the frame resists gravity and earthquake effects, and shall establish acceptance values for sustaining that mechanism. Portions of the mechanism that deviate from Code requirements shall be contained in the test specimens and shall be tested to determine upper bounds for acceptance values.

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SDC D, E & F

- **18.11—Special structural walls constructed using precast concrete**
- **18.11.1** *Scope*
- **18.11.1.1** This section shall apply to special structural walls constructed using precast concrete forming part of the seismic-force-resisting system.
- **18.11.2** *General*
- **18.11.2.1** Special structural walls constructed using precast concrete shall satisfy 18.10 and 18.5.2.
- **18.11.2.2** Special structural walls constructed using precast concrete and unbonded post-tensioning tendons and not satisfying the requirements of 18.11.2.1 are permitted provided they satisfy the requirements of ACI ITG-5.1.

ASCE 7-16

- *New diaphragm design requirements for precast concrete diaphragms in structures assigned to SDC C, D, E, and F.*
- *Based on Diaphragm Seismic Design Methodology*
- *Optional for other materials, except steel deck diaphragms are not included*