# Fundamentals of Structural Engineering

## *...for Building Officials*

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## Course Objectives

- ***The intent of this course is to...***
  1. To better understand the importance of ensuring a complete gravity and lateral load path.
  2. To get a general understanding of key referenced structural standards.
  3. To understand some of the key structural elements to review in relation to wood, steel, concrete, and masonry structures.

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# Seminar Format

***Day 1: Load Paths & Wood-Framed Construction***

1) Introduction
2) Load Paths
3) Wood-Framed Construction

***Day 2: Steel, Concrete & Masonry Construction***

4) Concrete Construction
5) Masonry Construction
6) Steel Construction

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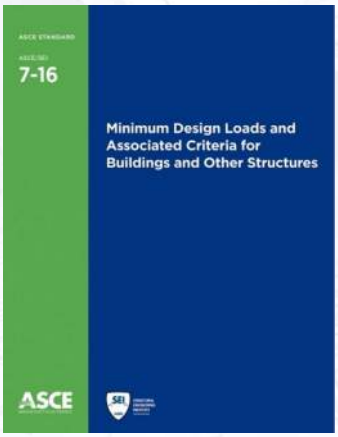
# Codes/Standards


International Code Council, 2021 IBC©




American Society of Civil Engineers, ASCE 7-16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# Resources


SEAOC, International Code Council & NCSEA ©

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# Resources

- ***2020 NEHRP Design Examples***
  - Free from FEMA's website
  - https://www.fema.gov/sites/default/files/documents/fema_nehrp_design-examples-training-materials_volume-1.pdf


FEMA P-2192-V1, Design Examples©

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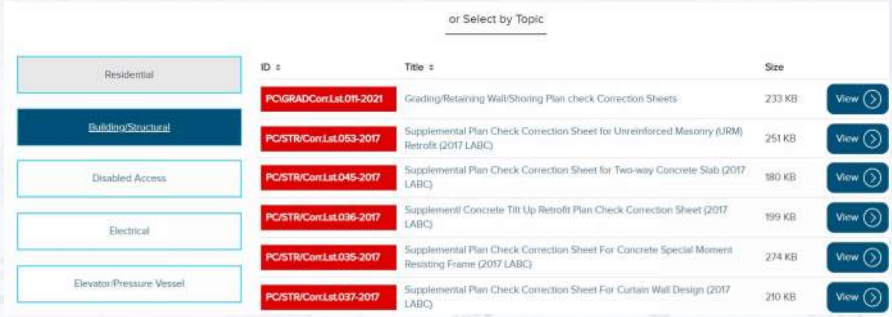
# Resources

- ***LADBS Standard Plan Check Correction Lists***
  - https://www.ladbs.org/forms-publications/forms/standard-correction-list

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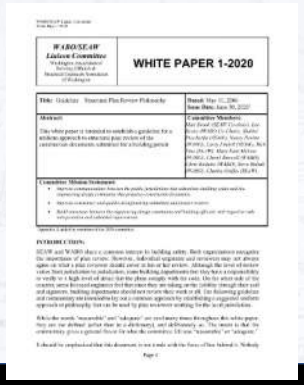
# WABO / SEAW White Papers

- ***Structural Plan Review Philosophy***
- ***Structural Permit Submittal Guidelines***





***https://www.seaw.org/codeswhite-papers***

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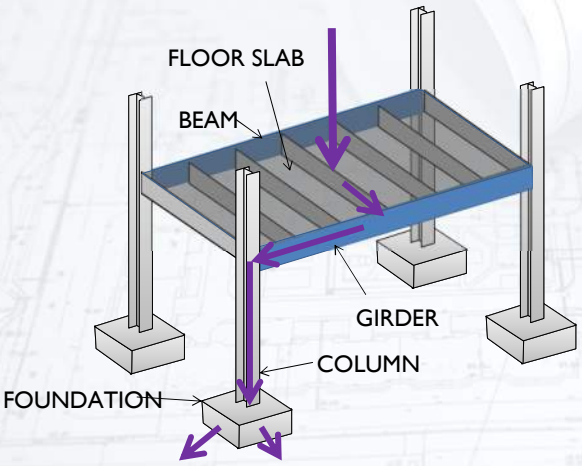
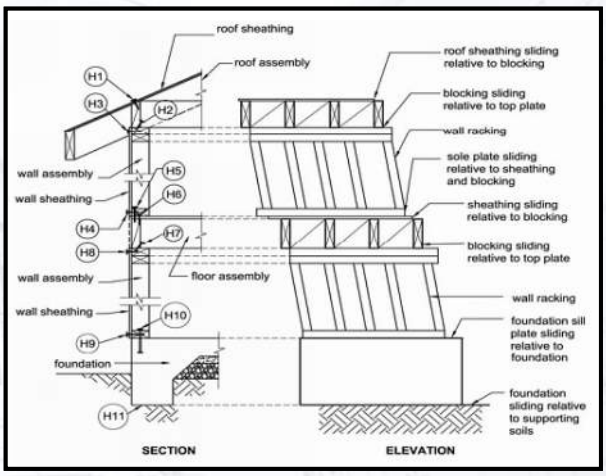
# Gravity, Lateral & Uplift Load Paths




FEMA 232: "Homebuilder's Guide to Earthquake Resistant Design and Construction"

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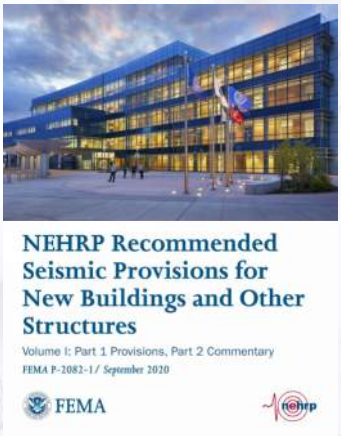
# NEHRP Provisions

***Serve as basis of IBC seismic provisions:***

- Main purpose is to prevent serious injury and life loss
- Focuses on collapse prevention
- "The degree to which these goals can be achieved depends on a number of factors including ***structural framing type***, ***building configuration***, ***materials***, ***as-built details*** and ***overall quality of design***."




National Earthquakes Hazard Reduction Program (NEHRP), FEMA P-2082-1, 2020

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# Construction Documents

- Shall show size, section & relative location of structural members with floor levels, column centers and offsets dimensioned. (IBC 1603.1)
- Load information must be provided.

**GENERAL**

1 **Building Code: International Building Code (IBC), 2018 Edition.**
Material Codes:
ASCE 7-16, "Minimum Design Loads and Associated Criteria for Buildings and Other Structures"
AISC 360-16, "Specification for Structural Steel Buildings"
AISC 341-16, "Seismic Provisions for Structural Steel Buildings"
ACI 318-14, "Building Code Requirements for Structural Concrete and Commentary"
ACI 530, 2013 ed. "Building Code Requirements and Specification for Masonry Structures"

2 **Design Gravity Loads:**
Roof Dead Load = 16 psf
Roof Live Load (Reducible) = 20 psf
Floor Live Load = 100 psf
Assumed Construction Live Load = 50 psf

3 **Design Wind Loads:**
Ultimate Design Wind Speed ($V_{ult}$) = 103 mph
Nominal Design Wind Speed ($V_{ASD}$) = 80 mph
Risk Category = II
Wind Exposure Category = C
Internal Pressure Coeff, $GC_{pi}$ = +/-0.18

**Components and Cladding:**
Refer Components and Cladding Diagram and Schedule

4 **Design Snow Loads:**
Ground Snow Load, $p_g$= 25 psf
Flat Roof Snow Load, $p_f$ = 20 psf
Snow Exposure Factor, $c_e$ = 0.9
Snow Load Importance Factor, I = 1.0
Thermal Factor; $c_t$ = 1.0

5 **Design Seismic Loads:**
Seismic Importance Factor, I = 1.0
Risk Category = II
5% Damped Spectral Response Acceleration Parameter, $S_s$ = 1.027
1-sec Period Spectral Response Acceleration Parameter, $S_1$ = 0.910
Site Class = F
5% Damped Spectral Response Coefficient, $S_{DS}$ = 0.685
1-sec Period Spectral Response Coefficient, $S_{D1}$ = 1.517
Seismic Design Category = D
Seismic Force Resisting System = Bearing Wall, Intermediate Precast Shear Walls
Response Modification Factor, R = 4
Seismic Force Resisting System = Steel Special Concentrically Braced Frames
Response Modification Factor, R = 6
Seismic Response Coefficient, $C_s$ = 0.171 (for R=4)
Analysis Method = Equivalent Lateral Force Procedure
Design Base Shear (V) = 0.171 W (0.120 W Service)

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# Wood-Framed Construction

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# PART 4
## Concrete Construction

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## Codes/Standards


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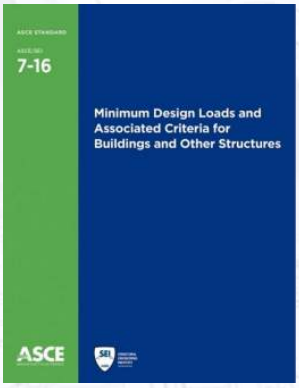
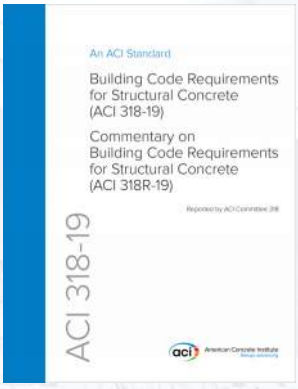



American Society of Civil Engineers, ASCE 7-16©




American Concrete Institute, ACI 318-19©

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# Resources


FEMA P-1051, Design Examples©


SEAOC, International Code Council & NCSEA ©


SEAOC, International Code Council & NCSEA ©

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# Concrete Construction

- ❑ Shallow foundations *(footings & foundation walls)*
- ❑ Deep foundations
- ❑ Retaining walls
- ❑ Shear & bearing walls
- ❑ Columns
- ❑ Diaphragms
- ❑ Slabs-on-grade
- ❑ Precast / Tilt-up
- ❑ Post- or pre-tensioned

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# IBC Requirements

- ***IBC Chapter 17 – Special Inspections***
  - Should be included in Statement of Special Inspections *(IBC 1704.3)*
  - **Several Concrete Exceptions** *(IBC 1705.3)*:
    - Isolated footings of buildings ≤ 3-stories
    - Continuous footings of buildings ≤ 3-stories, if…
      - Light-frame construction, or…
      - Per IBC Table 1809.7, or…
      - Designed considering 2,500psi for strength
    - Nonstructural slabs & flatwork
    - Foundations walls constructed per IBC Table 1807.1.6.2


International Code Council, 2021 IBC©

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**TABLE 1705.3**
**REQUIRED SPECIAL INSPECTIONS AND TESTS OF CONCRETE CONSTRUCTION**

| TYPE | CONTINUOUS SPECIAL INSPECTION | PERIODIC SPECIAL INSPECTION | REFERENCED STANDARD[a] | IBC REFERENCE |
|---|---|---|---|---|
| 1. Inspect reinforcement, including prestressing tendons, and verify placement. | — | X | ACI 318: Ch. 20, 25.2, 25.3, 26.6.1-26.6.3 | — |
| 2. Reinforcing bar welding: | | | | |
| a. Verify weldability of reinforcing bars other than ASTM A706; | — | X | AWS D1.4 ACI 318: 26.6.4 | — |
| b. Inspect single-pass fillet welds, maximum $^5/_{16}$"; and | — | X | | |
| c. Inspect all other welds. | X | — | | |
| 3. Inspect anchors cast in concrete. | — | X | ACI 318: 17.8.2 | — |
| 4. Inspect anchors post-installed in hardened concrete members.[b] | | | | |
| a. Adhesive anchors installed in horizontally or upwardly inclined orientations to resist sustained tension loads. | X | — | ACI 318: 17.8.2.4 | — |
| b. Mechanical anchors and adhesive anchors not defined in 4.a. | — | X | ACI 318: 17.8.2 | |
| 5. Verify use of required design mix. | — | X | ACI 318: Ch. 19, 26.4.3, 26.4.4 | 1904.1, 1904.2 |
| 6. Prior to concrete placement, fabricate specimens for strength tests, perform slump and air content tests, and determine the temperature of the concrete. | X | — | ASTM C31 ASTM C172 ACI 318: 26.5, 26.12 | — |
| 7. Inspect concrete and shotcrete placement for proper application techniques. | X | — | ACI 318: 26.5 | — |
| 8. Verify maintenance of specified curing temperature and techniques. | — | X | ACI 318: 26.5.3-26.5.5 | — |
| 9. Inspect prestressed concrete for: | | | | |
| a. Application of prestressing forces; and | X | — | ACI 318: 26.10 | — |
| b. Grouting of bonded prestressing tendons. | X | — | | |
| 10. Inspect erection of precast concrete members. | — | X | ACI 318: 26.9 | — |
| 11. For precast concrete diaphragm connections or reinforcement at joints classified as moderate or high deformability elements (MDE or HDE) in structures assigned to Seismic Design Category C, D, E or F, inspect such connections and reinforcement in the field for: | | | ACI 318: 26.13.1.3 | — |
| a. Installation of the embedded parts | X | — | | |
| b. Completion of the continuity of reinforcement across joints. | X | — | ACI 550.5 | |
| c. Completion of connections in the field. | X | — | | |
| 12. Inspect installation tolerances of precast concrete diaphragm connections for compliance with ACI 550.5. | — | X | ACI 318: 26.13.1.3 | — |
| 13. Verify in-situ concrete strength, prior to stressing of tendons in post-tensioned concrete and prior to removal of shores and forms from beams and structural slabs. | — | X | ACI 318: 26.11.2 | — |
| 14. Inspect formwork for shape, location and dimensions of the concrete member being formed. | — | X | ACI 318: 26.11.1.2(b) | — |

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***Is an SSI simply reproducing the tables?***

***Are there items in Table 1705.3 that commonly do not apply?***

***What does periodic mean?***

***Who is qualified to perform concrete special inspections?***

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# IBC Requirements

- ***IBC Chapter 18 - Foundations***
  - Much of this Chapter applies to soils items, but there are several concrete elements discussed as well.
  - This includes:
    - Foundation & Retaining Walls
    - Concrete Foundations
    - Shallow Foundations
    - Deep Foundations


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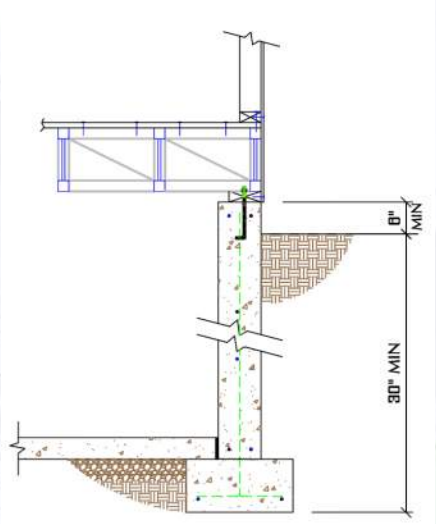
# IBC Requirements

- ***Foundation & Retaining Walls***
  - **Restrained Foundation Wall** (IBC 1610.1): Walls *"…in which horizontal movement is restricted at the top…"*

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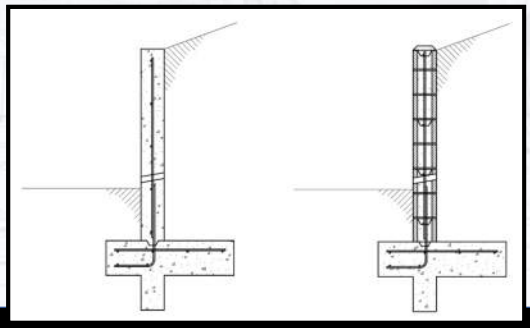
# IBC Requirements

## ❑ *Foundation & Retaining Walls*

- **Retaining Walls:** *"A wall not laterally supported at the top, that resists lateral soil load and other imposed loads."*
- Wikipedia: *"**Structures** designed to restrain soil to unnatural slopes."*





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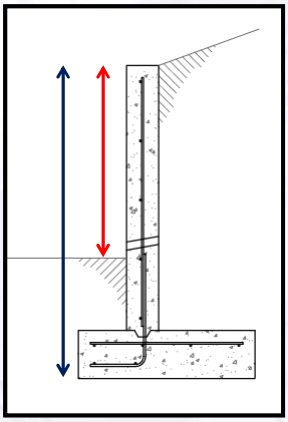
# IBC Requirements

## ❑ *Foundation & Retaining Walls*

- **IBC 105.2:** *"Retaining walls that are not over 4 feet in height measured from the bottom of the footing to the top of the wall, unless supporting a surcharge…"*
- There are two very important items to consider…
  - **Item #1:**
    - How tall above grade can the wall be in your jurisdiction?
    - 30" Frost → 18" grade-to-grade
  - **Item #2:**
    - What is a surcharge?





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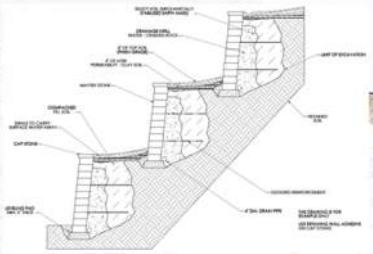
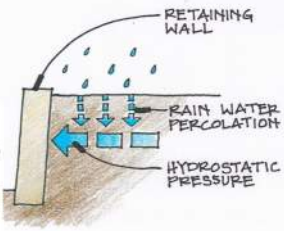
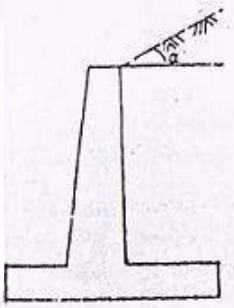
# IBC Requirements

- ***Foundation & Retaining Walls***
- **Potential Surcharge Loads…**
  - Vehicle surcharge
  - Sloped backfill
  - Hydrostatic pressure
  - Terracing





Positive surcharge of sloping earth

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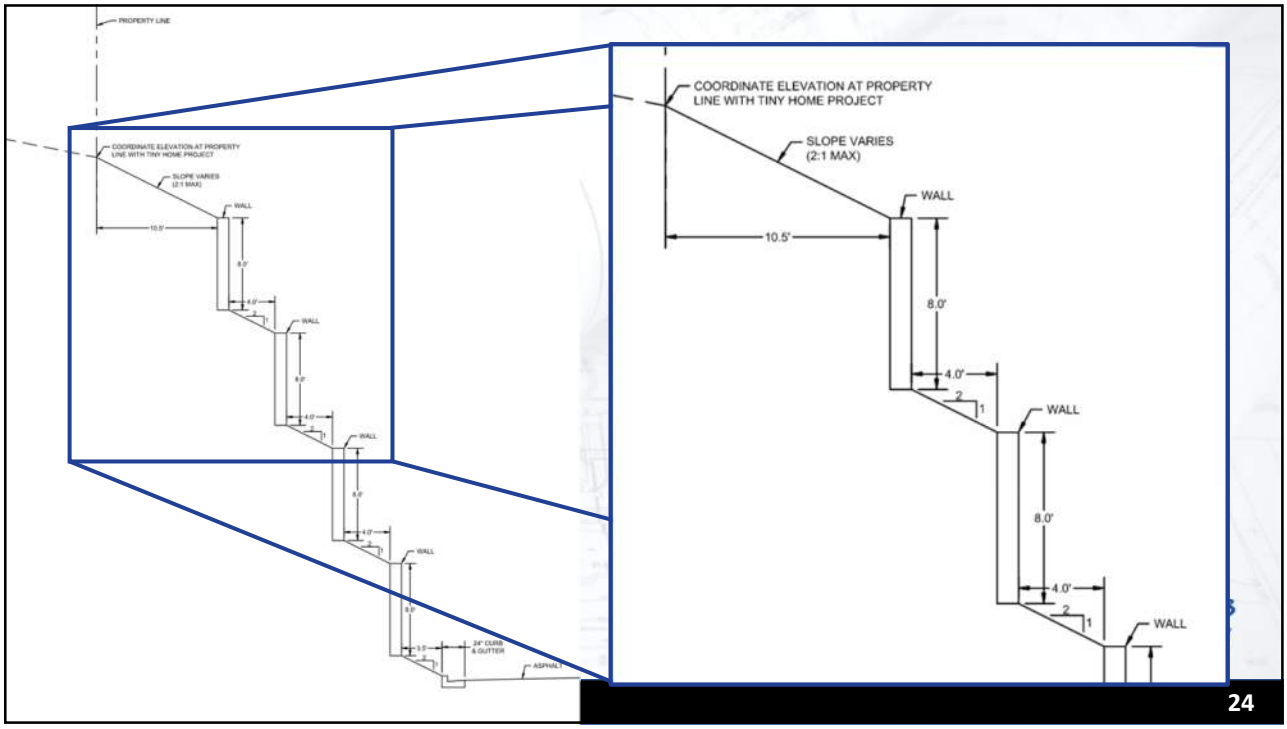


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# IBC Requirements

## ❑ *Foundation & Retaining Walls*

- **IBC 1610.1:** *"Foundation and retaining walls shall be designed to resist lateral soil loads."*
- IBC Table 1610.1 can be used unless a geotechnical investigation is mandated.
- Restrained Foundation Walls → At-rest Pressure
  - Exception: ≤ 8-feet & laterally supported → Active
- Retaining Walls → Active Pressure
- Surcharge loads shall be added to lateral earth pressure

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**TABLE 1610.1**
**LATERAL SOIL LOAD**

| DESCRIPTION OF BACKFILL MATERIAL[c] | UNIFIED SOIL CLASSIFICATION | DESIGN LATERAL SOIL LOAD[a] (pound per square foot per foot of depth) | |
|---|---|---|---|
| | | Active pressure | At-rest pressure |
| Well-graded, clean gravels; gravel-sand mixes | GW | 30 | 60 |
| Poorly graded clean gravels; gravel-sand mixes | GP | 30 | 60 |
| Silty gravels, poorly graded gravel-sand mixes | GM | 40 | 60 |
| Clayey gravels, poorly graded gravel-and-clay mixes | GC | 45 | 60 |
| Well-graded, clean sands; gravelly sand mixes | SW | 30 | 60 |
| Poorly graded clean sands; sand-gravel mixes | SP | 30 | 60 |
| Silty sands, poorly graded sand-silt mixes | SM | 45 | 60 |
| Sand-silt clay mix with plastic fines | SM-SC | 45 | 100 |
| Clayey sands, poorly graded sand-clay mixes | SC | 60 | 100 |
| Inorganic silts and clayey silts | ML | 45 | 100 |
| Mixture of inorganic silt and clay | ML-CL | 60 | 100 |
| Inorganic clays of low to medium plasticity | CL | 60 | 100 |
| Organic silts and silt clays, low plasticity | OL | Note b | Note b |
| Inorganic clayey silts, elastic silts | MH | Note b | Note b |
| Inorganic clays of high plasticity | CH | Note b | Note b |
| Organic clays and silty clays | OH | Note b | Note b |

For SI: 1 pound per square foot per foot of depth = 0.157 kPa/m, 1 foot = 304.8 mm.

a. Design lateral soil loads are given for moist conditions for the specified soils at their optimum densities. Actual field conditions shall govern. Submerged or saturated soil pressures shall include the weight of the buoyant soil plus the hydrostatic loads.

b. Unsuitable as backfill material.

c. The definition and classification of soil materials shall be in accordance with ASTM D2487.



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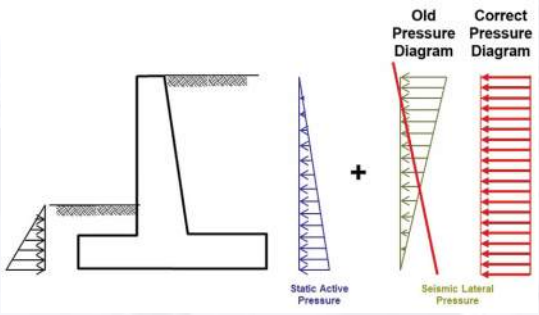
# IBC Requirements

- ***Foundation & Retaining Walls***
  - **IBC 1803.5.12 & 1807.2.2:** Seismic lateral earth pressures must be considered for both foundation and retaining walls if > 6-feet of backfill.
  - Prescriptive requirements are not given. A geotechnical engineer must specify these pressures.




Structure® Magazine, "Common Misunderstandings with Geotechnical Work", December 2016

**1807.2.2 Design lateral soil loads.** Retaining walls shall be designed for the lateral soil loads set forth in Section 1610. For structures assigned to Seismic Design Category D, E, or F, the design of retaining walls supporting more than 6 feet (1829 mm) of backfill height measured to the bottom of the footing shall incorporate the additional seismic lateral earth pressure in accordance with the geotechnical investigation where required in Section 1803.2.

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# IBC Requirements

1.03 ≈ 1.5

- ***Foundation & Retaining Walls***
  - **IBC 1807.2:** Retaining walls must be designed for overturning, sliding, excessive foundation pressure, and water uplift.
  - A minimum ***safety factor of 1.5*** must be achieved against sliding and overturning.
    - Exception: This can be reduced to 1.1 when earthquake loads are included.

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# IBC Requirements

## ❑ *Presumptive Load-Bearing Values*

TABLE 1806.2
PRESUMPTIVE LOAD-BEARING VALUES

| CLASS OF MATERIALS | VERTICAL FOUNDATION PRESSURE (psf) | LATERAL BEARING PRESSURE (psf/ft below natural grade) | LATERAL SLIDING RESISTANCE | |
|---|---|---|---|---|
| | | | Coefficient of friction[a] | Cohesion (psf)[b] |
| 1. Crystalline bedrock | 12,000 | 1,200 | 0.70 | — |
| 2. Sedimentary and foliated rock | 4,000 | 400 | 0.35 | — |
| 3. Sandy gravel and gravel (GW and GP) | 3,000 | 200 | 0.35 | — |
| 4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM and GC) | 2,000 | 150 | 0.25 | — |
| 5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH) | 1,500 | 100 | — | 130 |

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# IBC Requirements

## ❑ *Presumptive Load-Bearing Values*

- Would you allow the following?

9. Allowable Soil Bearing Pressure: 2500 psf (assumed),

- How about this?

bearing pressure of 100,000 psf may be used.

**SOIL ANALYSIS**

A soil sample was obtained from the site, using a bucket and a shovel. The soil sample was analyzed in the geotechnical laboratory. Testing consisted of moisture content and sieve analysis tests. The sieve analysis resulted in a soil classification of Silty Sand with Gravel (SM). The fine content of the sample was 33% with the fines classification as silt (ML). The moisture content of the soil was 18%. The laboratory results are attached to this letter.

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# IBC Requirements

- ***Concrete Foundations*** *(IBC 1808.8)*
  - Minimum compressive strength per Table 1808.8.1

**TABLE 1808.8.1**
**MINIMUM SPECIFIED COMPRESSIVE STRENGTH $f'_c$ OF CONCRETE OR GROUT**

| FOUNDATION ELEMENT OR CONDITION | SPECIFIED COMPRESSIVE STRENGTH, $f'_c$ |
|---|---|
| 1. Foundations for structures assigned to Seismic Design Category A, B or C | 2,500 psi |
| 2a. Foundations for Group R or U occupancies of light-frame construction, two stories or less in height, assigned to Seismic Design Category D, E or F | 2,500 psi |
| 2b. Foundations for other structures assigned to Seismic Design Category D, E or F | 3,000 psi |
| 3. Precast nonprestressed driven piles | 4,000 psi |
| 4. Socketed drilled shafts | 4,000 psi |
| 5. Micropiles | 4,000 psi |
| 6. Precast prestressed driven piles | 5,000 psi |



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# IBC Requirements

- ***Concrete Foundations*** *(IBC 1808.8)*
  - Minimum concrete cover per Table 1808.8.2

**TABLE 1808.8.2**
**MINIMUM CONCRETE COVER**

| FOUNDATION ELEMENT OR CONDITION | MINIMUM COVER |
|---|---|
| 1. Shallow foundations | In accordance with Section 20.6 of ACI 318 |
| 2. Precast nonprestressed deep foundation elements<br>Exposed to seawater<br>Not manufactured under plant conditions<br>Manufactured under plant control conditions | <br>3 inches<br>2 inches<br>In accordance with Section 20.6.1.3.3 of ACI 318 |
| 3. Precast prestressed deep foundation elements<br>Exposed to seawater<br>Other | <br>2.5 inches<br>In accordance with Section 20.6.1.3.3 of ACI 318 |
| 4. Cast-in-place deep foundation elements not enclosed by a steel pipe, tube or permanent casing | 2.5 inches |
| 5. Cast-in-place deep foundation elements enclosed by a steel pipe, tube or permanent casing | 1 inch |
| 6. Structural steel core within a steel pipe, tube or permanent casing | 2 inches |
| 7. Cast-in-place drilled shafts enclosed by a stable rock socket | 1.5 inches |



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# IBC Requirements

- ***Concrete Foundations*** *(IBC 1808.8)*
  - Shall be protected from freezing *"during depositing and for a period of not less than 5 days thereafter"*.
  - IBC Table 1705.3 requires special inspection of curing temperature and techniques.
  - ACI 306R-16 defines "cold weather" as the air temperature is expected to fall below ***40°F***.

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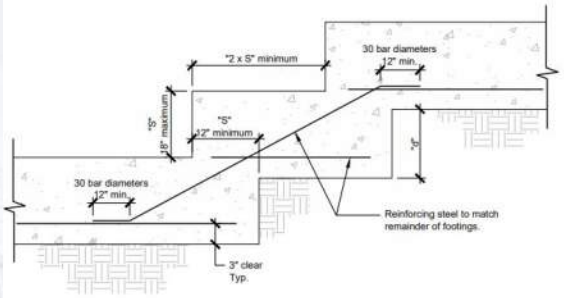
# IBC Requirements

- ***Shallow Foundations*** *(IBC 1809)*
  - If compacted fill, or CLSM is required, a geotechnical report is needed in addition to special inspections.
  - Top surface shall be level, but bottom surface can have a maximum 10% slope (1V:10H)
  - Greater differences require steps in footings




City of Santa Clarita, Typical Stepped Footing Detail

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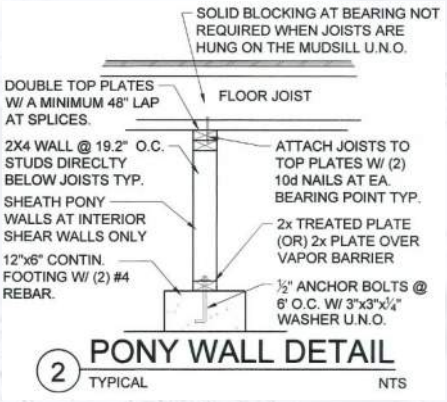
# IBC Requirements

- ***Shallow Foundations*** *(cont.)*
  - Minimum depth = 12-inches
  - Minimum width = 12-inches
  - Extend to below frost line
  - Plain concrete thickness = 8-inches (Group R-3 = 6-inches)

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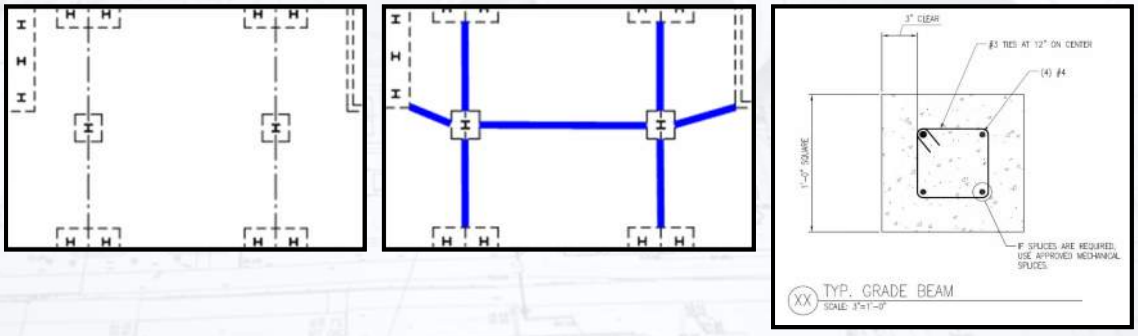
# IBC Requirements

- ***Shallow Foundations*** *(cont.)*
  - **IBC 1809.13:** Site Class E & F soils in high seismic regions require all footings to have "seismic ties".

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# IBC Requirements

- ***Deep Foundations*** *(IBC 1810)*
  - Installed on basis of a geotechnical report
  - Existing elements shall meet current code
  - Unbraced in air, water or fluid shall be designed as columns
  - **Special Types:**
    - Approved by B.O.
    - Acceptable test data
    - Calculations
    - Other information
    - Stresses cannot exceed IBC 1810

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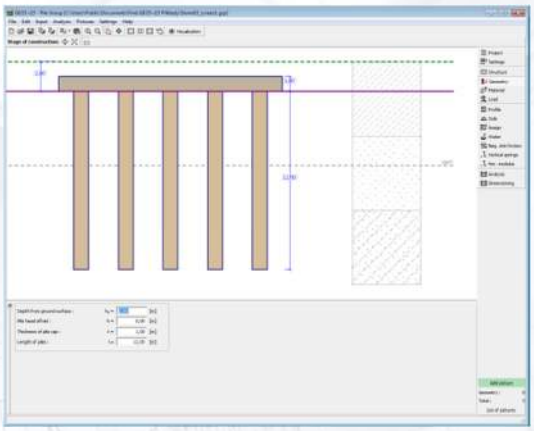
# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **IBC 1810.2:** Analysis must address…
    - Lateral support*
    - Stability*
    - Settlement*
    - Lateral loads*
    - Group effects



38

# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **IBC 1810.2.1:** Lateral Support
    - Soil, other than fluid soil, provide lateral support
    - Lateral support is needed for standard design of deep foundation elements and to prevent buckling
    - Unbraced sections are considered braced once 5-feet into stiff soil or 10-feet into soft soils.

Example Review Comment:
IBC 1810.2.1 notes that deep foundation elements that are unbraced, or are located in fluid soils, may be considered as not having lateral support. As these piles will be driven through varying layers of refuse, in addition to some liquefiable soil layers, please confirm that adequate lateral support will be provided to the piles.

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# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **IBC 1810.2.2:** Stability
    - Elements must be braced to provide lateral stability in all directions
    - ≥ 3 elements connected to a pile cap are braced
    - 2 elements are braced along the axis in which they are connected
    - Elements supporting walls shall be placed symmetrically under the C.G. for the wall.
    - Methods of bracing shall be approved by B.O.

Example Review Comment:
IBC 1810.2.2 requires deep foundation elements to be braced if there are less than three elements connected by a rigid pile cap. The foundation plans currently show several individual piles without proper restraint. Interconnection by means of grade beams, or another approved method, must be provided. Please address.

40

# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **IBC 1810.2.3:** Settlement
    - Shall be estimated by "approved" methods.
    - Shall not cause distortion or instability to the structure.
    - Shall not cause any element to be loaded beyond capacity.

| Settlement Within the Pier Zone (inch) | Settlement Below the Pier Zone (inch) | Total Expected Settlement (inch) |
|---|---|---|
| 0.40 | 0.18 | 0.58 |
| 0.63 | 0.26 | 0.89 |
| 0.52 | 0.33 | 0.85 |
| 0.57 | 0.36 | 0.93 |

41

# IBC Requirements

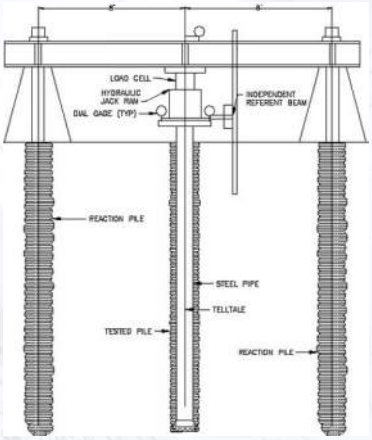
- ***Deep Foundations*** *(cont.)*
  - **IBC 1810.2.4:** Lateral Loads
    - Shall be checked for moment, shear, and lateral deflection and consider soil interaction
    - If SDC 'D-F', and…
    - Site Class 'E or F'…
    - Must be designed to withstand maximum curvatures due to earthquake ground motions

Example Review Comment:
Please confirm that deep foundation elements have been designed to withstand the maximum imposed curvatures due to seismic ground motions as required by IBC 1810.2.4.1.

42

# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **IBC 1810.3.3:** Allowable Loads
    - The "allowable" load is specified by the SER
    - The "ultimate" load is required to have a safety factor of 2.0
    - This applies to axial, uplift, and lateral loads
    - Load tests should be provided if…
      - Noted in geotechnical report
      - Design compressive stresses > Table 1803.2.6
      - CIP elements have an enlarged base
      - Capacity is questionable

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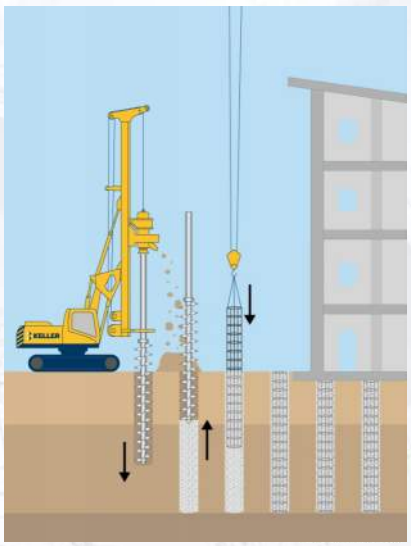
# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **CIP Piles** (IBC 1810.3.5.2):
    - **Cased** → 8"Ø
    - **Uncased** → 12"Ø
  - IBC 1810.3.9.3:
    - Reinforcement shall be placed as a unit before filled with concrete

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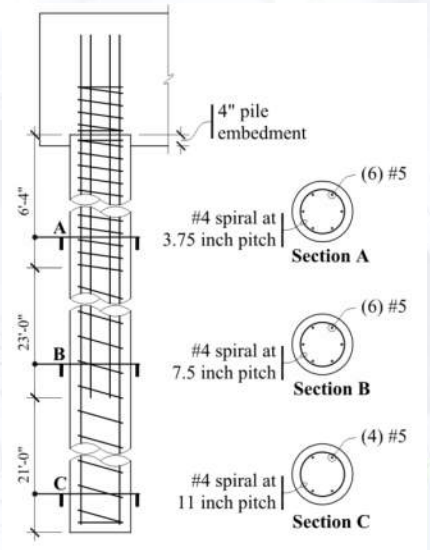
# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - Larger amounts of reinforcement where moments and shear are high
  - Minimum amounts must extend beyond theoretical cutoff points

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# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **SDC 'C':** Vertical Steel
    - 4 vertical bars minimum
    - Min. Ratio of Steel (ρ)= 0.0025
    - Minimum Reinforced Length:
      - 1/3 length of element
      - 10-feet
      - 3 * the width or diameter
      - Where $ØM_n > M_{req}$

**ρ = 0.0025**

#4 ≤ 20"ø
#5 ≤ 25"ø
#6 ≤ 30"ø
#7 ≤ 35"ø

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# IBC Requirements

## ❑ *Deep Foundations (cont.)*

- **SDC 'C':** Transverse Steel
  - #3 bar minimum
  - Maximum spacing = $16d_b$ of vert. steel
  - Upper spacing = maximum of…
    - 3 * least dimension, or
    - 8db of longitudinal steel, or
    - 6-inches

**$16d_b$**

#4 = 8"
#5 = 10"
#6 = 12"
#7 = 14"

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# IBC Requirements

## ❑ *Deep Foundations (cont.)*

- **SDC 'D-F':** Vertical Steel
  - 4 vertical bars minimum
  - Min. Ratio of Steel (ρ)= 0.005
  - Minimum Reinforced Length
    - 1/2 length of element
    - 10-feet
    - 3 * the width or diameter
    - Where ØMn > Mreq

**ρ = 0.005**

#4 ≤ 14"ø
#5 ≤ 17"ø
#6 ≤ 21"ø
#7 ≤ 24"ø

48

# IBC Requirements

## ❑ *Deep Foundations (cont.)*

- **SDC 'D-F':** Transverse Steel
  - If ≤ 20"ø use #3 bar min, otherwise #4 bar
  - Maximum spacing:
    - $12d_b$, or…
    - 0.5 * least dimension of element
    - 12-inches
  - Upper spacing…

**12db**

#4 = 6"
#5 = 7.5"
#6 = 9"
#7 = 10.5"

49

# IBC Requirements

## ❑ *Deep Foundations (cont.)*

- **SDC 'D-F':** Transverse Steel – Upper Portion
  - For all site classes, the minimum spacing shall be…
    - 0.25 * least dimension, or…
    - $6d_b$, or…
    - Calculated → $s_o$ ($s_{max} \leq$ *6-inches;* $s_{min} \geq$ *4-inches*)
  - Site Classes 'A-D':
    - Distance = 3 * least dimension (from bottom of pile cap)
  - Site Classes 'E-F':
    - Distance = 7 * least dimension, or…
    - Within 7 * least dimension of interfaces with liquefiable layers or soft- to medium-stiff clay

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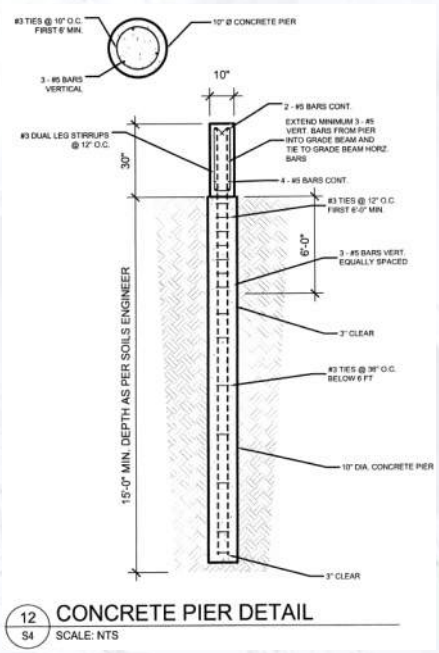
# IBC Requirements

- ***Deep Foundations*** *(cont.)*
- Do you see any problems with this detail?
  - SDC 'D'
  - 10ø uncased
  - (3) #5 vertical bars
  - #3 ties @ 10"o.c. (upper 6')
  - #3 ties @ 36"o.c. (lower 9')
  - 15'-0" depth

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# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **IBC 1810.3.11:** Pile Caps
    - Shall consist of reinforced concrete
    - Do not consider bearing of soil below
    - Foundation elements embedded ≥ 3" into cap
    - Caps shall extend ≥ 4" past foundation element
    - Tops of elements shall be cut or chipped back to sound material before capping
    - Special requirements for SDC 'C-F' in relation to the anchorage of piles resisting uplift and lateral loads.

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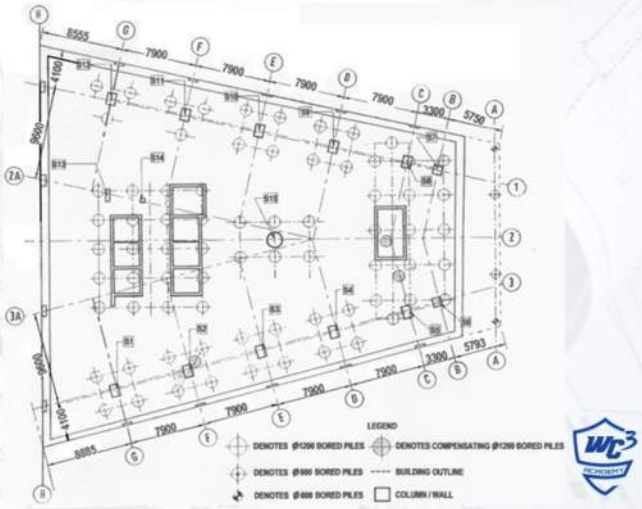
# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **IBC 1810.4.3:** Location Plan
    - Shall be filed with B.O.
    - Location and designation of deep foundation elements

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# IBC Requirements

- ***Deep Foundations*** *(cont.)*
  - **IBC 1810.4.12:** Special Inspections
    - Driven Deep Foundations (IBC 1705.7)
    - Cast-in-Place Deep Foundations (IBC 1705.8)
    - Helical Piles (IBC 1705.9)
    - Who is responsible for these inspections/tests?
    - What minimum qualifications should they have?

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# IBC Requirements

- ***IBC Chapter 19 – Concrete Construction***
  - Provides requirements for…
    - Construction documents
    - Durability
    - Modifications to ACI 318
    - Structural plain concrete
    - Slab provisions


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# IBC Requirements

- ***Construction Documents*** *(IBC 1901.5)*
  - Shall include:
    - Concrete compressive strengths
    - Strength & grade of reinforcement
    - Size & location of structural elements, reinforcing & anchors
    - Magnitude & location of prestressing forces
    - Lap splice lengths & anchorage lengths
    - Type & location of mechanical and welded splices
    - Contraction & isolation joint details
    - Strength & stressing sequence for posttensioning
    - SDC "D-F" → Statement if slab on grade is a structural diaphragm

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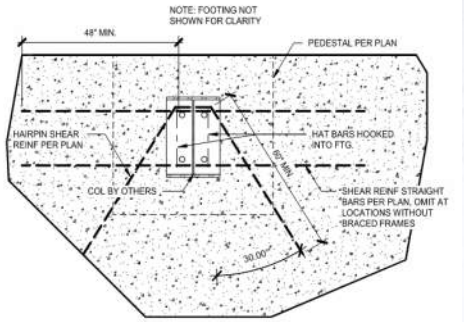
# IBC Requirements

- ***Construction Documents*** *(IBC 1901.5)*




Example Review Comment:

The plans show hairpins anchoring the columns to the slab to resist column kick-out forces. Please address the following:

A. Please provide calculations showing that the portion of floor slab used able to transfer the required forces to the supporting soils.

B. Per IBC 1901.5 and Section 18.13.3.2 of ACI 318-19 the slab is to be designed as a structural diaphragm in accordance with Section 18.12 of ACI 318-19.

C. Since the slab-on-grade is a structural diaphragm special inspection will be required.

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# IBC Requirements

- ***Durability*** *(IBC 1904)*
  - Shall conform to ACI 318-19 *(Exception: R-2 & R-3 ≤ 3-stories)*
  - Section 19.3.1 of ACI 318-19:
    - Freezing (F0, F1, F2, & F3)
    - Sulfate (S0, S1, S2, & S3)
    - Permeability (P0, P1, P2, & P3)
    - Corrosive (C0, C1, & C2)

    - 0 = Not applicable
    - 1 = Moderate
    - 2 = Severe
    - 3 = Very severe

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**Table 19.3.1.1—Exposure categories and classes**

| Category | Class | Condition | |
|---|---|---|---|
| Freezing and thawing (F) | F0 | Concrete not exposed to freezing-and-thawing cycles | |
| | F1 | Concrete exposed to freezing-and-thawing cycles with limited exposure to water | |
| | F2 | Concrete exposed to freezing-and-thawing cycles with frequent exposure to water | |
| | F3 | Concrete exposed to freezing-and-thawing cycles with frequent exposure to water and exposure to deicing chemicals | |
| Sulfate (S) | | Water-soluble sulfate ($SO_4^{2-}$) in soil, percent by mass[1] | Dissolved sulfate ($SO_4^{2-}$) in water, ppm[2] |
| | S0 | $SO_4^{2-} < 0.10$ | $SO_4^{2-} < 150$ |
| | S1 | $0.10 \le SO_4^{2-} < 0.20$ | $150 \le SO_4^{2-} < 1500$ or seawater |
| | S2 | $0.20 \le SO_4^{2-} \le 2.00$ | $1500 \le SO_4^{2-} \le 10{,}000$ |
| | S3 | $SO_4^{2-} > 2.00$ | $SO_4^{2-} > 10{,}000$ |
| In contact with water (W) | W0 | Concrete dry in service | |
| | W1 | Concrete in contact with water where low permeability is not required | |
| | W2 | Concrete in contact with water where low permeability is required | |
| Corrosion protection of reinforcement (C) | C0 | Concrete dry or protected from moisture | |
| | C1 | Concrete exposed to moisture but not to an external source of chlorides | |
| | C2 | Concrete exposed to moisture and an external source of chlorides from deicing chemicals, salt, brackish water, seawater, or spray from these sources | |

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**Table 19.3.2.1—Requirements for concrete by exposure class**

| Exposure class | | Maximum $w/cm$[1,2] | Minimum $f'_c$, psi | Additional requirements: Air content | | | Limits on cementitious materials |
|---|---|---|---|---|---|---|---|
| F0 | | N/A | 2500 | N/A | | | N/A |
| F1 | | 0.55 | 3500 | Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete | | | N/A |
| F2 | | 0.45 | 4500 | Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete | | | N/A |
| F3 | | 0.40[3] | 5000[3] | Table 19.3.3.1 for concrete or Table 19.3.3.3 for shotcrete | | | 26.4.2.2(b) |
| | | | | Cementitious materials[4] — Types | | | Calcium chloride admixture |
| | | | | ASTM C150 | ASTM C595 | ASTM C1157 | |
| S0 | | N/A | 2500 | No type restriction | No type restriction | No type restriction | No restriction |
| S1 | | 0.50 | 4000 | II[5][6] | Types with (MS) designation | MS | No restriction |
| S2 | | 0.45 | 4500 | V[6] | Types with (HS) designation | HS | Not permitted |
| S3 | Option 1 | 0.45 | 4500 | V plus pozzolan or slag cement[7] | Types with (HS) designation plus pozzolan or slag cement[7] | HS plus pozzolan or slag cement[7] | Not permitted |
| | Option 2 | 0.40 | 5000 | V[8] | Types with (HS) designation | HS | Not permitted |

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| W0 | N/A | 2500 | None | | |
|---|---|---|---|---|---|
| W1 | N/A | 2500 | 26.4.2.2(d) | | |
| W2 | 0.50 | 4000 | 26.4.2.2(d) | | |
| | | | Maximum water-soluble chloride ion ($Cl^-$) content in concrete, percent by mass of cementitious materials[9,10] | | |
| | | | Nonprestressed concrete | Prestressed concrete | Additional provisions |
| C0 | N/A | 2500 | 1.00 | 0.06 | None |
| C1 | N/A | 2500 | 0.30 | 0.06 | |
| C2 | 0.40 | 5000 | 0.15 | 0.06 | Concrete cover[11] |



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# IBC Requirements

- ***Durability*** *(cont.)*
  - Section 19.3.1.1 of ACI 318-19: *"Licensed design professional shall assign exposure classes in accordance with the severity of the anticipated exposures…"*

| CONCRETE ELEMENT: | STRENGTH: | EXPOSURE CLASS: |
|---|---|---|
| FOOTINGS & FOUNDATION WALLS: | 4000 PSI | (F1, S0, W0, C1) |
| TILT-UP CONCRETE WALL PANELS | 4500 PSI | (F2, S0, W1, C1) |
| INTERIOR SLABS ON GRADE: | 3500 PSI | (F0, S0, W0, C0) |
| SITE CONCRETE: | 4500 PSI | (F3, S0, W1, C2) |

Example Review Comment:
Section 19.3.1.1 of ACI 318-19 requires the design professional to assign exposure classes to structural concrete members in accordance with Table 19.3.1.1. Please address.

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# IBC Requirements

- ***Modifications to ACI 318*** *(IBC 1905)*
  - **IBC 1905.1.2:** Modified Section 18.2.1.2 of ACI 318 to state that ***plain concrete*** structural elements are not allowed in SDC "C-F" except as noted in IBC 1905.1.7.
  - **IBC 1905.1.3:** Added additional requirement for Intermediate Precast Walls. It notes that connections that are designed to yield shall be capable of maintaining ***80%*** of their design strength at design displacement or shall use ***Type 2 mechanical splices***.

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# IBC Requirements

- ***Modifications to ACI 318*** *(IBC 1905)*
  - **IBC 1905.1.7:** Modified Section 14.1.4 to…
    - Applies to SDC "C-F"
    - Allowed only for…
      1. Group R-3 foundation walls reinforced per Section 14.6.1, not taller than 8-feet and retaining no more than 4-feet of soil.
      2. Isolated footings supporting columns or pedestals provided the footing does not extend more than the member thickness from the face of the supported member.
      3. Wall footings having two continuous bars. (#4 minimum & rho ≥ 0.002)

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# IBC Requirements

- ***Modifications to ACI 318*** *(IBC 1905)*
  - **IBC 1905.1.8:** Provides exception to ACI 318 anchoring provisions for the sill anchorage of light-frame wood & metal stud structures. Must satisfy the following:
    - Shear strength is determined using AWC NDS Table 12E *(except metal stud)*
    - Maximum diameter of 5/8-inch
    - Embedded 7-inches
    - Minimum of 1.75-inches from edge of concrete

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# IBC Requirements

- ***Minimum Slab Provisions*** *(IBC 1907)*
  - Minimum thickness = 3.5-inches
  - 6-mil vapor retarder with joints lapped 6-inches

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# IBC Requirements

- ***Wall Anchorage Requirements*** *(ASCE 7-16)*
  - Wall anchorage forces per §12.11.2.1
  - If concrete or masonry walls in SDC "C-F"…
    - "Diaphragms shall be provided with continuous ties or struts between diaphragm chords to distribute these anchorage forces into the diaphragms… Added chords are permitted to be used to form subdiaphragms to transmit the anchorage forces to the main continuous crossties.
    - Wood diaphragms → Diaphragm sheathing shall not be considered effective for providing ties or struts required by this section.
    - Metal deck diaphragm → Metal deck shall not be as the continuous tie in the direction perpendicular to the deck span.

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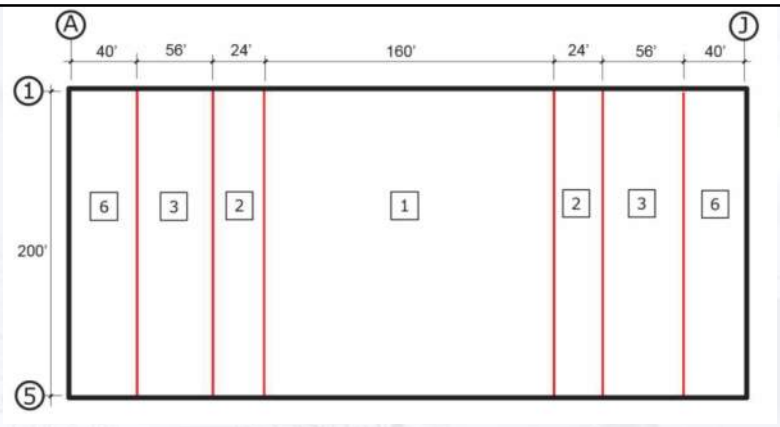


| Nailing Zone | Distance from Boundary | Maximum Unit Shear | ASD Unit Shear | Allowable Shear Capacity |
|---|---|---|---|---|
| 6 | 0 feet | $v_{max}$ = 1656 plf | $v_{ASD}$ = 1159 plf | 1289 plf |
| 5 | - | - | - | 1005 plf |
| 4 | - | - | - | 820 plf |
| 3 | 40 feet | $v_{max}$ = 883 plf | $v_{ASD}$ = 618 plf | 640 plf |
| 2 | 96 feet | $v_{max}$ = 574 plf | $v_{ASD}$ = 401 plf | 425 plf |
| 1 | 120 feet | $v_{max}$ = 442 plf | $v_{ASD}$ = 309 plf | 320 plf |

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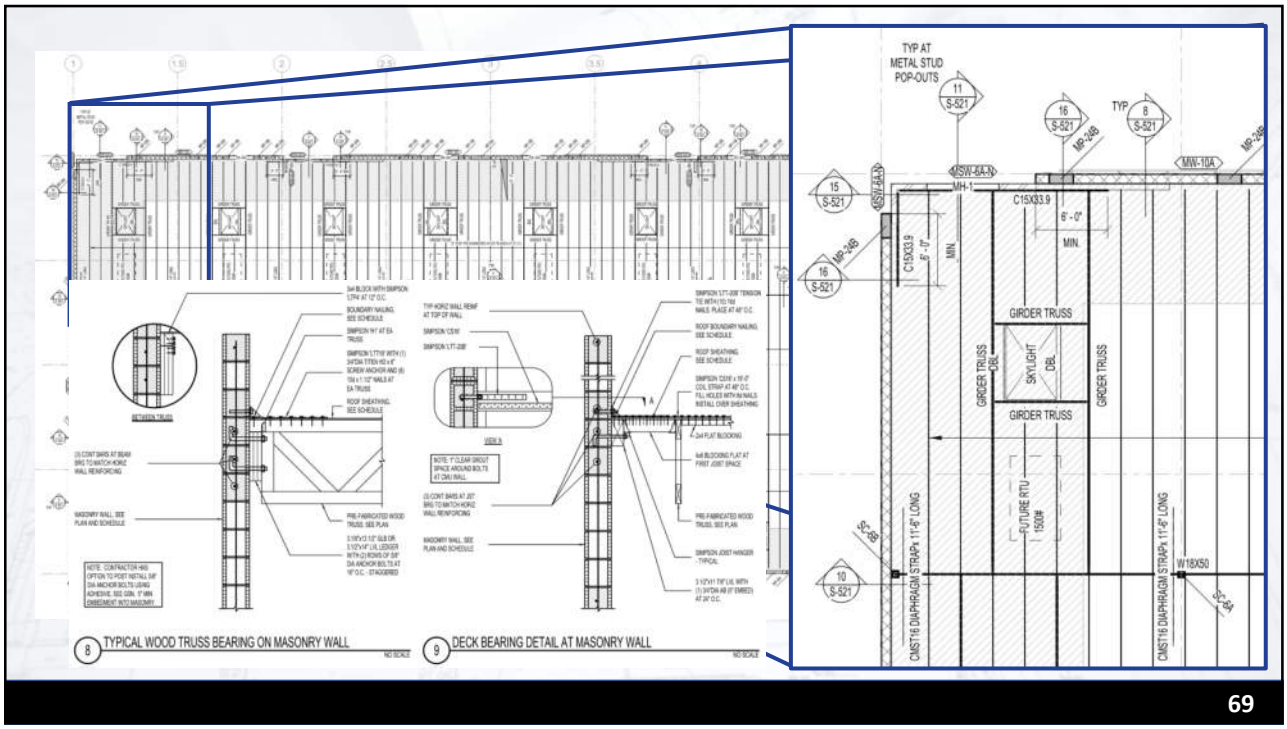


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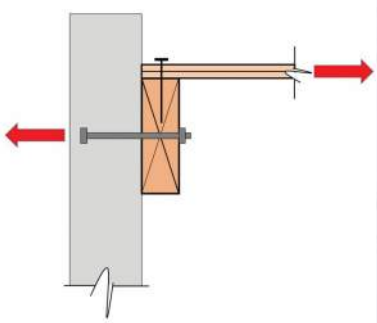
# IBC Requirements

- ***Wall Anchorage Requirements*** *(ASCE 7-16)*
  - https://www.ladbs.org/docs/default-source/forms/plan-check-2017/supplemental-structural-correction-sheet-for-flexible-diaphragm-with-rigid-wall.pdf?sfvrsn=1b27fe53_18



Pre-1972 UBC Connection

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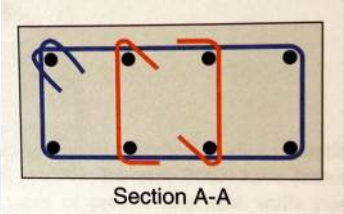
# ACI 318 Requirements

- ***Significant Changes in ACI 318-19:***
  - Introduces high-strength reinforcement
  - Modifies development length provisions
  - Introduces screw anchors and shear lugs
  - Introduces shotcrete provisions
  - Extensive additions to foundation chapter
  - Important changes to special shear walls
  - Important changes to seismic detailing
  - https://shop.skghoshassociates.com/web-seminar-recordings.html

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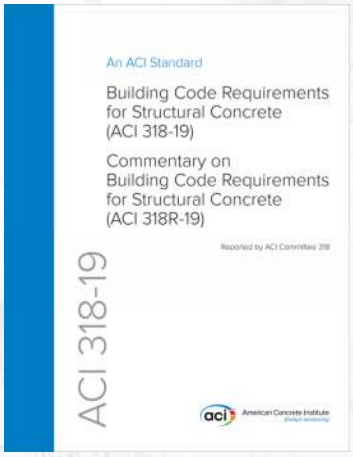
# ACI 318 Requirements

- ***Key Items***
  - Foundations
  - Anchoring
  - Earthquake-Resistant Structures
  - Concrete Details

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# ACI 318 Requirements

## *Footings:*

- Reinforced ≥ 9.5-inch thickness
  - §13.3.1.2 of ACI 318-19 → 6" min. to bottom reinforcement
  - Diameter of reinforcing
  - Concrete cover

Example Review Comment:
Footings F-16 and F-18 are not thick enough to satisfy Section 13.3.1.2 of ACI 318-19 which requires an effective depth to bottom reinforcement of at least 6 inches and ACI Table 20.5.1.3.1 which requires 3 inches of cover. Please address.

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# ACI 318 Requirements

## *Footings:*

- Flexural Reinforcing:
  - §13.3.2.1 of ACI 318-19 requires compliance with Chapters 7 & 9
  - §7.6.1.1 of ACI 318-19 requires a minimum flexural steel ratio of 0.0018*Ag

| Footings | | | | | | | |
|---|---|---|---|---|---|---|---|
| Width | Depth | $A_{conc}$ | Bar | # | $A_{steel}$ | Rho | |
| 12 | 12 | 144 | 4 | 1 | 0.20 | 0.00139 | *No Good!* |
| 42 | 12 | 504 | 4 | 3 | 0.60 | 0.00119 | *No Good!* |
| 54 | 12 | 648 | 4 | 6 | 1.20 | 0.00185 | |
| 60 | 14 | 840 | 5 | 5 | 1.55 | 0.00185 | |
| 60 | 12 | 720 | 4 | 7 | 1.40 | 0.00194 | |
| 72 | 16 | 1152 | 5 | 7 | 2.17 | 0.00188 | |
| 96 | 20 | 1920 | 6 | 9 | 3.96 | 0.00206 | |

Example Review Comment:
Footings F-XX do not appear to meet the minimum flexural reinforcing requirements of ACI 318-19 Sections 13.3.2.1 and 7.6.1.1. Please address.

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# ACI 318 Requirements

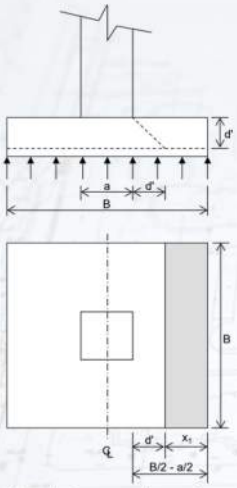

Figure 1. One-way or beam shear.

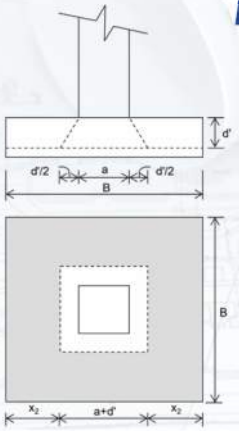

Figure 2. Two-way or punching shear.

## *Footings:*

- Both footings and slabs should be checked for one-way and two-way shear.
- Two-way, or "punching", shear governs many large isolated spot footings as well as suspended slabs.
- If there are large spot footings of minimal thickness, verify that calculations include a check for one-way and two-way shear and not just bearing capacity.

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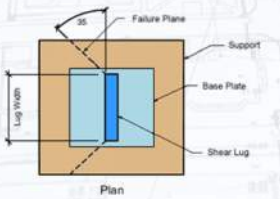
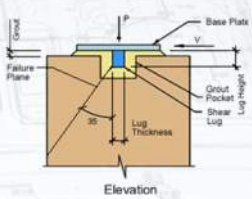
# ACI 318 Requirements

## *Anchoring:*

- Chapter 17 applies to cast-in, post-installed, undercut, adhesive, and screw anchors as well as shear lugs.
- Anchors are checked for tension, shear, or a combination of both.
- High-cycle fatigue or impact loads are not addressed.
- New: The removal and resetting of post-installed mechanical anchors is prohibited!



Plan



Elevation

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# ACI 318 Requirements

***Anchoring:***

- SDC "C-F":
  - Special provisions in §17.10 for these anchors.
  - Post-installed anchors must be qualified per ACI 355.2 or ACI 355.4.
  - Horizontal or upwardly inclined adhesive anchors shall be qualified for such application by ACI 355.4. These also require installer qualification and special inspections.

| | |
|---|---|
| Profile: | Rectangular HSS (AISC), HSS12X4X.500; (L x W x T) = 12.000 |
| Base material: | cracked concrete, 2500, $f_c'$ = 2,500 psi; h = 12.000 in. |
| Reinforcement: | tension: condition B, shear: condition B; edge reinforcement: none or < No. 4 bar |
| Seismic loads (cat. C, D, E, or F) | no |

CBFEM - The anchor calculation is based on a component-based Finite Element Method (CBFEM)

**Geometry [in.] & Loading [lb, in.lb]**

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# ACI 318 Requirements

- ***Anchoring:***
- There are alternate ways to get around, or to meet, the tension requirements.
  - Plates at the bottom of anchor bolts
  - Tension confining reinforcement

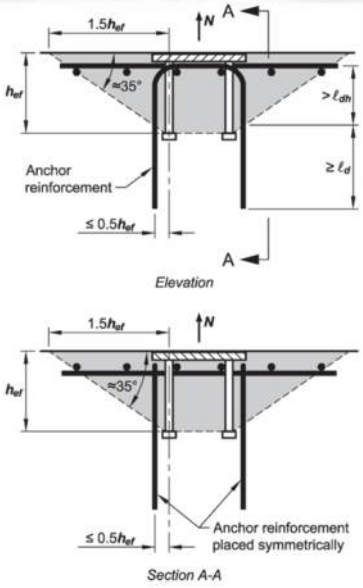


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*Fig. R17.4.2.9—Anchor reinforcement for tension.*

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# ACI 318 Requirements

- ***Anchoring:***
- There are several ways to get around or to meet shear requirements.
  - Shear lugs
  - Shear confining reinforcing

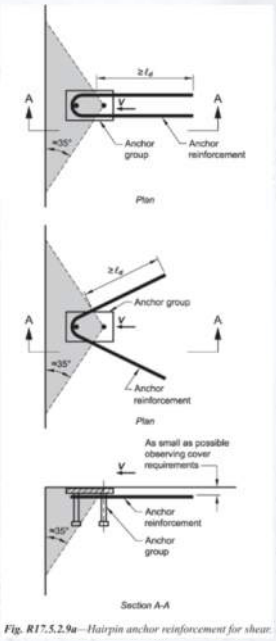


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Fig. R17.5.2.9a—Hairpin anchor reinforcement for shear.

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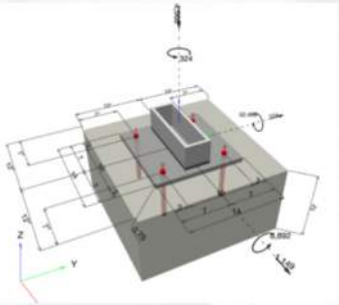
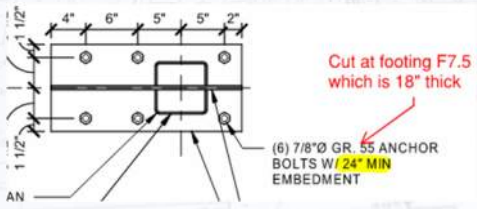
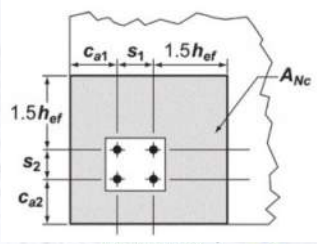
# ACI 318 Requirements

- ***Anchoring:***
- Pay special attention to the edge distances.
- Often the designer will list an infinite value, but the anchors are actually within a few inches from the edge of concrete.



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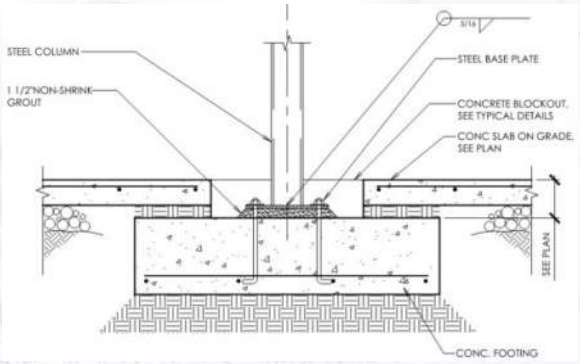
# ACI 318 Requirements

- ***Anchoring:***
- §17.7.1.2.1 requires a 20% reduction in shear strength for anchors installed at built-up grout pads.
- Has this been considered in the calculations?

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# ACI 318 Requirements

## *Earthquake-Resistant Structures*

- Chapter 18 includes provisions for…
  - ~~Ordinary moment frames~~
  - ~~Intermediate moment frames~~
  - Intermediate precast walls
  - Special moment frames
  - Special precast moment frames
  - Special structural walls
  - Special precast structural walls
  - Diaphragms & trusses
  - Foundations

**Table R18.2—Sections of Chapter 18 to be satisfied in typical applications[1]**

| Component resisting earthquake effect, unless otherwise noted | SDC | | | |
|---|---|---|---|---|
| | A (None) | B (18.2.1.3) | C (18.2.1.4) | D, E, F (18.2.1.5) |
| Analysis and design requirements | None | 18.2.2 | 18.2.2 | 18.2.2, 18.2.4 |
| Materials | | None | None | 18.2.5 through 18.2.8 |
| Frame members | | 18.3 | 18.4 | 18.6 through 18.9 |
| Structural walls and coupling beams | | None | None | 18.10 |
| Precast structural walls | | None | 18.5 | 18.5[2], 18.11 |
| Diaphragms and trusses | | None | None | 18.12 |
| Foundations | | None | None | 18.13 |
| Frame members not designated as part of the seismic-force-resisting system | | None | None | 18.14 |
| Anchors | | None | 18.2.3 | 18.2.3 |



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# ACI 318 Requirements

## *Earthquake-Resistant Structures*

- § 18.2.1.7 allows other structural systems provided sufficient experimental evidence and analysis is provided.


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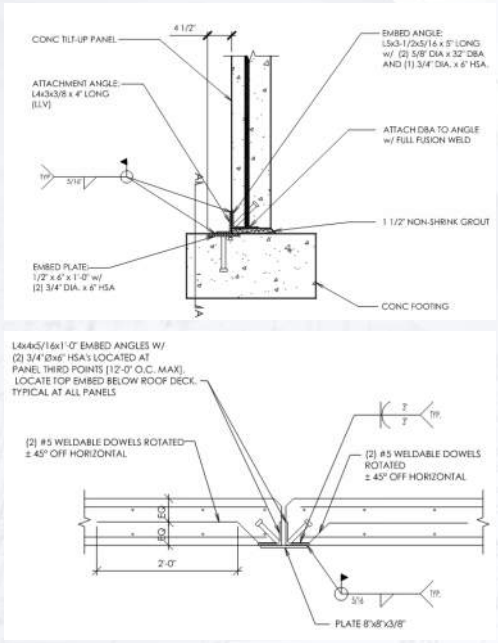
# ACI 318 Requirements

## *Earthquake-Resistant Structures*

- Intermediate Precast Structural Walls (§18.5)
  - Connections between wall panels, and panels to footings, shall have yielding restricted to steel elements or reinforcing.
  - Connection elements that are not designed to yield shall have a required strength of $1.5*S_y$ of the yielding portion of the connection.
  - Wall piers shall comply with…
    - §18.10.8 (Special Structural Walls), or…
    - §18.14 (Not part of SFRS)

84




Example Review Comment:

Per Section 18.5.2.1 of ACI 318-19, connections between panels and to the foundation are required to be designed to limit yielding to steel elements or reinforcing. Please provide details and calculations for these connections to show how panels will be tied together or tied to the foundation and show that yielding elements are limited to steel.

A. Per ACI 318-19 Section 18.5.2.2, non-yielding elements in these connections are required to be designed for 1.5 times the strength of the yielding members. (e.g., concrete breakout is required to be 1.5 times the strength of the yielding element.)

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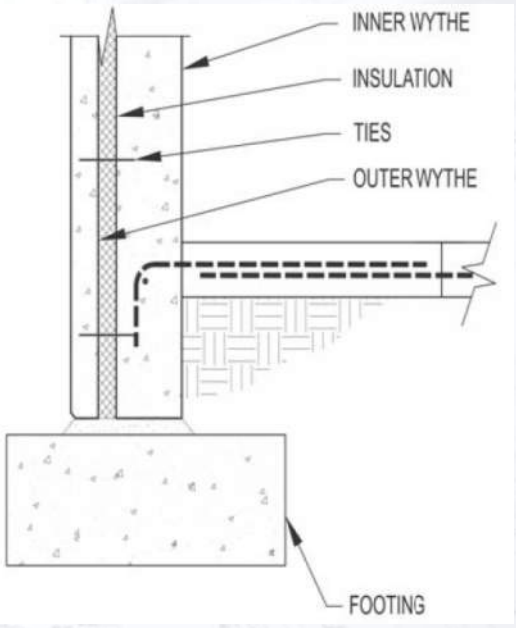
Example Review Comment:

The project calls for tilt-up panels to be directly connected to the floor slab, with no physical connection to the footing. Please provide calculations showing that the portion of the floor slab that is used is capable of transferring the required forces to the supporting soils. In addition, please provide a check of the panel-to-slab connection for side-edge concrete breakout.

Example Review Comment:

No details or supporting calculations have been provided for the connection of the precast panel wythes to the rigid insulation. Please address. *(As an example, if a system such as Thermomass is being used, the design and installation must comply with ESR-1746 and supporting calculations for the selection of the appropriate anchors and their spacing must be provided.)*

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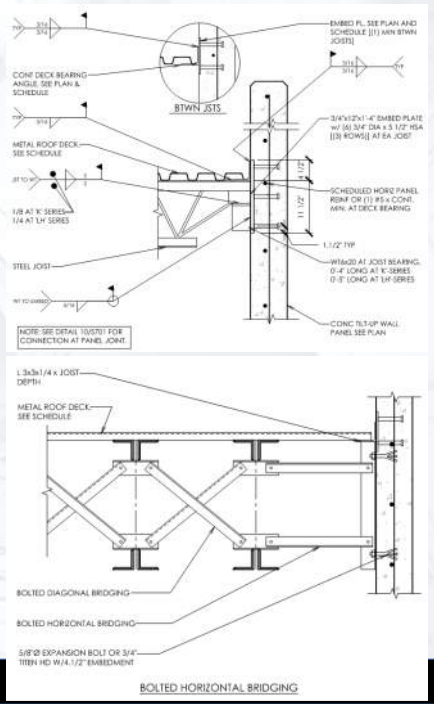
Example Review Comment:

ASCE 7-16 Section 12.10, requires that diaphragms, chords, and collectors be designed. Please address the following:

A. As this is tilt-up building, please provide information for the continuous chord/collector member which will be designed to resist the forces per ASCE 7-16 Section 12.10.1 for both shear and flexure (tension/compression chord force) and transfer these forces to the shear walls.

B. Per ASCE 7-16 §12.10.2.1, the collector element is required to be designed to include the overstrength factor.



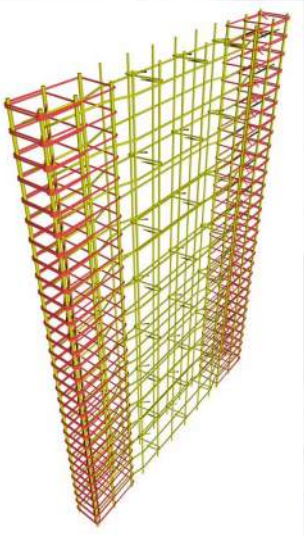
BOLTED HORIZONTAL BRIDGING

# ACI 318 Requirements

#4 @17 5/8" O.C.(EA.FACE)

## *Earthquake-Resistant Structures*

- Special Structural Walls (§18.10)
  - $\rho_l$ & $\rho_t \geq$ ***0.0025***
  - Maximum spacing of ***18-inches*** in each direction
  - §11.7.2.3 requires two layers of reinforcing steel in walls > 10-inches, but §18.10.2.2 also requires two curtains if $h_w/l_w \geq 2.0$.
  - Transverse reinf. in boundary elements:
    - 1/4 minimum element dimension
    - $6*d_b$ *($6*d_b$ for Grade 80)*
    - Spacing of longitudinal bars laterally supported shall not > 14-inches or 2/3 * element thickness



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# ACI 318 Requirements

## *Earthquake-Resistant Structures*

- Special Structural Walls (§18.10)
  - Transverse reinforcement in boundary elements:
    - ***Vertical spacing of ties now must also comply with Table 18.10.6.5(b)!!!***

**Table 18.10.6.5(b)—Maximum vertical spacing of transverse reinforcement at wall boundary**

| Grade of primary flexural reinforcing bar | Transverse reinforcement required | Maximum vertical spacing of transverse reinforcement[1] | |
|---|---|---|---|
| 60 | Within the greater of $\ell_w$ and $M_u/4V_u$ above and below critical sections[2] | Lesser of: | $6d_b$ |
| | | | 6 in. |
| | Other locations | Lesser of: | $8d_b$ |
| | | | 8 in. |
| 80 | Within the greater of $\ell_w$ and $M_u/4V_u$ above and below critical sections[2] | Lesser of: | $5d_b$ |
| | | | 6 in. |
| | Other locations | Lesser of: | $6d_b$ |
| | | | 6 in. |
| 100 | Within the greater of $\ell_w$ and $M_u/4V_u$ above and below critical sections[2] | Lesser of: | $4d_b$ |
| | | | 6 in. |
| | Other locations | Lesser of: | $6d_b$ |
| | | | 6 in. |

[1]In this table, $d_b$ is the diameter of the smallest primary flexural reinforcing bar.
[2]Critical sections are defined as locations where yielding of longitudinal reinforcement is likely to occur as a result of lateral displacements.



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# ACI 318 Requirements

## *Earthquake-Resistant Structures*

- Special Structural Walls (§18.10)
  - A ***wall pier*** is a wall segment within a structural wall that is bounded by two openings, or by an opening and an edge, with…
  - A ratio of horizontal length to wall thickness ***($l_w/b_w$) ≤ 6.0***, and…
  - A clear height to horizontal length ***($h_w/l_w$) ≥ 2.0***.

**Table R18.10.1—Governing design provisions for vertical wall segments[1]**

| Clear height of vertical wall segment/length of vertical wall segment, ($h_w/\ell_w$) | Length of vertical wall segment/wall thickness ($\ell_w/b_w$) | | |
|---|---|---|---|
| | $(\ell_w/b_w) \le 2.5$ | $2.5 < (\ell_w/b_w) \le 6.0$ | $(\ell_w/b_w) > 6.0$ |
| $h_w/\ell_w < 2.0$ | Wall | Wall | Wall |
| $h_w/\ell_w \ge 2.0$ | Wall pier required to satisfy specified column design requirements; refer to 18.10.8.1 | Wall pier required to satisfy specified column design requirements or alternative requirements; refer to 18.10.8.1 | Wall |

[1]$h_w$ is the clear height, $\ell_w$ is the horizontal length, and $b_w$ is the width of the web of the wall segment.



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# ACI 318 Requirements

## *Earthquake-Resistant Structures*

- Special Structural Walls (§18.10)
  - Wall piers ***($l_w/b_w$) ≤ 2.5*** shall meet the requirements for columns in special moment frames (§18.7.4, §18.7.5, §18.7.6)
  - Wall piers ***($l_w/b_w$) > 2.5***:
    - Transverse reinforcement shall be hoops
    - Single-leg allowed if one curtain, but shall have 180-degree bends at each end
    - Vertical spacing ≤ 6-inches o.c.
    - Shall extent at least 12-inches above and below wall pier clear height

Example Review Comment:
There are multiple wall piers shown in the concrete tilt walls as defined by ACI 318-19. Please indicate all wall piers and provide information for their special reinforcing requirements per Section 18.10.8 of ACI 318-19.

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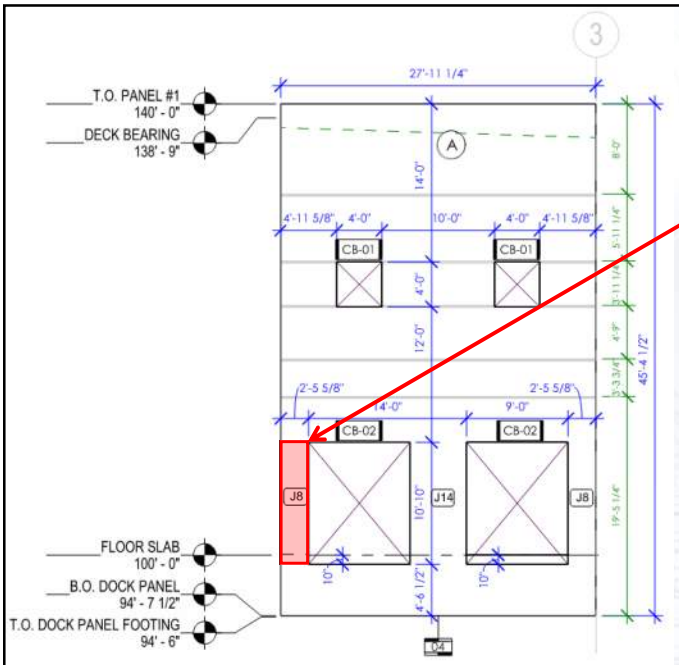


**Example:**
Width = 2'-6"
Height = 11'-0"
Thickness = 7.25"

$l_w/b_w$ = 30"/7.25" = 4.13 < 6.0

$h_w/l_w$ = 132"/30" = 4.4 > 2.0

As both are met, it is a wall pier.

Since $l_w/b_w$ > 2.0, not detailed as a moment frame column

***Does "J8" comply?***

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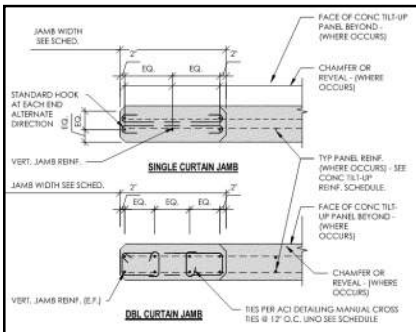


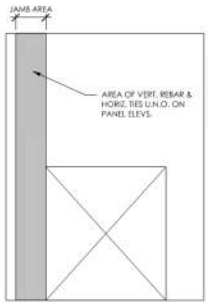


**JAMB REBAR SCHEDULE**

| JAMB TYPE | WIDTH (MIN.) U.N.O. | VERTICAL REINF. | TIES & SPACING |
|---|---|---|---|
| TYPICAL | | PROVIDE (2) #5 CONT. BARS @ EACH EDGE OF OPENING U.N.O., SEE 4/S309 | |
| J1 | FULL WIDTH | (3) #6 BARS E.F. | #3 TIES @ 6" O.C. |
| J2 | FULL WIDTH | (3) #6 BARS E.F. | #3 TIES @ 3" O.C. |
| J3 | FULL WIDTH | (4) #6 BARS E.F. | #3 TIES @ 12" O.C. |
| J4 | FULL WIDTH | (4) #6 BARS E.F. | #3 TIES @ 8" O.C. |
| J5 | FULL WIDTH | (5) #6 BARS E.F. | #3 TIES @ 6" O.C. |
| J6 | FULL WIDTH | (5) #6 BARS E.F. | #3 TIES @ 3" O.C. |
| J7 | FULL WIDTH | (6) #6 BARS E.F. | N/A |
| J8 | FULL WIDTH | (6) #6 BARS E.F. | #3 TIES @ 10" O.C. |
| J9 | FULL WIDTH | (7) #6 BARS E.F. | #3 TIES @ 12" O.C. |
| J10 | FULL WIDTH | (7) #6 BARS E.F. | #3 TIES @ 10" O.C. |
| J11 | FULL WIDTH | (7) #6 BARS E.F. | #3 TIES @ 8" O.C. |
| J12 | FULL WIDTH | (8) #6 BARS E.F. | N/A |
| J13 | FULL WIDTH | (8) #6 BARS E.F. | #3 TIES @ 12" O.C. |
| J14 | FULL WIDTH | (8) #6 BARS E.F. | #3 TIES @ 10" O.C. |
| J15 | FULL WIDTH | (9) #6 BARS E.F. | N/A |
| J16 | FULL WIDTH | (9) #6 BARS E.F. | #3 TIES @ 8" O.C. |
| J17 | FULL WIDTH | (10) #6 BARS E.F. | #3 TIES @ 8" O.C. |
| J18 | FULL WIDTH | (8) #6 BARS E.F. | #3 TIES @ 6" O.C. |

NOTES:
1. VERTICAL REINFORCING SPECIFIED FOR JAMB REPLACES DOUBLE BAR @ EDGE OF OPENING.
2. JAMB REINFORCING (INCLUDING TIES), SHALL EXTEND THE FULL HEIGHT OF THE PANEL CONT., SPACE TIES @ 12" O.C. FROM 2'-0" BEYOND TOP OPENING TO THE TOP OF THE PANEL.
3. JAMB REINFORCING TO BE PLACED ON EACH FACE OF THE PANEL WHEN DOUBLE LAYER JAMB REINFORCING IS USED. (EF=EACH FACE)
4. WIDTH OF JAMB IS TO BE MEASURED FROM EDGE OF PANEL TO EDGE OF OPENING OR EDGE OF OPENING TO EDGE OF OPENING.
5. THICKNESS OF JAMB = THICKNESS OF WALL.
6. PROVIDE ADDITIONAL REINFORCING AS REQUIRED FOR LIFTING. OPTION: INCREASE BAR SIZES. TYPICAL.

Ties must be a maximum of 6"o.c.!

Example Review Comment:
The panel elevation calls for a J8 jamb, however the tie reinforcement specified in the jamb schedule does not meet the minimum reinforcement requirements of Section 18.10.8.1 of ACI 318-19 for wall piers. Please revise accordingly.

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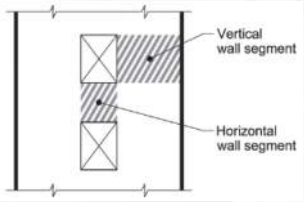
# ACI 318 Requirements

## *Earthquake-Resistant Structures*

- Special Structural Walls (§18.10)
  - A horizontal wall segment is also referred to as a ***coupling beam*** when the openings are aligned vertically over the building height.
  - If $l_w/h) \geq 4.0$ → per §18.6
  - If $l_w/h) < 2.0$ & $Vu \geq 4 * \sqrt{f'c} * Acw$ → two groups of diagonally reinforced bars are required
  - Otherwise, diagonally reinforced bars or reinforcing per §18.6.3 thru §18.6.5 is allowed
  - Special provisions outlined for diagonally reinforced bars

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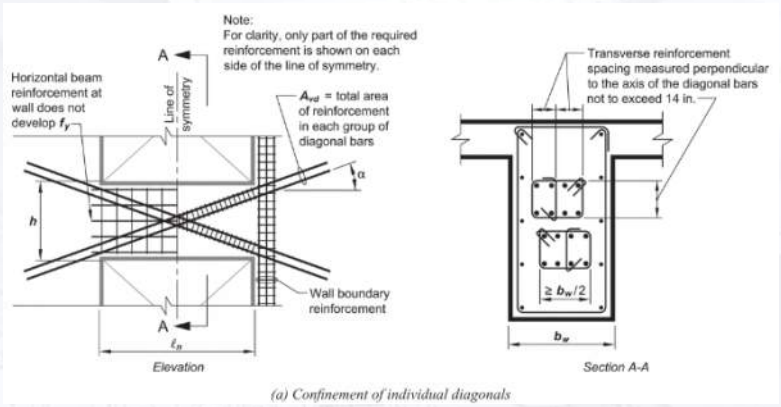


*(a) Confinement of individual diagonals*

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Example Review Comment:
There appear to be multiple coupling beams in the exterior concrete walls. Please provide calculations and reinforcing details as required for the design of these coupling beams per Section 18.10.7 of ACI 318-19.

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# ACI 318 Requirements

**Concrete Cover:** *Table 20.5.1.3.1 – Nonprestressed CIP Members*

| Exposure | Member | Reinforcement | Cover (in.) |
|---|---|---|---|
| Cast against and permanently in contact with ground | All | All | 3 |
| Exposed to weather or in contact with ground | All | No. 6 thru 18 | 2 |
| | | WWF or ≤ No. 5 | 1.5 |
| Not exposed to weather or in contact with ground | Slabs, joists, and walls Beams, columns, pedestals, and tension ties | No. 14 & No. 18 | 1.5 |
| | | ≤ No. 11 | 0.75 |
| | Beams, columns, pedestals, and tension ties | Primary reinforcement, stirrups, ties, spirals, and hoops | 1.5 |

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# ACI 318 Requirements

**Concrete Cover:** *Table 20.5.1.3.2 – Prestressed CIP Members*

| Exposure | Member | Reinforcement | Cover (in.) |
|---|---|---|---|
| Cast against and permanently in contact with ground | All | All | 3 |
| Exposed to weather or in contact with ground | Slabs, joists, and walls | All | 1 |
| | All other | All | 1.5 |
| Not exposed to weather or in contact with ground | Slabs, joists, and walls | All | 0.75 |
| | Beams, columns, and tension ties | Primary reinforcement | 1.5 |
| | | Stirrups, ties, spirals, and hoops | 1 |

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# ACI 318 Requirements

**Concrete Cover:** *Table 20.5.1.3.4 – Deep Foundation Members*

| Exposure | Member | Reinforcement | Cover (in.) |
|---|---|---|---|
| *Not* enclosed by steel pipe, tube permanent casing, or stable rock socket | Cast-in-place | All | 3 |
| Enclosed by steel pipe, tube, permanent casing, or stable rock socket | Cast-in-place | All | 1.5 |
| Permanently in contact with ground | Precast-nonprestressed | All | 1.5 |
| | Precast-prestressed | | |
| Exposed to seawater | Precast-nonprestressed | All | 2.5 |
| | Precast-prestressed | All | 2 |

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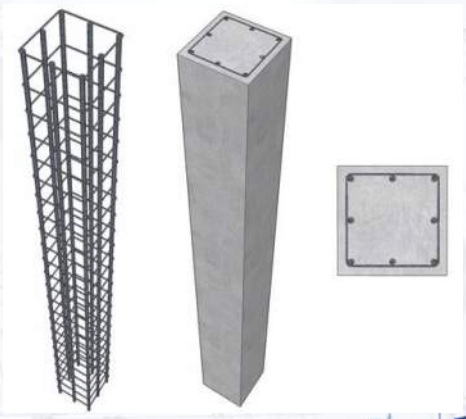
# ACI 318 Requirements

## *Concrete Details:*

- **Ties** (§ 25.7.2):
  - Minimum Bar Size
    - < #10 vertical bar → ***#3 ties***
    - #11, 14 or 18 → ***#4 ties***
  - Maximum Vertical Spacing
    - $16d_b$ vertical bars (e.g. #5 = 10")
    - $48d_b$ tie bars (e.g. #3 = 18")
    - Least dimension of member



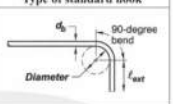
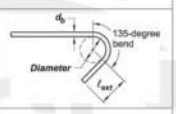
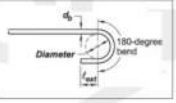
99 99

# ACI 318 Requirements

## *Concrete Details:*

- **Ties** (cont.):
  - Seismic hooks, used to anchor stirrups, ties, hoops, and crossties shall…
    - Have a minimum 90-degree bend for circular hoops, or…
    - 135-degree bend for all other hoops, and…
    - Hook shall engage longitudinal bar and extend 6db, but a minimum of 3-inches, into the interior of the stirrup or hoop

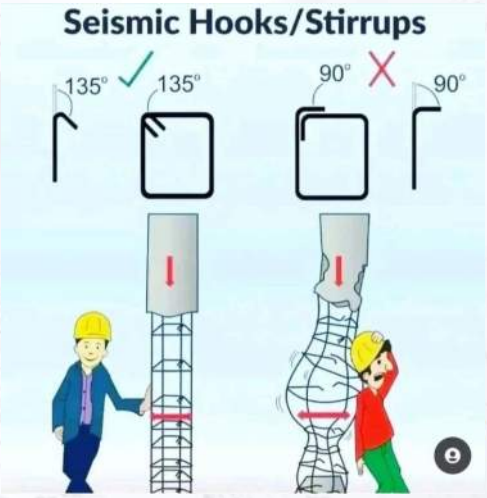
**Table 25.3.2—Minimum inside bend diameters and standard hook geometry for stirrups, ties, and hoops**

| Type of standard hook | Bar size | Minimum inside bend diameter, in. | Straight extension[1] $\ell_{ext}$, in. | Type of standard hook |
|---|---|---|---|---|
| 90-degree hook | No. 3 through No. 5 | $4d_b$ | Greater of $6d_b$ and 3 in. |  |
| | No. 6 through No. 8 | $6d_b$ | $12d_b$ | |
| 135-degree hook | No. 3 through No. 5 | $4d_b$ | Greater of $6d_b$ and 3 in. |  |
| | No. 6 through No. 8 | $6d_b$ | | |
| 180-degree hook | No. 3 through No. 5 | $4d_b$ | Greater of $4d_b$ and 2.5 in. |  |
| | No. 6 through No. 8 | $6d_b$ | | |



100 100

# ACI 318 Requirements

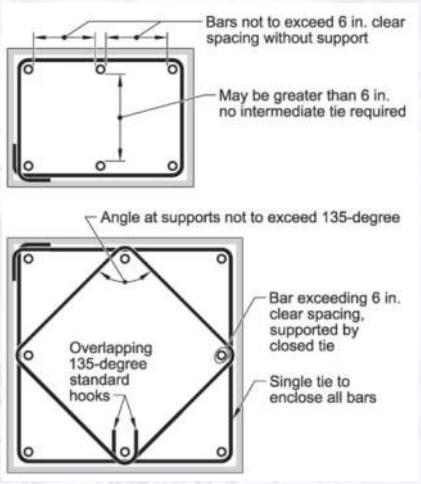



101 101

# ACI 318 Requirements

### *Concrete Details:*

- **Ties** (cont.):
- "Every corner or alternate longitudinal bar shall have lateral support provided by the corner of a tie... No bar shall be further than ***6" clear***… from such a laterally supported bar."




American Concrete Institute, ACI 318-14 ©

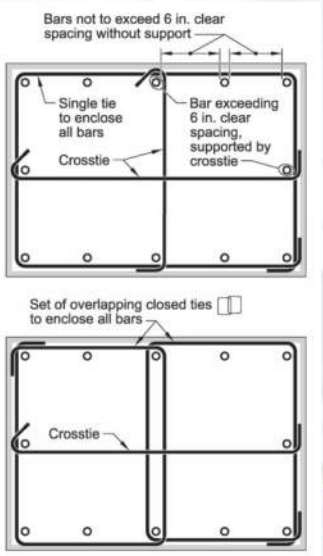
102 102

# ACI 318 Requirements

## *Concrete Details:*

- **Ties** (cont.):

Example Review Comment:
Please review the lateral tie requirements shown in the concrete column details. Vertical bars should be tied in such a fashion as to ensure the maximum distance between laterally tied bars is less than or equal to 6-inches. See Section 25.7.2.3 of ACI 318-19.

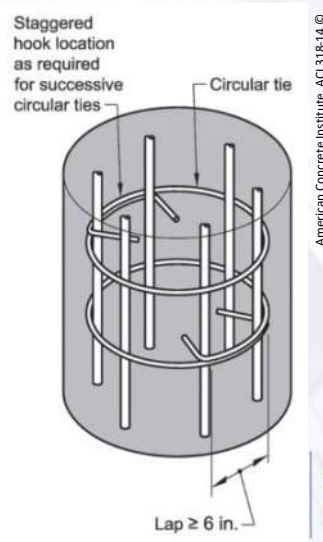



103 103

# ACI 318 Requirements

## *Concrete Details:*

- **Ties** (cont.):
- Circular ties are permitted at circular cross sections.
- Ends must overlap 6-inches
- Shall terminate in standard hooks and engage vertical bar
- Overlaps of adjacent circular ties must be staggered



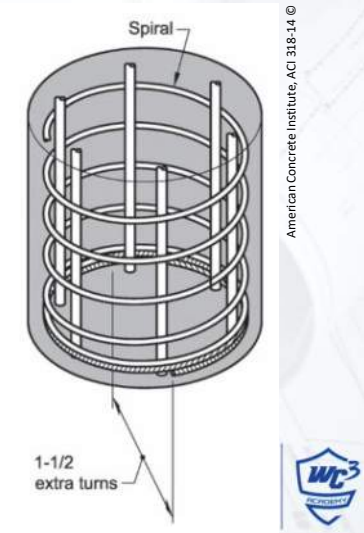

104 104

# ACI 318 Requirements

## *Concrete Details:*

- **Spirals** (§ 25.7.3):
- Consists of 3/8"Ø evenly spaced continuous bar with a clear spacing meeting both…
  1. Greater of 1-inch and $(4/3)d_{agg}$
  2. Not > 3-inches
- Anchored by 1.5 extra turns at each end

Example Review Comment:
A spiral spacing of 6-inches is currently specified. Section 25.7.3.1 of ACI 318-19 does not allow a spiral clear spacing of more than 3-inches. Please address.

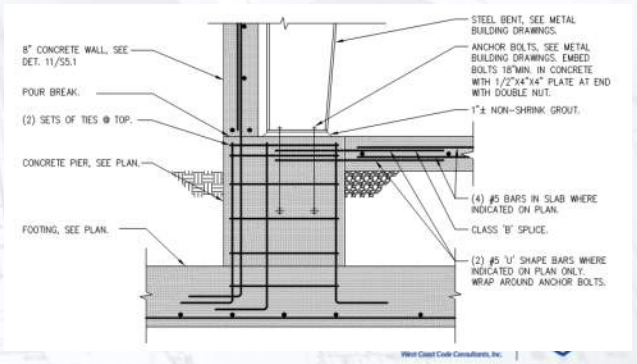



105 105

# ACI 318 Requirements

## *Concrete Details:*

- **Anchor Bolts in Column/Pedestal** (§ 10.7.6.1.5):
  - Anchor bolts placed in the top of column or pedestal shall be enclosed by ties surrounding at least four vertical bars.
  - Ties shall consist of…
    - (2) #4 or (3) #3 ties
    - Distributed within top 5"




106

# ACI 318 Requirements

***Prestressed Concrete:***

- IBC 1901.5 & Section 26.10.1 of ACI 318-19 require:
  - Magnitude & location of prestressing forces
  - Stressing sequence of tendons
- § 26.10.2 of ACI 318-19 requires concrete strength to be…
  - Single-strand tendons ≥ 2,500psi
  - Multi-strand tendons ≥ 4,000psi

Example Review Comment:
The plans call for tendons to be stressed when concrete reaches 2,000 PSI. Per Section 26.10.2 of ACI 318-19, prestressing of tendons is not to occur until concrete has reached 2,500 PSI. Please clarify.

107 107

# Plan Review Items

- ❑ ***Remember the WABO white paper***
- ❑ ***What should be included in a comment?***
- ❑ ***What should not?***
- ❑ ***How do we begin?***
- ❑ ***How much of our time should be spent reviewing…***
  - The plans?
  - The structural calculations?
  - Anything else?

108

# Plan Review Items

***Structural General Notes:***

- Are materials requirements specified?
  - IBC 1901.5, ACI 318-19, etc.
  - Is concrete durability addressed?
- Do specific installations meet code?
  - Is required concrete compressive strength at posttensioning specified?
- Is extraneous information listed?
- Are there any deferred submittals?
  - Are they allowed?
- Are any special inspections noted?
  - Is a special inspection agreement form required?

109

# Plan Review Items

***Foundation Plan:***

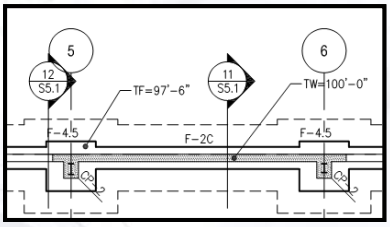
- Is geotechnical report requirements for foundation prep clearly called out?
- Are footing, foundation, grade beam, and pedestal dimensions clearly noted, and their reinforcing specified?
- Is frost depth clearly called out?
- Load path connections (holdowns, anchor bolts, foundation dowels, etc.)
- Connection callouts (correct detail references)
- Is the slab-on-grade a diaphragm?
- Are footing seismic ties required at isolated footings?

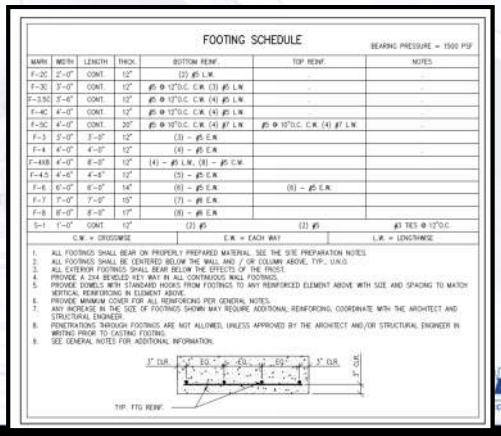
110

# Plan Review Items

***Foundation Plan:***

- ☒ Footings specified on plan?
- ☒ Proper Reinforcement?
- ☒ Calculations Provided?



FOOTING SCHEDULE

BEARING PRESSURE = 1500 PSF

| MARK | WIDTH | LENGTH | THICK. | BOTTOM REINF. | TOP REINF. | NOTES |
|---|---|---|---|---|---|---|
| F-2C | 2'-0" | CONT. | 12" | (2) #5 L.W. | | |
| F-3C | 3'-0" | CONT. | 12" | #5 @ 12"O.C. C.W. (3) #5 L.W. | | |
| F-3.5C | 3'-6" | CONT. | 12" | #5 @ 12"O.C. C.W. (4) #5 L.W. | | |
| F-4C | 4'-0" | CONT. | 12" | #5 @ 12"O.C. C.W. (4) #5 L.W. | | |
| F-5C | 4'-0" | CONT. | 20" | #5 @ 10"O.C. C.W. (4) #7 L.W. | #5 @ 10"O.C. C.W. (4) #7 L.W. | |
| F-3 | 3'-0" | 3'-0" | 12" | (3) – #5 E.W. | | |
| F-4 | 4'-0" | 4'-0" | 12" | (4) – #5 E.W. | | |
| F-4XB | 4'-0" | 8'-0" | 12" | (4) – #5 L.W., (8) – #5 C.W. | | |
| F-4.5 | 4'-6" | 4'-6" | 12" | (5) – #5 E.W. | | |
| F-6 | 6'-0" | 6'-0" | 14" | (6) – #5 E.W. | (6) – #5 E.W. | |
| F-7 | 7'-0" | 7'-0" | 15" | (7) – #5 E.W. | | |
| F-8 | 8'-0" | 8'-0" | 17" | (8) – #5 E.W. | | |
| S-1 | 1'-0" | CONT. | 12" | (2) #5 | (2) #5 | #3 TIES @ 12"O.C. |

C.W. = CROSSWISE E.W. = EACH WAY L.W. = LONGITUDINAL

1. ALL FOOTINGS SHALL BEAR ON PROPERLY PREPARED MATERIAL SEE THE SITE PREPARATION NOTES.
2. ALL FOOTINGS SHALL BE CENTERED BELOW THE WALL AND / OR COLUMN ABOVE, TYP., U.N.O.
3. ALL EXTERIOR FOOTINGS SHALL BEAR BELOW THE EFFECTS OF THE FROST.
4. PROVIDE A 2X4 BEVELED KEY WAY IN ALL CONTINUOUS WALL FOOTINGS.
5. PROVIDE DOWELS WITH STANDARD HOOKS FROM FOOTINGS TO ANY REINFORCED ELEMENT ABOVE WITH SIZE AND SPACING TO MATCH VERTICAL REINFORCING IN ELEMENT ABOVE.
6. PROVIDE MINIMUM COVER FOR ALL REINFORCING PER GENERAL NOTES.
7. ANY INCREASE IN THE SIZE OF FOOTINGS SHOWN MAY REQUIRE ADDITIONAL REINFORCING. COORDINATE WITH THE ARCHITECT AND STRUCTURAL ENGINEER.
8. PENETRATIONS THROUGH FOOTINGS ARE NOT ALLOWED, UNLESS APPROVED BY THE ARCHITECT AND/OR STRUCTURAL ENGINEER IN WRITING PRIOR TO CASTING FOOTING.
9. SEE GENERAL NOTES FOR ADDITIONAL INFORMATION.



111[111]

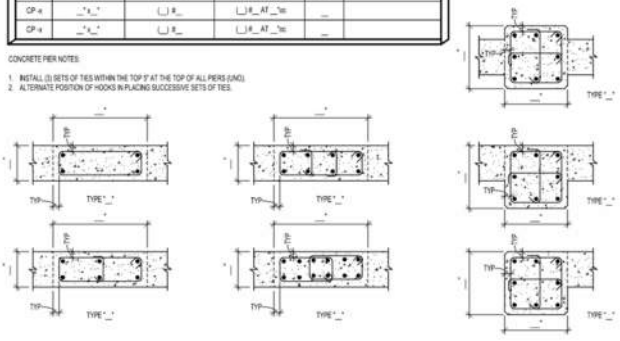
# Plan Review Items

CONCRETE PIER SCHEDULE

| MARK | PIER SIZE | REINFORCING | | TYPE | COMMENTS |
|---|---|---|---|---|---|
| | | VERTICAL | TIES | | |
| CP-4 | _"x_" | (_) #_ | (_) #_ AT _"oc | _ | |
| CP-6 | _"x_" | (_) #_ | (_) #_ AT _"oc | _ | |
| CP-9 | _"x_" | (_) #_ | (_) #_ AT _"oc | _ | |

CONCRETE PIER NOTES:

1. INSTALL (3) SETS OF TIES WITHIN THE TOP 5" AT THE TOP OF ALL PIERS (U.N.O.).
2. ALTERNATE POSITION OF HOOKS IN PLACING SUCCESSIVE SETS OF TIES.




CONCRETE JAMB COLUMN SCHEDULE

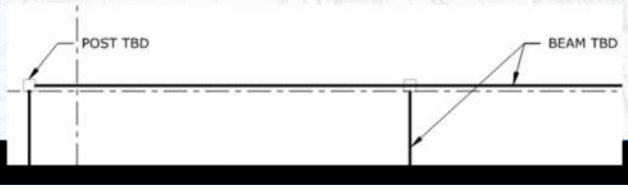
| MARK | DIMENSIONS | | REINFORCEMENT | | REMARKS |
|---|---|---|---|---|---|
| | WIDTH | LENGTH | VERTICAL | TIES | |

112[112]

# Plan Review Items

***Floor & Roof Framing Plans:***

- Beam dimensions, reinforcement, and spans
- Column dimensions, reinforcement, and connections
- Wall dimensions, reinforcement, and connections
- Load path connections (additional chord reinforcing, diaphragm-to-wall connections, etc.)
- Connection callouts (correct detail references)
- Diaphragm requirements (thickness, reinforcing, composite requirements, etc.)




113

# Plan Review Items

***Sections & Details:***

- ***Structural Connections:***
  - Foundation details
  - Diaphragm-to-Wall
  - Joist-to-Beam
  - Beam-to-Beam
  - Beam-to-Column
  - Column-to-Foundation
  - Wall-to-Foundation

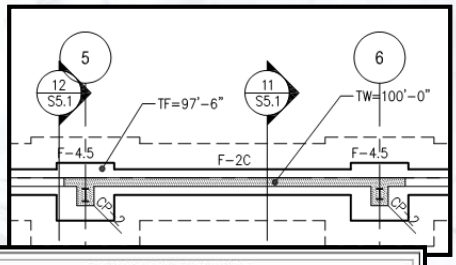
***This is the opportunity to verify that a complete load path is provided!***

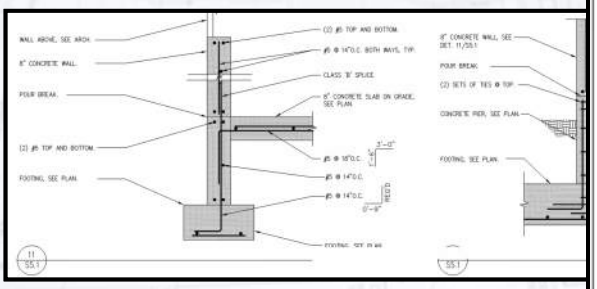
114

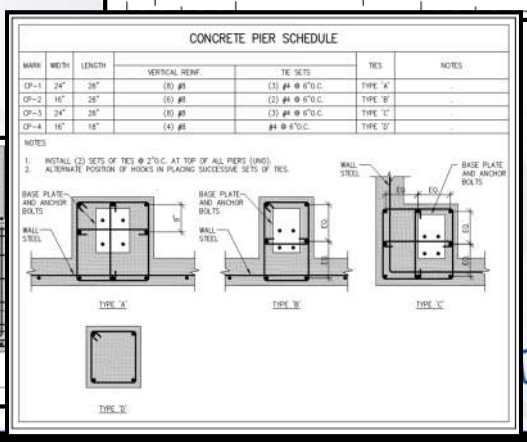
# Plan Review Items

***Sections & Details:***

- ☒ Check Details
- ☒ Verify Piers on Table



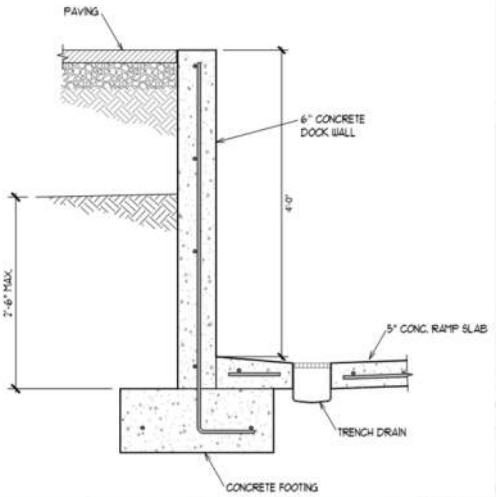



115

# Plan Review Items

***Sections & Details:***

- ❑ Do the sections and details look right?

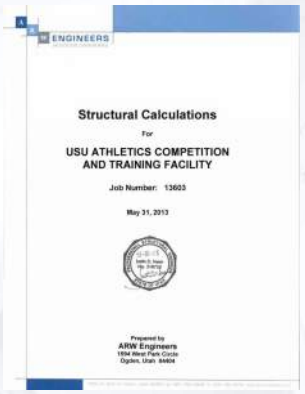



116

# Plan Review Items

## *Structural Calculations:*

- Remember, it is not our responsibility to verify the mathematical accuracy of the calculations.
- When reviewing plans, note significant structural members and make sure that a calculation is included.



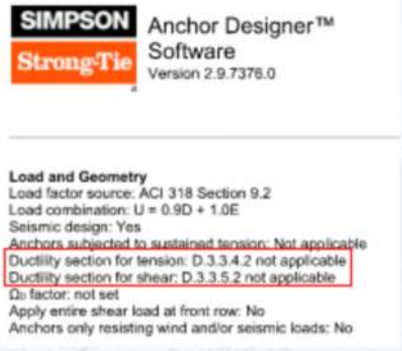

Example Review Comment:
Please provide supporting calculations for the following…
A. The GB7 grade beam specified on sheet S1.02.
B. The footings and retaining walls at ramps shown on sheet S1.04.
C. The retaining walls in the elevator pit area shown on sheet S1.05.

117

# Plan Review Items

## *Structural Calculations:*

- ❑ Is the analysis per the current code and referenced standards?




Example Review Comment:
Many of the calculations were performed in reference to outdated building codes and standards. Please confirm that calculations meet the requirements of the 2021 IBC and its referenced standards as listed in Chapter 35.

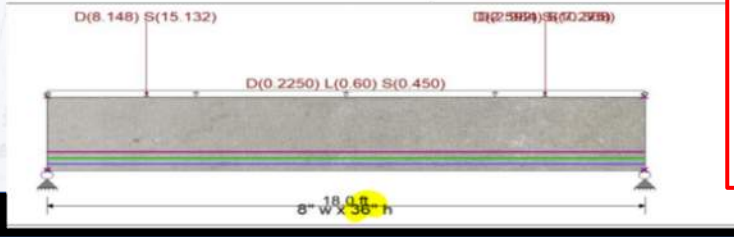
118

# Plan Review Items

***Perform a check of as many as possible:***

| FB-2 | 32" LINTEL W/(6) #6 BAR TOP & (2) #6 BAR BOT, & #3 TIES @ 6" O.C. |
|---|---|

122.0 ksi Fy - Stirrups 40.0 ksi
60.0 ksi E - Stirrups = 29,000.0 ksi
000.0 ksi Stirrup Bar Size # 3
mber of Resisting Legs Per Stirrup = 2




1. **Specified beam is 4-inches shorter.**
2. **The bottom reinforcement is specified as the top.**
3. **Only 1/3 of required bottom reinforcement is specified.**
4. **The calculation shows the beam as 75% stressed, so this would probably have failed if constructed as detailed.**

119

# Plan Review Items

***Perform a check of as many as possible:***

| File Name | Typical Beam for Concession Building (Shorter Span) |
|---|---|

Input

| | | | | | | |
|---|---|---|---|---|---|---|
| Trib for Loading | 10 | ft | Deck Orientation | Perpendicular | | D |
| Length | 18.67 | ft | Deck Type | W | | C |
| Design provision | ASD | | f'c | 3.5 | ksi | D |
| Stud Diameter | 0.75 | in | Concrete Type | [illegible] | | C |
| Studs Per Deck Rib | 1 | | Total slab depth | 6.25 | in | |
| Construction Method | Unshored | | Deck depth | 3 | in | |

Uniform and Trapezoidal Loads

| Location | | | Construction Dead Loads | | | Dead Loads | | |
|---|---|---|---|---|---|---|---|---|
| | X Start | X End | | Start | End | | Start | End |

6. Clinch seams before welding interlocking seams.

Steel Floor Deck (Roof of the Concessions Building)

a. Steel floor deck shall be 3" deep X 20 gage minimum phosphatized/painted composite type "W" deck with interlocking side seams with the following properties:

| | 22 Gage | 20 Gage | 19 Gage | 18 Gage | 16 Gage |
|---|---|---|---|---|---|
| Minimum S ($in^3/_{ft}$) = | 0.410 | 0.528 | 0.652 | 0.768 | 0.966 |
| Minimum I ($in^4/_{ft}$) = | 0.736 | 0.907 | 1.067 | 1.213 | 1.516 |

Deck shall be galvanized (G60) when used below mechanical equipment rooms.

b. Steel deck with 3.1/4" thick (6.1/4" overall) normal weight concrete slab shall have a minimum allowable diaphragm shear capacity of 600 lbs/ft for a 7'-0" deck span.

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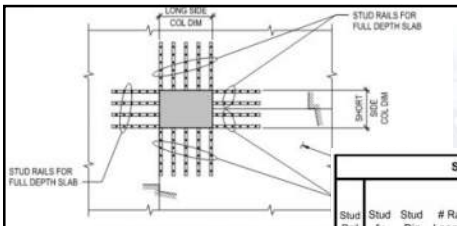


TYPICAL SLAB STEP STUD RAIL LAYOUT

**STUD RAIL SCHEDULE**

| SLAB THICKNESS (IN) | COLUMN DIMENSION (IN) | STUD DIAMETER (IN) | STUD SPACING (IN) | NUMBER OF STUDS PER RAIL | NUM RAI |
|---|---|---|---|---|---|
| 8 | 16 | 1/2 | 3 | 11 | |
| 8 | 18 | 1/2 | 3 | 11 | 3 |
| 8 | 24 | 1/2 | 3 | 11 | 3 |
| 8 | 27 | 1/2 | | | |
| 8 | 30 | 1/2 | | | |
| 8 | 36 | 1/2 | | | |
| 9 | 24 | 1/2 | | | |
| 9 | 30 | 1/2 | | | |
| 9 | 36 | 1/2 | | | |
| 10 | 16 | 1/2 | | | |
| 10 | 18 | 1/2 | | | |
| 10 | 24 | 1/2 | | | |
| 10 | 30 | 1/2 | 3 | 16 | 3 |
| 10 | 36 | 1/2 | 3 | 16 | 4 |
| 12 | 24 | 1/2 | 3 | 17 | 3 |
| 12 | 30 | 1/2 | 3 | 17 | 3 |
| 12 | 36 | 1/2 | 3 | 17 | 4 |
| 14 | 24 | 1/2 | 3 | 19 | 3 |
| 14 | 30 | 1/2 | 3 | 19 | 3 |
| 14 | 36 | 1/2 | 3 | 19 | 4 |

**Stud Rail Parameters**

| Stud Rail Type | Stud fy (ksi) | Stud Dia (in) | # Rails - Long Side (#) | # Rails - Short Side (#) | # Studs / Rail (#) | First Stud ($s_o$) (in) | Stud Spg (s) (in) |
|---|---|---|---|---|---|---|---|
| R1 | 50 | 0.50 | 3 | 3 | 13 | 2 | 3 |
| R1 | 50 | 0.50 | 3 | 3 | 13 | 2 | 3 |
| R1 | 50 | 0.50 | 3 | 3 | 13 | 2 | 3 |
| R2 | 50 | 0.50 | 4 | 4 | 13 | 2 | 3 |
| R2 | 50 | 0.50 | 4 | 4 | 13 | 2 | 3 |

**Analysis Results**

| vu/ϕ √f'c | vc √f'c | vn √f'c | vua/ϕ √f'c | vub/ϕ √f'c | vuc/ϕ √f'c | vud/ϕ √f'c | Min # Rails - Long Side (#) | Min # Rails - Short Side (#) | Rail Length (in) | Vu / ϕVc | Vu / ϕVn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.37 | 4.00 | 6.70 | 1.77 | 1.91 | 1.86 | -- | 3 | 3 | 36 | 1.84 | 1.10 |
| 7.37 | 4.00 | 6.70 | 1.77 | 1.98 | 1.98 | -- | 3 | 3 | 36 | 1.82 | 1.09 |
| 4.85 | 4.00 | 6.70 | 1.29 | 1.42 | 1.42 | -- | 3 | 3 | 36 | 1.21 | 0.72 |
| 4.98 | 3.94 | 7.27 | 1.61 | 1.73 | -- | -- | 4 | 4 | 36 | 1.26 | 0.69 |
| 5.05 | 3.94 | 7.27 | 1.53 | 1.64 | -- | -- | 4 | 4 | 36 | 1.28 | 0.69 |

Example Review Comment:
The punching shear checks (stud rail design) provided on page 321 of the calculations lists several of the checks as exceeding the allowable shear stress (see Section 22.6 of ACI 318-19). Please address.

121

# Inspection Items

- ***No matter how good the review, inspection issues will arise.***
- ***IBC 110 lists when inspections are required.***
- ***Are approved plans onsite?***
- ***Is a complete load path provided?***
- ***Do member sizes match the approved plans?***

122

# Quiz

- ❑ What ACI standard, and what version, governs the design of concrete structures in addition to the IBC and ASCE 7?
- ❑ What is the required concrete cover when cast against earth?
- ❑ What is a way around providing standard calculations for concrete anchorages in accordance with Chapter 17 of ACI?
- ❑ When are special inspections required for concrete construction?
- ❑ What is the minimum ratio of still for concrete footings?
- ❑ What are things to look for in relation to transverse tie reinforcement?
- ❑ What should be looked at in relation to the diaphragm?

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# PART 5
## Masonry Construction

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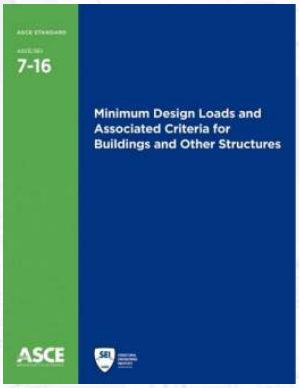
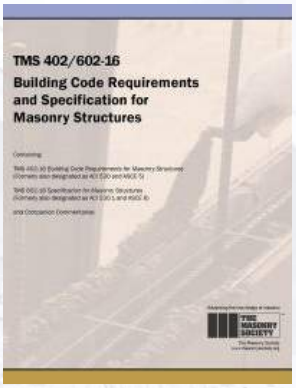
# Codes/Standards


International Code Council, 2021 IBC©




American Society of Civil Engineers, ASCE 7-16©




The Masonry Society, TMS 403/602-16©

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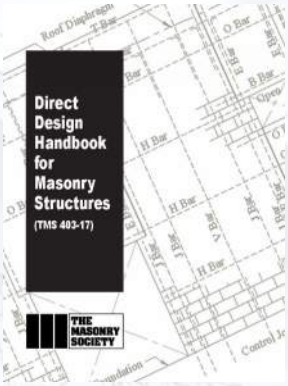
# Resources


FEMA P-2192-V1, Design Examples©


SEAOC, International Code Council & NCSEA ©

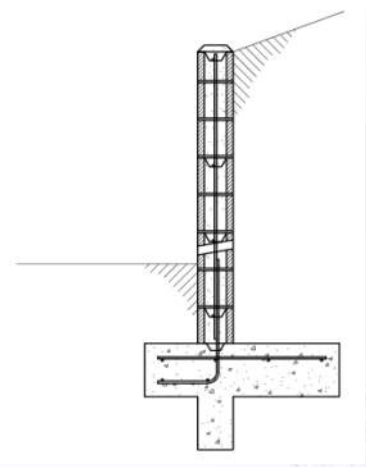



The Masonry Society, TMS 403-17 ©

126

# Masonry Construction

- ❑ Shear & bearing walls
- ❑ Retaining walls
- ❑ Columns & pilasters
- ❑ Beams, deep beams, lintels
- ❑ Veneer



West Coast Code Consultants, Inc ©

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# IBC Requirements

- ❑ ***IBC Chapter 21***
  - Numerous topics discussed…
    - Materials
    - ~~Construction~~
    - ~~Quality Assurance~~
    - ~~Seismic Design~~
    - Allowable Stress Design
    - Strength Design
    - ~~Empirical Design~~
    - ~~Glass Units~~
    - ~~Fireplaces, Heaters, Chimneys~~
    - ~~Dry Stack Masonry~~

**Simply refers to TMS**


International Code Council, 2021 IBC©

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# IBC Requirements

- ***Materials***
  - Masonry Units → Article 2.3 of TMS 602
  - Architectural Cast Stone → ASTM C1364 & TMS 504
  - Adhered Veneer → ASTM C1670
  - Mortar → Article 2.1 & 2.6A of TMS 602
  - Grout → Article 2.2 of TMS 602 → ≥ CMU, but not less than 2,000psi
  - Metal Reinforcement → Article 2.4 of TMS 602

129

# IBC Requirements

- ***Allowable Stress Design***
  - Provides alternate lap splice determination
    - $l_d = 0.002 * d_b * f_s$
    - Not < 12-inches or $40d_b$
    - Increase 50% for epoxy coated bars
  - Removes 125% of yield strength for welded and mechanical splices
  - Requires mechanical splice for > #9 bar

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# IBC Requirements

- ***Strength Design***
  - Added a maximum development length of $72d_b$
  - Welded lap splices not required to conform to AWS D1.4 and does not allow an option to ASTM A706 bar.
  - Welded splices are not allowed in plastic hinge zones of intermediate and special reinforced walls.
  - Does not require mechanical splices to develop 125% of yield strength.

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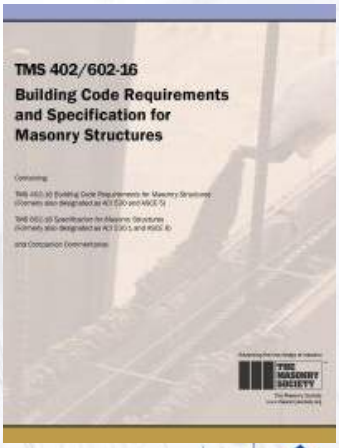
# TMS 402/602 Requirements

- ***Key Items***
  - Construction Documents
  - Quality Assurance Program
  - Seismic Design Requirements
  - Veneer

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# TMS 402/602 Requirements

- ***Construction Documents*** *(§1.2.1)*
  - Shall include…
    - Loads used for design
    - Specified compressive strength of masonry
    - Size & location of structural members
    - Details of anchorages, including the type, size & location
    - Details of reinforcement, including size, grade, type, lap splice length & location
    - If reinforcing bars are to be welded & their requirements
    - Size & permitted locations of conduits, pipes & sleeves
    - Shall specify the quality assurance plan

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# TMS 402/602 Requirements

- ***Quality Assurance Program***
  - Requirements removed in 2015 IBC
  - Now refers to TMS 402 & 602 *(IBC 1705.4)*
  - Can you recall some of the masonry special inspection and testing requirements?


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# TMS 402/602 Requirements

- ***Quality Assurance Program***
  - TMS 402 → Table 3.1

| | Designed in accordance with | Risk Category I, II or III | Risk Category IV |
|---|---|---|---|
| | Part 3, or… Appendix B, or… Appendix C | Level 2 | Level 3 |
| **Prescriptive** | Part 4 | Level 1 | Level 2 |
| **Empirical** | Appendix A | Level 1 | Not permitted |

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# TMS 402/602 Requirements

- ***Quality Assurance Program***
  - TMS 602 → Must comply with Tables 3 & 4

| Minimum Verification | Required for Quality Assurance | | | Reference for Criteria |
|---|---|---|---|---|
| | Level 1 | Level 2 | Level 3 | TMS 602 |
| Prior to construction, verification of compliance submittals | R | R | R | Art. 1.5 |
| Prior to construction, verification of $f'_m$ and $f'_{aac}$, except where specifically exempted by the Code. | NR | R | R | Art. 1.4 B |
| During construction, verification of Slump flow and Visual Stability Index (VSI) when self-consolidating grout is delivered to the project site. | NR | R | R | Art. 1.5 & 1.6.3 |
| During construction, verification of $f'_m$ and $f'_{aac}$ for every 5,000 square feet. | NR | NR | R | Art. 1.4 B |
| During construction, verification of proportions of materials delivered to the project site for premixed or preblended mortar, prestressing grout, and grout other than self-consolidating grout. | NR | NR | R | Art. 1.4 B |

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**Table 4 — Minimum Special Inspection Requirements**

| Inspection Task | MINIMUM SPECIAL INSPECTION Frequency [a] Level 1 | Level 2 | Level 3 | Reference for Criteria TMS 402 | TMS 602 |
|---|---|---|---|---|---|
| 1 As masonry construction begins, verify that the following are in compliance: | | | | | |
| a. Proportions of site-prepared mortar | NR | P | P | | Art. 2.1, 2.6 A, & 2.6 C |
| b. Grade and size of prestressing tendons and anchorages | NR | P | P | | Art. 2.4 B & 2.4 H |
| c. Grade, type and size of reinforcement, connectors, anchor bolts,and prestressing tendons and anchorages | NR | P | P | | Art. 3.4 & 3.6 A |
| d. Prestressing technique | NR | P | P | | Art. 3.6 B |
| e. Properties of thin-bed mortar for AAC masonry | NR | C[b]/P[c] | C | | Art. 2.1 C.1 |
| f. Sample panel construction | NR | P | C | | Art. 1.6 D |
| 2. Prior to grouting, verify that the following are in compliance: | | | | | |
| a. Grout space | NR | P | C | | Art. 3.2 D & 3.2 F |
| b. Placement of prestressing tendons and anchorages | NR | P | P | Sec. 10.8 & 10.9 | Art. 2.4 & 3.6 |
| c. Placement of reinforcement, connectors, and anchor bolts | NR | P | C | Sec. 6.1, 6.3.1, 6.3.6, & 6.3.7 | Art. 3.2 E & 3.4 |
| d. Proportions of site-prepared grout and prestressing grout for bonded tendons | NR | P | P | | Art. 2.6 B & 2.4 G.1.b |

**Not everything applies. An SSI should be project-specific.**

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| 3. Verify compliance of the following during construction: | | | | | |
|---|---|---|---|---|---|
| a. Materials and procedures with the approved submittals | NR | P | P | | Art. 1.5 |
| b. Placement of masonry units and mortar joint construction | NR | P | P | | Art. 3.3 B |
| c. Size and location of structural members | NR | P | P | | Art. 3.3 F |
| d. Type, size, and location of anchors, including other details of anchorage of masonry to structural members, frames, or other construction | NR | P | C | Sec. 1.2.1(e), 6.2.1, & 6.3.1 | |
| e. Welding of reinforcement | NR | C | C | Sec.6.1.6.1.2 | |
| f. Preparation, construction, and protection of masonry during cold weather (temperature below 40°F (4.4°C)) or hot weather (temperature above 90°F (32.2°C)) | NR | P | P | | Art. 1.8 C & 1.8 D |
| g. Application and measurement of prestressing force | NR | C | C | | Art. 3.6 B |
| h. Placement of grout and prestressing grout for bonded tendons is in compliance | NR | C | C | | Art. 3.5 & 3.6 C |
| i. Placement of AAC masonry units and construction of thin-bed mortar joints | NR | C[b]/P[c] | C | | Art. 3.3 B.9 & 3.3 F.1.b |
| 4 Observe preparation of grout specimens, mortar specimens, and/or prisms | NR | P | C | | Art. 1.4 B.2.a.3, 1.4 B.2.b.3, 1.4 B.2.c.3, 1.4 B.3, & 1.4 B.4 |

(a) Frequency refers to the frequency of inspection, which may be continuous during the listed task or periodically during the listed task, as defined in the table. NR=Not Required, P=Periodic, C=Continuous

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# TMS 402/602 Requirements

- ***Seismic Design Requirements***
  - Shear wall type is dependent upon the SDC
  - Table CC-7.3.2-1 outlines the SDC limitations

**TABLE CC-7.3.2-1 Requirements for Masonry Shear Walls Based on Shear Wall Designation[1]**

| Shear wall Designation | Design Methods | Reinforcement Requirements | Permitted In |
|---|---|---|---|
| Empirical Design of Masonry Shear Walls | Section A.3 | None | SDC A |
| Ordinary Plain (Unreinforced) Masonry Shear Walls | Section 8.2 or Section 9.2 | None | SDC A and B |
| Detailed Plain (Unreinforced) Masonry Shear Walls | Section 8.2 or Section 9.2 | Section 7.3.2.3.1 | SDC A and B |
| Ordinary Reinforced Masonry Shear Walls | Section 8.3 or Section 9.3 | Section 7.3.2.3.1 | SDC A, B, and C |
| Intermediate Reinforced Masonry Shear Walls | Section 8.3 or Section 9.3 | Section 7.3.2.5 | SDC A, B, and C |
| Special Reinforced Masonry Shear Walls | Section 8.3 or Section 9.3 | Section 7.3.2.6 | SDC A, B, C, D, E, and F |
| Ordinary Plain (Unreinforced) AAC Masonry Shear Walls | Section 11.2 | Section 7.3.2.7.1 | SDC A and B |
| Detailed Plain (Unreinforced) AAC Masonry Shear Walls | Section 11.2 | Section 7.3.2.8.1 | SDC A and B |
| Ordinary Reinforced AAC Masonry Shear Walls | Section 11.3 | Section 7.3.2.9 | SDC A, B, C, D, E, and F |
| Ordinary Plain (Unreinforced) Prestressed Masonry Shear Walls | Chapter 10 | None | SDC A and B |
| Intermediate Reinforced Prestressed Masonry Shear Walls | Chapter 10 | Section 7.3.2.11 | SDC A, B, and C |
| Special Reinforced Prestressed Masonry Shear Walls | Chapter 10 | Section 7.3.2.12 | SDC A, B, C, D, E, and F |

[1] Section and Chapter references in this table refer to Code Sections and Chapters.

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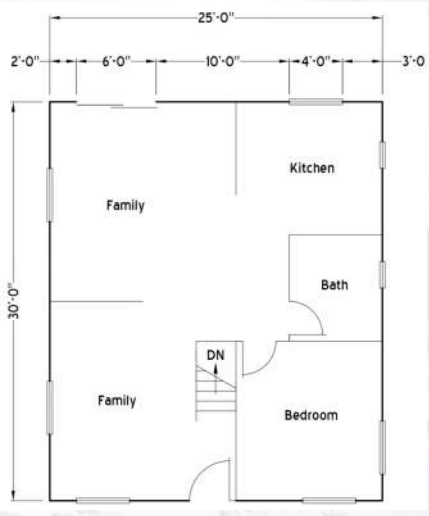
# TMS 402/602 Requirements

- ***Seismic Design Requirements***
  - § 7.3.2.6 of TMS 402-16
  - Maximum reinforcement spacing
    - 1/3 length of wall, or…
    - 1/3 height of wall, or…
    - 48”o.c.

**EXAMPLE**

**Given: 9-foot walls**

- **25’/3 = 8.33’**
- **9’/3 = 3.0’**
- **48”**

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# TMS 402/602 Requirements

## ❑ *Seismic Design Requirements*

- Ratio of reinforcing
  - $\rho_{min} \geq 0.0007$ in each direction ($\rho_h$ & $\rho_v$)
  - $\rho_{total} \geq 0.002$ ($\rho_h + \rho_v$)
- Plan Review Cheat Sheet…

**Actual Reinforcing Steel Ratio ($\rho_{act}$)**

| | Ag (in²) | #4 bars ($A_s$ =0.20in²) | | | | | #5 bars ($A_s$ =0.31in²) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 8"o.c. | 16"o.c. | 24"o.c. | 32"o.c. | 48"o.c. | 8"o.c. | 16"o.c. | 24"o.c. | 32"o.c. | 48"o.c. |
| 4" block | 43.5 | 0.00690 | 0.00345 | 0.00230 | 0.00172 | 0.00115 | 0.01069 | 0.00534 | 0.00356 | 0.00267 | 0.00178 |
| 6" block | 67.5 | 0.00444 | 0.00222 | 0.00148 | 0.00111 | 0.00074 | 0.00689 | 0.00344 | 0.00230 | 0.00172 | 0.00115 |
| 8" block | 91.5 | 0.00328 | 0.00164 | 0.00109 | 0.00082 | *0.00055* | 0.00508 | 0.00254 | 0.00169 | 0.00127 | 0.00085 |
| 10" block | 115.5 | 0.00260 | 0.00130 | 0.00087 | *0.00065* | *0.00043* | 0.00403 | 0.00201 | 0.00134 | 0.00101 | *0.00067* |
| 12" block | 139.5 | 0.00215 | 0.00108 | 0.00072 | *0.00054* | *0.00036* | 0.00333 | 0.00167 | 0.00111 | 0.00083 | *0.00056* |

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Example Review Comment:
Section 7.3.2.6 of TMS 402-16 requires a minimum reinforcement ratio of 0.002 times the gross cross-sectional area of the wall, with a minimum vertical and horizontal steel ratio of 0.0007. Currently the typical wall reinforcing is called out as a single #5 vertical bar at 32"o.c. and single #4 horizontal bar at 48"o.c. This results in a total steel ratio of less than 0.002 and a horizontal steel ratio of less than 0.0007. Please address.

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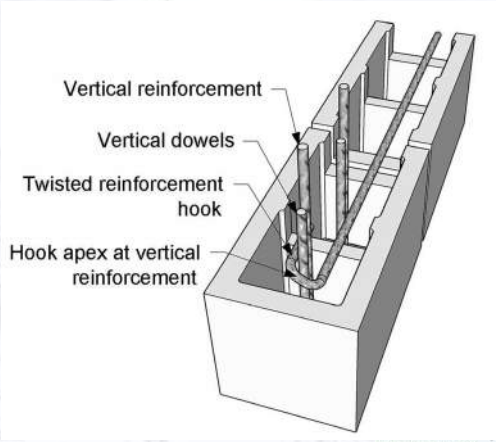
# TMS 402/602 Requirements

- ***Seismic Design Requirements***
  - Shear reinforcement shall be anchored around vertical bars with a standard hook

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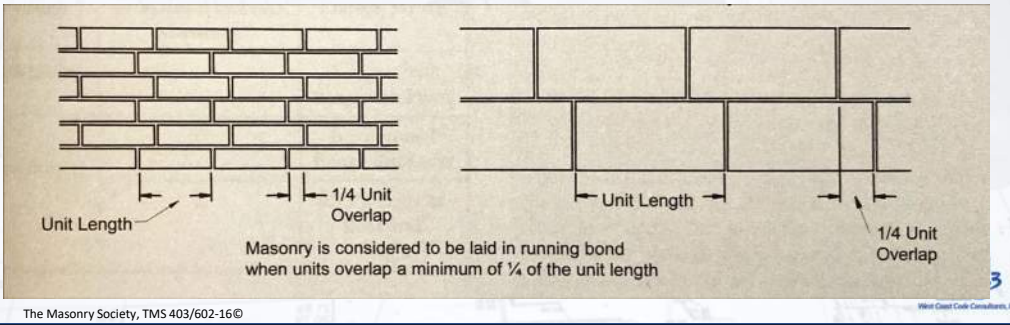
# TMS 402/602 Requirements

- ***Seismic Design Requirements***
  - For masonry not laid in a running bond…
    - $\rho_v \geq 0.0007$ & $\rho_h \geq 0.0015$
    - Shall be fully grouted

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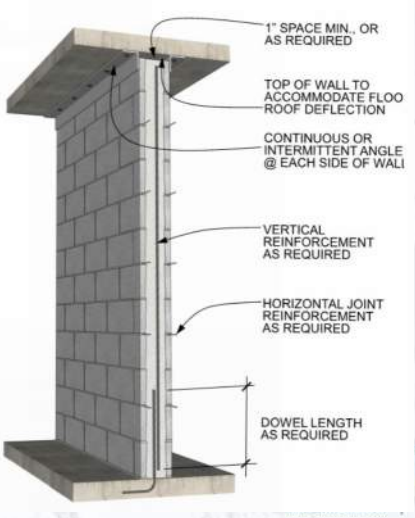
# TMS 402/602 Requirements

## ❑ *Seismic Design Requirements*

- Nonparticipating Elements:
  - If not intended to resist lateral forces…
  - Must be isolated in their own plane per §7.3.1 of TMS 402-16
  - Horizontal reinforcement:
    - Two wires of W1.7 @ 16"o.c., or…
    - #4 bar @ 48"o.c.
    - Within 16-inches of top and bottom
  - Vertical reinforcement:
    - #4 bar @ 120"o.c.
    - Within 16-inches of wall ends

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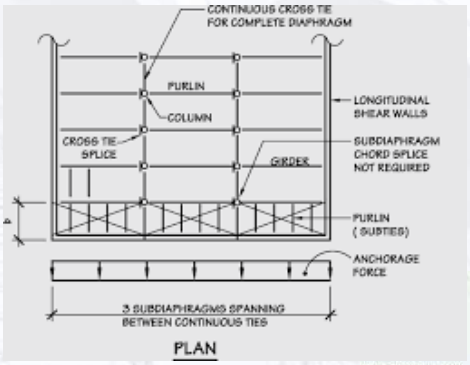
# TMS 402/602 Requirements

## ❑ *Seismic Design Requirements*

- Out-of-Plane Anchorage (§ 12.11.2.2 of ASCE 7)
  - Diaphragms shall be provided with continuous ties or struts. The l:w ratio shall not exceed 2.5:1
  - Forces on steel elements shall be increased by 1.4 times.

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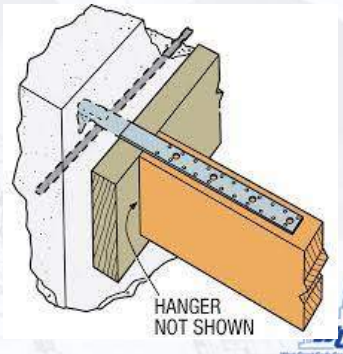
# TMS 402/602 Requirements

## ❑ *Seismic Design Requirements*

- Out-of-Plane Anchorage (§ 12.11.2.2 of ASCE 7)
  - Anchorage shall not be accomplished by ledgers in cross-grain bending.
  - The diaphragm sheathing shall not be considered effective for providing the ties or struts.

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# TMS 402/602 Requirements

## ❑ *Seismic Design Requirements*

- § 5.3.1.4: Similar tie requirements as for concrete…
  - Spacing ≤ $16b_d$ longitudinal or $48b_d$ of tie
  - ≤ 6-inch clearance from laterally supported bar

Example Review Comment:
Please review the lateral tie requirements shown in the masonry column details. Vertical bars should be tied in such a fashion as to ensure the maximum distance between laterally tied bars is less than or equal to 6-inches. See Section 5.3.1.4 of TMS 402-16.

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# TMS 402/602 Requirements

- ***Veneer***
  - Prescriptive Requirements for Anchored Veneer (§12.2.2):
    - Wind pressure ≤ 40psf
    - Weight shall be supported by noncombustible foundations
    - Noncombustible lintels over openings
      - 4-inch minimum bearing
      - Dead + Live → L/600
    - Height Limitations:
      - Wood backing ≤ 30-feet above noncombustible foundation (38-feet at gables)
      - Metal stud backing ≤ 30-feet above noncombustible foundation (Can be supported above this height)

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**Great article on alternative design of anchored masonry veneer:**
**https://csengineermag.com/code-compliant-designs/**

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# TMS 402/602 Requirements

- ***Veneer***
  - Prescriptive Requirements for Anchored Veneer (§12.2.2):
    - Corrugated sheet metal anchors
      - Minimum 7/8-inch wide * 0.03 inches thick
      - Embed into mortar joint 1.5-inches
    - Sheet metal anchors
      - Minimum 7/8-inch wide * 0.06 inches thick
      - Embed into mortar joint 1.5-inches
    - Wire anchors
      - Minimum wire size W1.7 with 2-inch extensions
      - Embed into mortar joint 1.5-inches
    - Joint reinforcement also allowed

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# C. Masonry Construction

***Masonry Veneer:***

- Attachment Requirements
  - Provide at least one anchor for every 2.67ft² of wall area
  - Space anchors at max. 32" horizontally and 25" vertically
  - Provide additional anchors around openings > 16-inches. Space anchors around perimeter a maximum of 3-feet o.c.

MasonryDirect.com, https://www.masonrydirect.com/products/hohmann-barnard-dw-10hs-anchors

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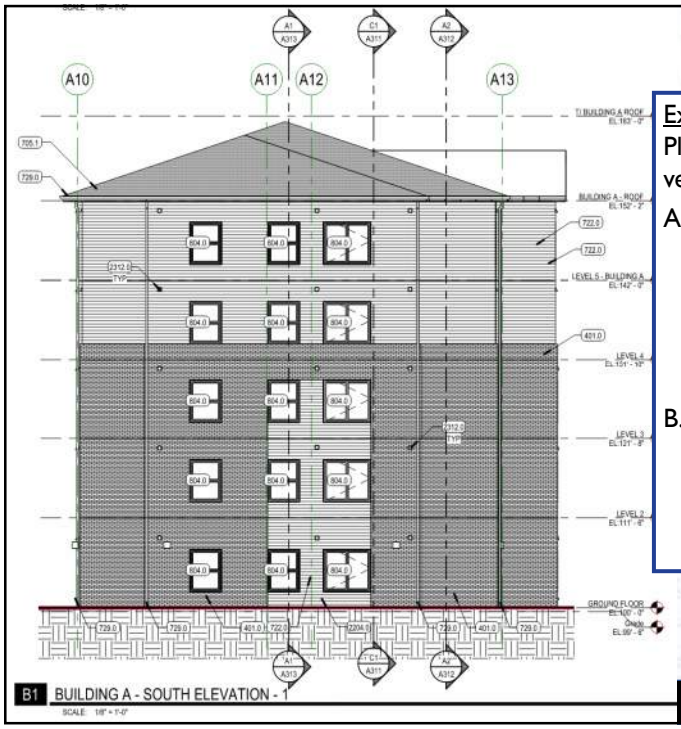


Example Review Comment:

Please address the following in relation to the masonry veneer specified on the architectural plans:

A. The plans show the masonry veneer extending to above the 4th Floor which is at an elevation of 32-feet above grade. The section views show this as standard brick, yet Section 12.2.2.6.1 of TMS 402 says that veneer with wood backing shall not exceed 30-feet. Please address.

B. The plans do not provide any details for the anchorage of the masonry veneer as required by Section 12.2 of TMS 402. Please note these requirements on the plans or list it as a deferred submittal.

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# Plan Review Items

- ***Remember the WABO white paper***
- ***What should be included in a comment?***
- ***What should not?***
- ***How do we begin?***
- ***How much of our time should be spent reviewing…***
  - The plans?
  - The structural calculations?
  - Anything else?

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# Plan Review Items

***Structural General Notes:***

- Are materials requirements specified?
  - IBC, TMS 402, TMS 602
- Do specific installations meet code?
  - Are treated ledgers specified?
- Is extraneous information listed?
- Are there any deferred submittals?
  - Are the allowed?
- Are any special inspections noted?
  - Is this compliant with TMS 602?
  - Is a special inspection agreement form required?

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# Plan Review Items


***Floor & Roof Framing Plans:***

- Wood beam & joist sizes, spans, and spacing
- Masonry shear walls (CMU, reinforcing, etc.)
- Masonry lintel/beam requirements
- Masonry columns/pilaster requirements
- Nonparticipating elements (Is isolation provided?)
- Load path connections (ledgers, anchor bolts, diaphragm ties, etc.)
- Connection callouts (correct detail references)
- Diaphragm requirements (sheathing, nailing, blocking, etc.)

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# Plan Review Items

## *Sections & Details:*

- ***Structural Connections:***
  - Wall intersection details
  - Foundation dowel requirements
  - Roof-to-wall connections
  - Block-outs & sleeves
  - Isolation joint details

***This is the opportunity to verify that a complete load path is provided!***

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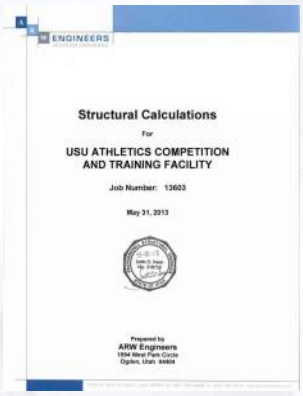
# Plan Review Items

## *Structural Calculations:*

- Remember, it is not our responsibility to verify the mathematical accuracy of the calculations.
- When reviewing plans, note significant structural members and make sure that a calculation is included.




Example Review Comment:
Please provide supporting calculations for the following…
A. The GB7 grade beam specified on sheet S1.02.
B. The footings and retaining walls at ramps shown on sheet S1.04.
C. The retaining walls in the elevator pit area shown on sheet S1.05.

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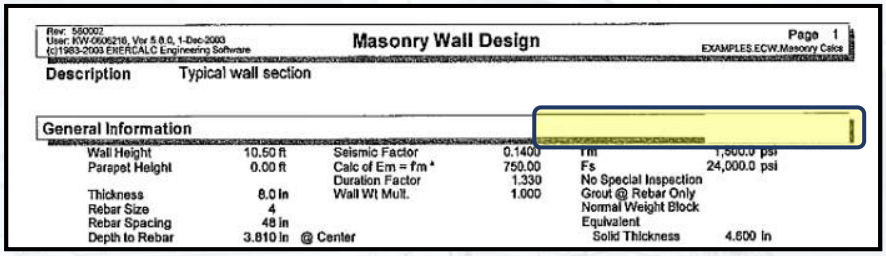
# Plan Review Items

***The equations for allowable shear stress have changed. See Section 8.3.5***

***Structural Calculations:***



Rev: 580002
User: KW-0606216, Ver 5.8.0, 1-Dec-2003
(c)1983-2003 ENERCALC Engineering Software

**Masonry Wall Design**

Page 1
EXAMPLES.ECW:Masonry Calcs

Description Typical wall section

General Information

| | | | | | |
|---|---|---|---|---|---|
| Wall Height | 10.50 ft | Seismic Factor | 0.1400 | f'm | 1,500.0 psi |
| Parapet Height | 0.00 ft | Calc of Em = f'm * | 750.00 | Fs | 24,000.0 psi |
| | | Duration Factor | 1.330 | No Special Inspection | |
| Thickness | 8.0 in | Wall Wt Mult. | 1.000 | Grout @ Rebar Only | |
| Rebar Size | 4 | | | Normal Weight Block | |
| Rebar Spacing | 48 in | | | Equivalent | |
| Depth to Rebar | 3.810 in @ Center | | | Solid Thickness | 4.600 in |

Example Review Comment:
Many of the calculations were performed in reference to outdated building codes and standards. Please confirm that calculations meet the requirements of the 2021 IBC and its referenced standards as listed in Chapter 35.

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# Inspection Items

- ***No matter how good the review, inspection issues will arise.***
- ***IBC 110 lists when inspections are required.***
- ***Are approved plans onsite?***
- ***Is a complete gravity, lateral, and uplift load path provided?***
- ***Do member sizes match the approved plans?***

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# Quiz

- ❑ What TMS standards govern the design of masonry buildings in addition to the IBC and ASCE 7?
- ❑ What is required in relation to nonparticipating elements?
- ❑ Describe three requirements of special reinforced masonry shear walls.
- ❑ When are special inspections required for masonry construction?
- ❑ How tall can anchored masonry veneer be applied to wood backing?
- ❑ What is the minimum grout compressive strength?

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# PART 6
## Steel Construction

https://corebrace.com/

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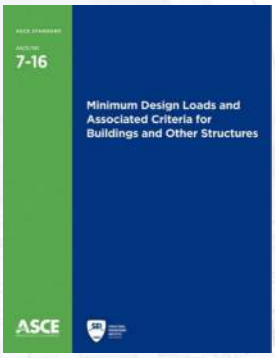
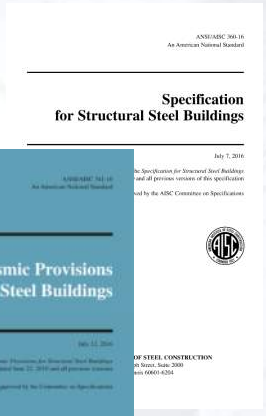
# Codes/Standards


International Code Council, 2021 IBC©




American Society of Civil Engineers, ASCE 7-16©



American Institute of Steel Construction, AISC 360-16, AISC 341-16, AISC 358-16 ©



# Resources

*https://www.aisc.org/globalassets/aisc/manual/v15.1-companion/v15.1_vol-1_design-examples.pdf*


FEMA P-2192-V1, Design Examples©


SEAOC, International Code Council & NCSEA ©


American Institute of Steel Construction, Design Examples ©

# Steel Construction

- ❑ Columns
- ❑ Beams
- ❑ Diaphragms
- ❑ Braced Frames
- ❑ Moment Frames
- ❑ Cantilevered Columns
- ❑ Shear Walls
- ❑ Miscellaneous Components

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# IBC Requirements

- ❑ ***IBC Chapter 22***
  - Numerous topics discussed…
    - Protection
    - Connections
    - Structural Steel
    - Composite Construction
    - Steel Joists
    - ~~Steel Cable Structures~~
    - ~~Steel Storage Racks~~
    - ~~Cold-Formed Steel~~
    - ~~Light-Frame Construction~~


International Code Council, 2021 IBC©

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# IBC Requirements

- ***Protection*** *(IBC 2203)*
  - Painting of structural steel elements per AISC 360.
  - Section M3.1 of AISC 360 notes that shop painting is not required unless specified. The AISC Commentary refers to SSPC publications for painting recommendations.
  - Section M3.4 states that machine-finished surfaces are to be protected against corrosion by means of a rust inhibitive primer that can be removed.

Example Review Comment:
Please indicate the structural steel protection requirements per IBC 2203.

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# IBC Requirements

- ***Connections*** *(IBC 2204)*
  - The details of welding, welding qualification and welding personnel shall comply with the appropriate standard.
  - The details of bolting shall comply with the appropriate standard.
  - Anchor rods should be set per the approved construction documents. The protrusion shall be sufficient to allow full engagement of the threads of the nuts.
  - Special inspections are required to verify all these items.

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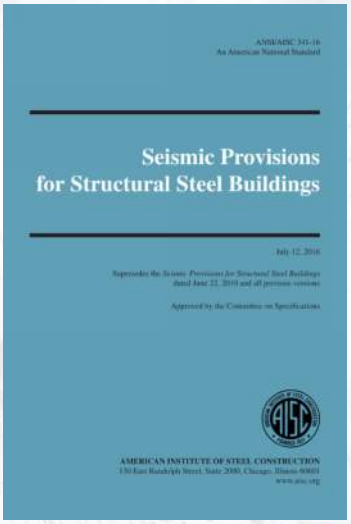
# IBC Requirements

- ***Structural Steel*** *(IBC 2205)*
  - Design, fabrication and erection per AISC 360.
  - SDC "D-F" → AISC 341
  - SDC "B-C" → AISC 341 is only required if an "R" from Table 12.2-1 of ASCE 7 is used. Otherwise, these buildings can be designed assuming *"Steel systems not specifically listed for seismic resistance"* (R, Cd, $\Omega_0$ = 3.0)



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# IBC Requirements

- ***Composite Construction*** *(IBC 2206)*
  - Most conform to both AISC 360 & ACI 318
  - If using Table 12.2-1 of ASCE 7 → designed and detailed using AISC 341

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# IBC Requirements

- ***Steel Joists*** *(IBC 2207)*
  - Design, fabrication & use per SJI 100 or SJI 200
  - Free download at https://steeljoist.org/
  - SER shall…
    - Note joist and girder designations
    - Show joist layout, end supports, anchorages & bridging
    - Special loads should be noted
    - Special considerations such as extended ends should be noted
    - Live & total load deflections specified if different from SJI standard

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# IBC Requirements

- ***Steel Joists*** *(IBC 2207)*
  - Joist MFR shall submit calculations if requested by the SER.
  - Joist MFR to provide steel joist placement plans for field installation.
  - At completion of fabrication, joist MFR to provide a certificate of compliance to owner for submission to the B.O.

Example Review Comment:
Please add a note to the "Open Web Steel Joists" section, stating that a certificate of compliance must be submitted to the building official upon completion of fabrication in accordance with IBC 2207.5.

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# IBC Requirements

- ***Nonstructural Components*** *(IBC 107.2.9)*
  - ***IBC 1613.1:*** "…nonstructural components that are permanently attached to structures and their supports and attachments, shall be designed and constructed to resist the effects of earthquake motions (per ASCE 7)..."
  - ***IBC Chapter 17:***
    - Designated Seismic Systems (IBC 1705.13.4 & 1705.14.3)
    - Architectural Components (IBC 1705.13.5)
    - MEP Components (IBC 1705.13.6)
    - Storage Racks (IBC 1705.13.7)
    - Nonstructural Component Testing (IBC 1705.14.2)

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# IBC Requirements

**107.2.9 Nonstructural components.** Construction documents shall indicate if structural support and anchoring documentation for nonstructural components is part of the design submittal or a deferred submittal. The construction documents for nonstructural components shall at a minimum identify the following:

**1.** All nonstructural components required by ASCE 7 Section 13.1.3 to have an importance factor of, Ip, of 1.5.

**2.** All mechanical equipment, fire sprinkler equipment, electrical equipment, and other nonstructural components required by ASCE 7 Section 13.1.3 Item 1 to be operational following a seismic event that require designated seismic systems per ASCE 7 Section 13.2.2 and special inspections per Section 1705.13.4.

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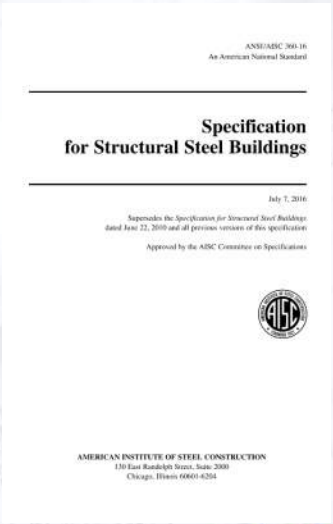
# AISC 360 Requirements

- ***Key Elements***
  - Chapter A – General Provisions
  - Chapter B – Design Requirements
  - Chapter C – Stability
  - Chapter D – Tension
  - Chapter E – Compression
  - Chapter F – Flexure
  - Chapter G – Shear
  - Chapter H – Combined Forces
  - Chapter I – Composite Members
  - Chapter N – Quality Control & Quality Assurance


ANSI/AISC 360-16
An American National Standard

Specification
for Structural Steel Buildings

July 7, 2016

Supersedes the *Specification for Structural Steel Buildings* dated June 22, 2010 and all previous versions of this specification

Approved by the AISC Committee on Specifications

AMERICAN INSTITUTE OF STEEL CONSTRUCTION
130 East Randolph Street, Suite 2000
Chicago, Illinois 60601-6204

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# Inspections & Tests

- ***Steel Construction (IBC 1705.2)***
  - Structural Steel → per AISC 360
  - Includes requirements for…
    - Prior to welding
    - During welding
    - After welding
    - Nondestructive testing
    - Prior to bolting
    - During bolting
    - After bolting

**TABLE N5.4-1**
**Inspection Tasks Prior to Welding**

| Inspection Tasks Prior to Welding | QC | QA |
|---|---|---|
| Welder qualification records and continuity records | P | O |
| WPS available | P | P |
| Manufacturer certifications for welding consumables available | P | P |
| Material identification (type/grade) | O | O |
| Welder identification system[a] | O | O |
| Fit-up of groove welds (including joint geometry)<br>• Joint preparations<br>• Dimensions (alignment, root opening, root face, bevel)<br>• Cleanliness (condition of steel surfaces)<br>• Tacking (tack weld quality and location)<br>• Backing type and fit (if applicable) | O | O |
| Fit-up of CJP groove welds of HSS T-, Y- and K-joints without backing (including joint geometry)<br>• Joint preparations<br>• Dimensions (alignment, root opening, root face, bevel)<br>• Cleanliness (condition of steel surfaces)<br>• Tacking (tack weld quality and location) | P | O |
| Configuration and finish of access holes | O | O |
| Fit-up of fillet welds<br>• Dimensions (alignment, gaps at root)<br>• Cleanliness (condition of steel surfaces)<br>• Tacking (tack weld quality and location) | O | O |
| Check welding equipment | O | – |

[a] The fabricator or erector, as applicable, shall maintain a system by which a welder who has welded a joint or member can be identified. Stamps, if used, shall be the low-stress type.

American Institute of Steel Construction, AISC 360-16 ©

# Inspections & Tests

- ***Steel Construction (IBC 1705.2)***
  - Structural Steel → per AISC 360
  - Periodic & continuous not used
  - Observer (O) → Observes items on a random basis
  - Perform (P) → Performed for each connection/weld

**TABLE N5.4-1**
**Inspection Tasks Prior to Welding**

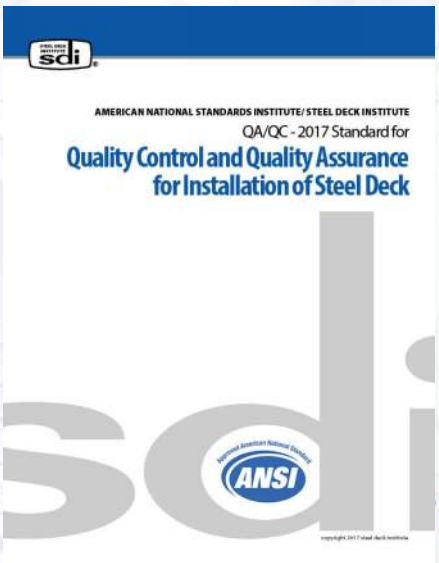
| Inspection Tasks Prior to Welding | QC | QA |
|---|---|---|
| Welder qualification records and continuity records | P | O |
| WPS available | P | P |
| Manufacturer certifications for welding consumables available | P | P |
| Material identification (type/grade) | O | O |
| Welder identification system[a] | O | O |
| Fit-up of groove welds (including joint geometry)<br>• Joint preparations<br>• Dimensions (alignment, root opening, root face, bevel)<br>• Cleanliness (condition of steel surfaces)<br>• Tacking (tack weld quality and location)<br>• Backing type and fit (if applicable) | O | O |
| Fit-up of CJP groove welds of HSS T-, Y- and K-joints without backing (including joint geometry)<br>• Joint preparations<br>• Dimensions (alignment, root opening, root face, bevel)<br>• Cleanliness (condition of steel surfaces)<br>• Tacking (tack weld quality and location) | P | O |
| Configuration and finish of access holes | O | O |
| Fit-up of fillet welds<br>• Dimensions (alignment, gaps at root)<br>• Cleanliness (condition of steel surfaces)<br>• Tacking (tack weld quality and location) | O | O |
| Check welding equipment | O | – |

[a] The fabricator or erector, as applicable, shall maintain a system by which a welder who has welded a joint or member can be identified. Stamps, if used, shall be the low-stress type.

American Institute of Steel Construction, AISC 360-16 ©

# Inspections & Tests

- ***Steel Construction (IBC 1705.2)***
  - Cold-formed Steel Deck → SDI QA/QC
  - SDI requires…
    - Verify deck materials (mill certificates)
    - Field welding per AWS D1.3 & SDI
    - Mechanical fasteners per SDI
    - Deck installation per approved construction documents




Steel Deck Institute, SDI QA/QC-2017 ©

# Inspections & Tests

- ***Steel Construction (IBC 1705.2)***
  - Open-web Steel Joists & Girders → per Table 1705.2.3

**TABLE 1705.2.3**
**REQUIRED SPECIAL INSPECTIONS OF OPEN-WEB STEEL JOISTS AND JOIST GIRDERS**

| TYPE | CONTINUOUS SPECIAL INSPECTION | PERIODIC SPECIAL INSPECTION | REFERENCED STANDARD[a] |
|---|---|---|---|
| 1. Installation of open-web steel joists and joist girders. | | | |
| a. End connections – welding or bolted. | — | X | SJI specifications listed in Section 2207.1. |
| b. Bridging – horizontal or diagonal. | — | — | — |
| 1. Standard bridging. | — | X | SJI specifications listed in Section 2207.1. |
| 2. Bridging that differs from the SJI specifications listed in Section 2207.1. | — | X | — |



# AISC 341 Requirements

- ***Discussion Topics:***
  - General Provisions
  - Moment Frames
  - Braced Frames
  - Quality Control & Quality Assurance

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# AISC 341 Requirements

## ❑ *General Provisions*

- **Demand Critical Welds** *(§A4.3.4b)*
- These are welds that…
  1. Are subject to yield-level stresses, and…
  2. Could cause catastrophic results if they fail
- DCW's shall be made with filler metals complying with clauses 6.1, 6.2, and 6.3 of AWS D1.8.
  - CVN toughness of 20 ft-lbf at 0°F, and…
  - CVN toughness of 40 ft-lbf at 70°F
- Ultrasonic testing of DSW's required in Chapter J of AISC 341

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# AISC 341 Requirements

## ❑ *General Provisions*

- **Demand Critical Welds** *(cont.)*
- AISC 341 requires that drawings show the demand critical welds for…
  - Special Steel Moment Frames
  - Intermediate Steel Moment Frames
  - Special Concentrically Braced Frames
  - Eccentrically Braced Frames
  - Column Splices
  - Column Anchorages

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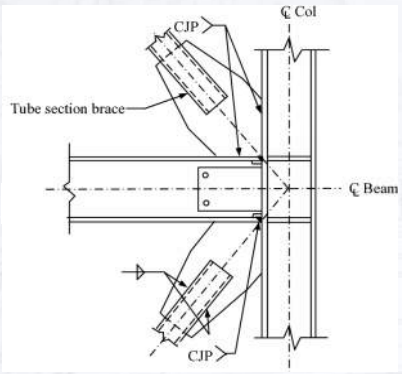
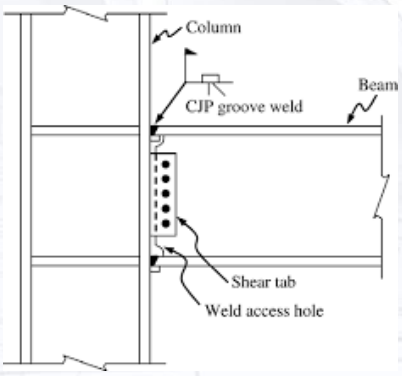
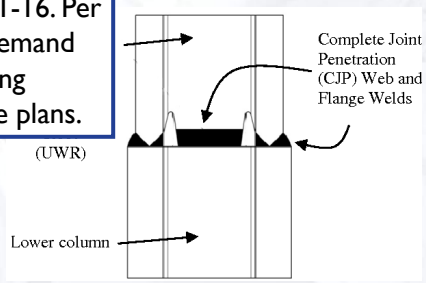
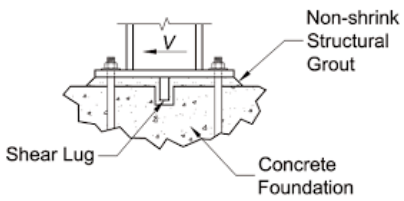
Example Review Comment:
Per IBC 2205.2.2, structural steel structures located within high seismic regions shall be designed and detailed in accordance with AISC 341-16. Per Section A4 of AISC 341-16, the drawings must clearly call out all demand critical welds, in addition to noting the specific weld filler and testing requirements. Please ensure that this is all clearly addressed on the plans.




Shear Lug Detail

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# AISC 341 Requirements

## ❑ *General Provisions*

- **Protected Zones** *(§A4.3.4b)*
- Areas of expected yielding
- Fabrication discontinuities are repaired
- Detrimental attachments are not permitted
- ***AISC 341-16*** requires drawings to show protected zones for…
  - Special Steel Moment Frames
  - Intermediate Steel Moment Frames
  - Special Concentrically Braced Frames
  - Eccentrically Braced Frames
  - Buckling Restrained Braced Frames

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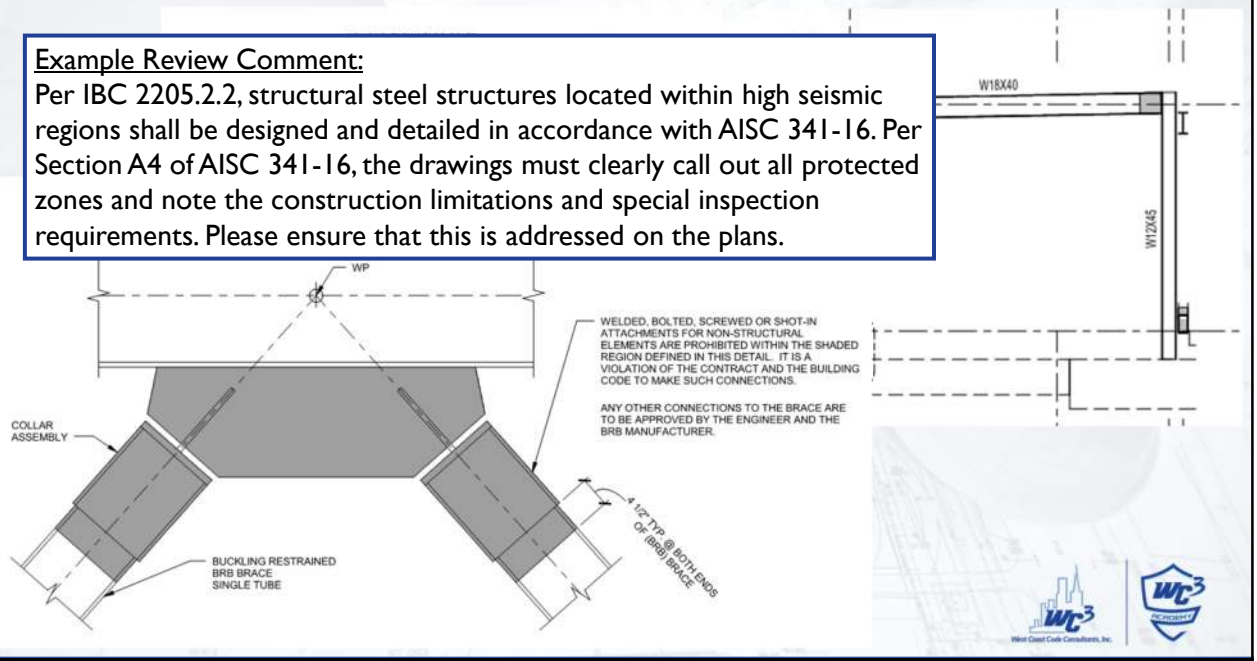
Example Review Comment:
Per IBC 2205.2.2, structural steel structures located within high seismic regions shall be designed and detailed in accordance with AISC 341-16. Per Section A4 of AISC 341-16, the drawings must clearly call out all protected zones and note the construction limitations and special inspection requirements. Please ensure that this is addressed on the plans.

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# AISC 341 Requirements

## ❑ *General Provisions*

- **Design Drawings** *(§A4)*
- The applicable building code & AISC standards should be noted.
- The plans should clearly indicate the following:
  1. Designation of the SFRS
  2. Identification of members and connections that are part of SFRS
  3. Locations & dimensions of protected zones
  4. Locations of demand critical welds
  5. Connection of concrete diaphragms and steel elements of SFRS
  6. Shop drawing or erection drawing requirements not addressed

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# AISC 341 Requirements

## ❑ *General Provisions*

- **Design Drawings** *(cont.)*
- It often is not clear how forces will be brought to SFRS.

Example Review Comment:
In accordance with Section A4 of AISC 341-16, the drawings must clearly designate all members that are part of the seismic-force-resisting-system (SFRS) and their connections. Please clearly call out all chords and drag members and ensure that their connections are properly accounted for on the plans.

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# AISC 341 Requirements

## ❑ *Moment Frames*

| Moment Frame | Response Modification Coefficient, R | Overstrength Factor, Ω | Design Category D Height Limitation |
|---|---|---|---|
| Ordinary MF | 3.5 | 3.0 | Not Permitted (exceptions) |
| Intermediate MF | 4.5 | 3.0 | 35 ft |
| Special MF | 8.0 | 3.0 | No Limit |
| Ordinary Cantilever Column | 1.25 | 1.25 | Not Permitted (exceptions) |
| Special Cantilever Column | 2.5 | 1.25 | 35 ft |

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# AISC 341 Requirements

## ❑ *Moment Frames*

| Moment Frame | Column | Beam | Beam-Column Relationship | Connection Design |
|---|---|---|---|---|
| Ordinary MF | None | None | None | AISC 360-16 |
| Intermediate MF | Moderately Ductile | Moderately Ductile | None | AISC 358-16 |
| Special MF | Highly Ductile | Highly Ductile | Weak beam, strong column $\Sigma M^*_{pc}/\Sigma M^*_{pb}>1.0$ | AISC 358-16 |
| Ordinary Cantilever Column | None | N/A | N/A | |
| Special Cantilever Column | Highly Ductile | N/A | N/A | |

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# AISC 341 Requirements

## ❑ *Highly Ductile*

- *"A member that meets the requirements for highly ductile members in Section D1."*
- Width-to-thickness ratio shall not exceed the limiting ratios from Table D1.1.

**TABLE D1.1**
**Limiting Width-to-Thickness Ratios for Compression Elements for Moderately Ductile and Highly Ductile Members**

| | Description of Element | Width-to-Thickness Ratio | Limiting Width-to-Thickness Ratio: $\lambda_{hd}$ Highly Ductile Members | Limiting Width-to-Thickness Ratio: $\lambda_{md}$ Moderately Ductile Members | Example |
|---|---|---|---|---|---|
| Unstiffened Elements | Flanges of rolled or built-up I-shaped sections, channels and tees; legs of single angles or double-angle members with separators; outstanding legs of pairs of angles in continuous contact | $b_f/t$ | $0.32\sqrt{\frac{E}{R_y F_y}}$ | $0.40\sqrt{\frac{E}{R_y F_y}}$ | |

American Institute of Steel Construction, AISC 341-16 ©

| Beam Size | $b_{bf}$ | $t_f$ | Width-to-Thickness (b/t) | Highly Ductile | Moderately Ductile |
|---|---|---|---|---|---|
| W12X50 | 8.08 | 0.64 | 6.3125 | 6.707752186 | 8.384690233 |

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# AISC 341 Requirements

## ❑ Moment Frames

| Braced Frame | Analysis Requirements |
|---|---|
| OMF | No special requirements |
| IMF | No special requirements |
| SMF | If part of two intersecting frames, analysis must consider yielding in both directions simultaneously. |
| OCCS | No special requirements |
| SCCS | No special requirements |

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# AISC 341 Requirements

## ❑ Moment Frames

| Braced Frame Type | Protected Zone |
|---|---|
| OMF | None |
| IMF | Ends of beams subject to inelastic straining.<br>AISC 358 or prequalification tests show extents. |
| SCBF | Ends of beams subject to inelastic straining.<br>AISC 358 or prequalification tests show extents. |
| OCCS | None |
| SCCS | Region at base of the column subject to inelastic straining.<br>Length is 2 times the column depth. |

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# AISC 341 Requirements

- ***Moment Frames***
  - AISC 358-16 provides prequalified moment connections and their requirements
  - These have been shown to meet the drift and other requirements.

**TABLE 2.1.**
**Prequalified Moment Connections**

| Connection Type | Chapter | Systems |
|---|---|---|
| Reduced beam section (RBS) | 5 | SMF, IMF |
| Bolted unstiffened extended end plate (BUEEP) | 6 | SMF, IMF |
| Bolted stiffened extended end plate (BSEEP) | 6 | SMF, IMF |
| Bolted flange plate (BFP) | 7 | SMF, IMF |
| Welded unreinforced flange-welded web (WUF-W) | 8 | SMF, IMF |
| Kaiser bolted bracket (KBB) | 9 | SMF, IMF |
| ConXtech ConXL moment connection (ConXL) | 10 | SMF, IMF |
| SidePlate moment connection (SidePlate) | 11 | SMF, IMF |
| Simpson Strong-Tie Strong Frame moment connection | 12 | SMF, IMF |
| Double-tee moment connection | 13 | SMF, IMF |

American Institute of Steel Construction, AISC 358-16 ©

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# AISC 341 Requirements

- ***Moment Frames***
  - **Example:** Reduced Beam Section (RBS)
  - Chapter 5 of AISC 358-16
  - ***Column Requirements:***
    - Beam must connect to the flange of the column.
    - W36 maximum
    - Box columns 24" max width & depth

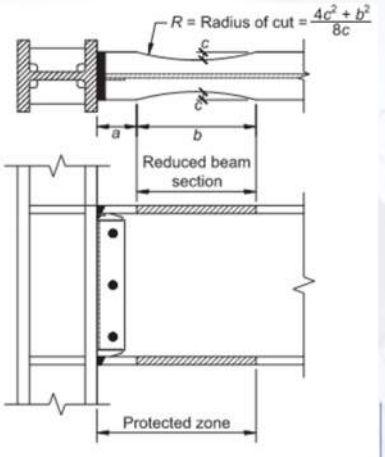


Fig. 5.1. Reduced beam section connection.

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# AISC 341 Requirements

- ***Moment Frames***
  - **Example:** Reduced Beam Section (RBS)
  - ***Beam Requirements:***
    - W or I shaped beams
    - Beam depth ≤ W36
    - Beam weight ≤ 302 plf
    - Beam $t_f$ ≤ 1-3/4"
    - Clear span to depth
      - SMF 7 or greater
      - OMF 5 or greater
    - Supplemental lateral bracing shall be provided within the beam depth of the RBS

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# AISC 341 Requirements

- ***Moment Frames***
  - **Example:** Reduced Beam Section (RBS)
  - ***RBS Section Limits***
    - $0.5b_{bf} \le a \le 0.75b_{bf}$
    - $0.65d \le b \le 0.85d$
    - $0.1b_{bf} \le c \le 0.25b_{bf}$

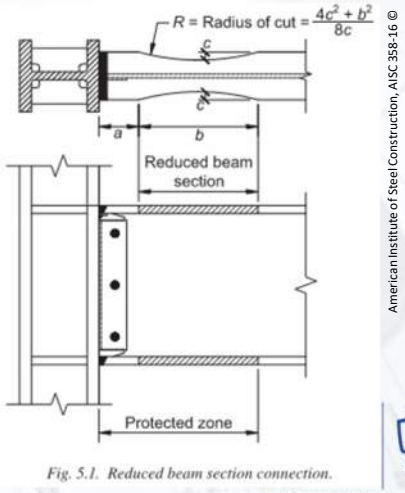


Fig. 5.1. Reduced beam section connection.

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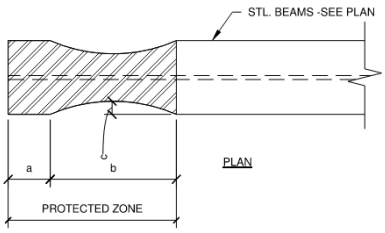
# AISC 341 Requirements

- ***Real World RBS Example:***
  - ***RBS Section Limits***
    - $0.5b_{bf} \le a \le 0.75b_{bf}$
    - $0.65d \le b \le 0.85d$
    - $0.1b_{bf} \le c \le 0.25b_{bf}$
    - a = distance to start of RBS cut
    - $b_{bf}$ = width of beam flange *(W14x22 = 5")*
    - b = length of RBS cut
    - c = depth of cut at center
    - d = depth of beam

| MOMENT FRAME SCHEDULE | | | | |
|---|---|---|---|---|
| LOCATION | BEAM SIZE | a | b | c |
| | | IN | IN | IN |
| GRID B - LEVEL 2 | W 14X22 | 4" | 12" | 3/4" |
| GRID B - ROOF | W 14X22 | 6" | 16" | 1" |
| GRID D - LEVEL 2 | W 14X22 | 4" | 12" | 3/4" |
| GRID D - ROOF | W 14X22 | 6" | 16" | 1" |




| Beam Size | $b_{bf}$ | d | $a_{provided}$ | $b_{provided}$ | $c_{provided}$ | $a_{min}$ | $a_{max}$ | $a_{check}$ | $b_{min}$ | $b_{max}$ | $b_{check}$ | $c_{min}$ | $c_{max}$ | $c_{check}$ | ACCEPTABLE? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W14X22 | 5 | 13.7 | 4 | 12 | 0.75 | 2.5 | 3.75 | NG | 8.905 | 11.645 | NG | 0.5 | 1.25 | OK | NG |

SCALE : NONE S5.1

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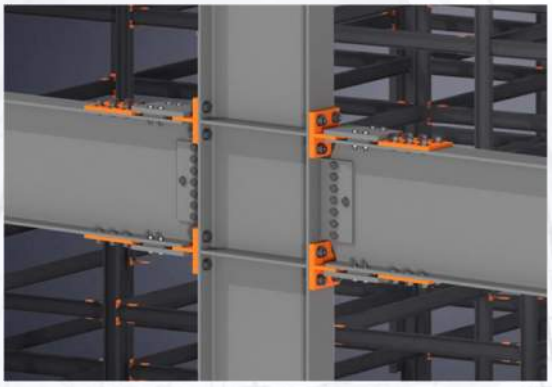
# AISC 341 Requirements



Simpson Yield-Link®


DuraFuse Frames

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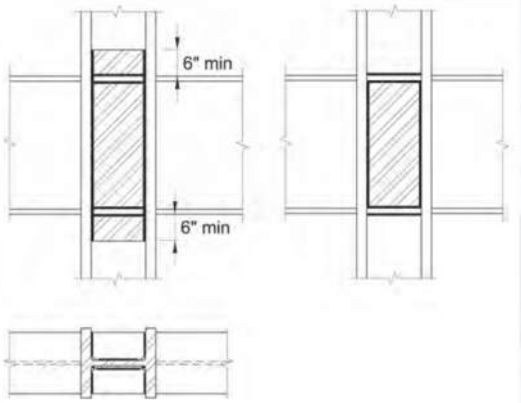
# AISC 341 Requirements

## ❑ *Moment Frames*

- **Continuity plates**
  - As prescribed in specific Chapter
  - *Example:* E2.6f for IMF
- **Doubler plates**
  - Added to stiffen panel-zone
  - 1/4-inch minimum thickness




(a) Doubler plate extended beyond continuity plates

(b) Doubler plate placed between continuity plates

*Fig. C-E3.8. Doubler plate used with continuity plates.*



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# AISC 341 Requirements

## ❑ *Braced Frames*

| Braced Frame | Response Modification Coefficient, R | Overstrength Factor, Ω | Design Category D Height Limitation |
|---|---|---|---|
| OCBF | 3.25 | 3.25 | 35 ft * |
| SCBF | 6.0 | 5.0 | 160 ft |
| BRBF | 8.0 | 5.0 | 160 ft |
| EBF | 8.0 | 8.0 | 160 ft |

* OCBF can be 60-ft in height for single-story buildings with maximum roof dead load of 20psf.

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# AISC 341 Requirements

## ❑ *Braced Frames*

| Braced Frame | Brace | Column | Beam |
|---|---|---|---|
| OCBF | Moderately Ductile | None | None |
| OCBF Tension Only | Slenderness > 200 | None | None |
| SCBF | Highly Ductile | Highly Ductile | Highly Ductile |
| BRBF | Buckling Restrained | Moderately Ductile | Moderately Ductile |
| EBF | Moderately Ductile | Highly Ductile | Moderately Ductile<br>Outside Link Beam |

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# AISC 341 Requirements

## ❑ *Real World RBS Example:*

***Three of four braces in schedule are not highly ductile!***

A1085 Gr A required → HSS4x4x1/4

Neither grade works → HSS5x5x5/16

A1085 Gr A required → HSS6x6x3/8

SPECIAL CONCENTRIC BRACED FRAME CONNECTION SCHEDULE

| BRACE SIZE | WELD (A) | WELD (B) | WELD (C) | WELD (D) | WELD (E) | GUSSET PLATE | SETBACK (Sb MIN) | COVER PLATE | GUSSET PLATE STIFFENER | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|
| HSS4x4x1/4 | 5/16"x10" | 7/16"x11" | 3/16"x5" | 1/4"x12" | - | 1" | 2" | 0.5"x4"x27" | - | AT COLUMN |
| | 5/16"x10" | - | - | 1/4"x12" | 7/16"x30" | 1" | 2" | 0.5"x4"x27" | 1" | AT FLOOR BEAM |
| HSS5x5x5/16 | 5/16"x13" | 5/8"x12" | 1/4"x12" | 5/16"x10" | - | 1" | 2" | 0.5"x4"x27" | - | AT COLUMN |
| | 5/16"x13" | - | - | 1/4"x12" | 3/4"x30" | 1" | 2.1/2" | 0.5"x4"x27" | 1.1/4" | AT FLOOR BEAM |
| HSS6x6x1/2 | 5/16"x24" | 3/4"x17" | 5/16"x12" | 5/16"x10" | - | 1" | 2" | 0.5"x4"x23" | - | AT COLUMN |
| | 5/16"x24" | - | - | 5/16"x10" | 1"x36" | 1" | 3.1/4" | 0.5"x4"x23" | 1.5/8" | AT FLOOR BEAM |
| HSS6x6x3/8 | 5/16"x18" | 5/8"x15" | 5/16"x12" | 5/16"x10" | - | 1" | 2" | 0.5"x4"x23" | - | AT COLUMN |
| | 5/16"x18" | - | - | 5/16"x10" | 11/16"x36" | 1" | 2.3/4" | 0.5"x4"x23" | 1.3/8" | AT FLOOR BEAM |

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# AISC 341 Requirements

| Braced Frame | Analysis Requirements |
|---|---|
| OCBF | Beams and their connections: Overstrength ($\Omega_o$)<br>Brace connections: Overstrength ($\Omega_o$) or<br>$R_yF_yA_g$ in tension, min($R_yF_yA_g/\alpha_s$ , $1.1F_{cre}A_g/\alpha_s$ ) in compression |
| SCBF | Columns, beams, struts, and connection: capacity-limited seismic load effect. This is the larger of:<br>Analysis with all braces at expected strengths<br>Analysis with tension braces at expected strengths and compression braces at post-buckling strength |
| BRBF | Columns, beams, struts and connections: capacity-limited seismic load effect which is:<br>Forces developed assuming the forces in all braces correspond to their adjusted strength in tension or compression. |
| EBF | Diagonal braces, connections, beams outside links, and columns designed for capacity-limited seismic load effect.<br>This is the forces developed assuming the link is at the adjusted link strength. |

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# AISC 341 Requirements

- ***Braced Frames***

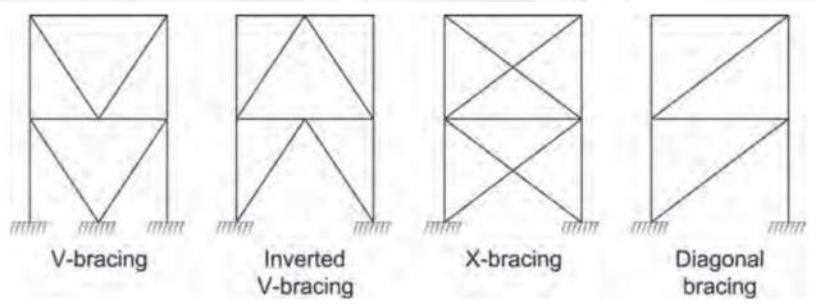


*Fig. C-F2.1. Examples of concentric bracing configurations.*

American Institute of Steel Construction, AISC 341-16 ©

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# AISC 341 Requirements

- ***Braced Frames***

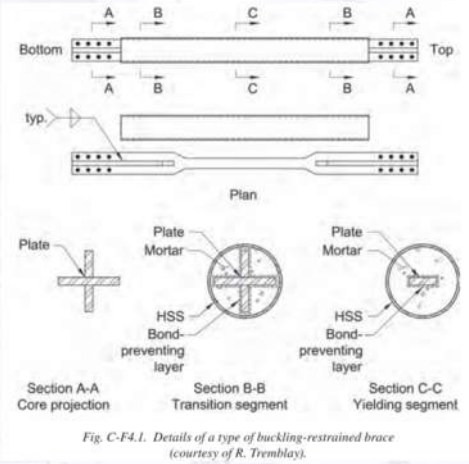


*Fig. C-F4.1. Details of a type of buckling-restrained brace (courtesy of R. Tremblay).*

American Institute of Steel Construction, AISC 341-16 ©

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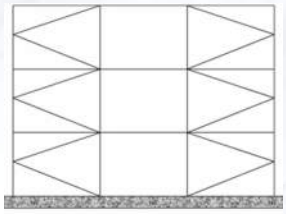
# AISC 341 Requirements



- ***Braced Frames***
  - ***K-Braced Frame:*** A braced-frame configuration in which two or more braces connect to a column at a point other than a beam-to-column or strut-to-column connection.
  - K-type braced frames are not allowed for OCBF (§F1.4b), SCBF (§F2.1.4c), and BRBF (§F4.4).
  - A similar condition occurs when a single brace connects to a column away from the base plate or beam. This is not allowed because OCBF and SCBF are "concentric". The code allows eccentricities ***less than the beam depth*** if eccentricities are accounted for. (§F1.2, §F2.2, §F4.2)

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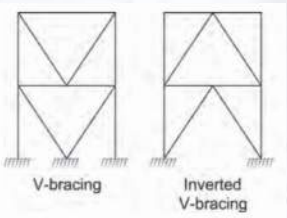
# AISC 341 Requirements




## ❑ Braced Frames

| Frame Type | Requirements |
|---|---|
| All | Beams continuous between columns<br>One set of lateral braces is required at the point of intersection of braces, unless beam has sufficient out of plane strength. |
| OCBF | For earthquake loads:<br>Tension braces assumed to be least of overstrength (Ωo) or the maximum force that can be developed by the system.<br>Compression braces assumed to be 0.3Pn |
| SCBF | Beams moderately ductile<br>Brace strengths same as other SCBFs |
| BRBF | Beams moderately ductile<br>Brace strengths same as other BRBFs |

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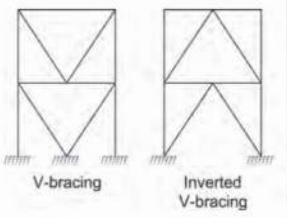
# AISC 341 Requirements




## ❑ Braced Frames

- **For OCBF**
  - Tension assumed to be overstrength (Ωo) or the maximum force developed.
  - Compression braces assumed to be $0.3P_n$
- **For SCBF**
  - Tension braces assumed to be $R_yF_yA_g$
  - Compression braces assumed to be lesser of $R_yF_yA_g$ and $(1/0.877)F_{cre}A_g$
    - $F_{cre}$ is $F_{cr}$ using $R_yF_y$ instead of $F_y$
    - The compression braces are assumed to carry a maximum of 0.3 times the expected compression strength
- **For BRBF**
  - Tension braces assumed to be $\omega R_yP_{ysc}$
  - Compression braces assumed to be $\beta\omega R_yP_{ysc}$

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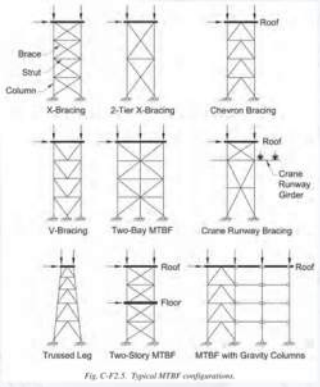
# AISC 341 Requirements

## ❑ *Braced Frames*

- AISC 341-16 defines multi-tiered braced frames as:
  - *"A braced frame configuration with two or more levels of bracing between diaphragm levels or locations of out-of-plane bracing."*
- These are seen in very tall braced frames, stadiums, etc.
- There are extensive requirements for these frames that were added in 2016
- The extra provisions can require significantly larger members.
- P-δ effects can significantly affect design and need to be considered.




American Institute of Steel Construction, AISC 341-16 ©

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# AISC 341 Requirements

| Braced Frame Type | Protected Zone |
|---|---|
| OCBF | None |
| SCBF | Braces – Center ¼ and at connection extending brace depth past |
| BRBF | Steel core of braces and elements that connect the steel core to beams and columns. |
| EBF | Links in eccentrically braced frames. |

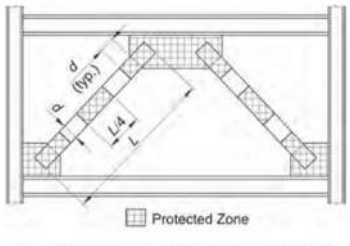


*Fig. C-F2.14. Protected zone of inverted V-braced frame.*

American Institute of Steel Construction, AISC 341-16 ©

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# AISC 341 Requirements

## ❑ *Braced Frames*

- §F2.3 requires SCBF connections to be designed for the expected strength in tension which is Ry*Fy*Ag.
- Connections typically need cover plates to strengthen the connection where the brace has been cut for the gusset to pass through.

Brace Reinforcing – Structure Magazine

Example Review Comment:
It does not appear that the connections for the special concentric braced frames (SCBF) have been checked for tensile rupture over the effective net area (Ae) per Section D2.b of AISC 360-16. Tensile rupture should exceed the required tensile strength for the connection as specified in Section F2.3 of AISC 341-16. Usually, the net area is required to be increased at the connection in order to meet this requirement. Please address.

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# AISC 341 Requirements

## ❑ *Quality Control & Quality Assurance*

- IBC 1705.12.1 & IBC 1705.13.1 refers to AISC 341 for special inspections of structural steel SFRS.
- These requirements are included in Chapter J of AISC 341.
- New Terms:
  - **Observe (O):** Random, daily basis. No need to delay operations pending observation.
  - **Perform (P):** Performed prior to final acceptance of the item.
  - **Document (D):**
    - Written reports
    - Fabricated – piece mark of item inspected
    - Field – grid lines and floor of item inspected
    - Highlight items not in compliance

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# AISC 341 Requirements

## ❑ *Quality Control & Quality Assurance*

- Table J6.1 – Prior to Welding
- Table J6.1 – During Welding
- Table J6.3 – After Welding
- Table J7.1 – Prior to Bolting
- Table J7.2 – During Bolting
- Table J7.3 – After Bolting
- Table J8.1 – Other Inspections

**TABLE J6.3**
**Visual Inspection Tasks After Welding**

| Visual Inspection Tasks After Welding | QC | | QA | |
|---|---|---|---|---|
| | Task | Doc. | Task | Doc. |
| Welds cleaned | O | — | O | — |
| Size, length, and location of welds | P | — | P | — |
| Welds meet visual acceptance criteria<br>–Crack prohibition<br>–Weld/base-metal fusion<br>–Crater cross section<br>–Weld profiles and size<br>–Undercut<br>–Porosity | P | D | P | D |
| *k*-area[1] | P | D | P | D |
| Placement of reinforcing or contouring fillet welds (if required) | P | D | P | D |
| Backing removed, weld tabs removed and finished, and fillet welds added (if required) | P | D | P | D |
| Repair activities | P | — | P | D |

1 When welding of doubler plates, continuity plates or stiffeners has been performed in the *k*-area, visually inspect the web *k*-area for cracks within 3 in. (75 mm) of the weld. The visual inspection shall be performed no sooner than 48 hours following completion of the welding.

American Iron and Steel Institute, AISC 360-16©

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**SPECIAL INSPECTION SCHEDULE**

| Areas requiring special inspection: | Frequency: Continuous | Frequency: Periodic | Comments: |
|---|---|---|---|
| **FABRICATORS (IBC 1704.2.5)** | | | |
| | ♦ | ♦ | If fabricator is approved, on-site inspection is not required but a certificate of completion must be provided to the B.O. (IBC 1704.2.5.1) |
| **SOILS (IBC 1705.6)** | | | |
| Verify adequate materials below footings | | ♦ | Prior to placement of concrete. |
| Excavation extend to proper depth and materials | | ♦ | Prior to placement of compacted fill or concrete. |
| Classification and testing of fill materials | | ♦ | Check classification and gradations at each lift, but not less than once for each 10,000ft² of surface area. |
| Verify proper fill materials, lift thicknesses and in-place densities | ♦ | | |
| Verify properly prepared site and subgrade | | ♦ | Prior to placement of concrete. |
| **CONCRETE CONSTRUCTION (IBC 1705.3)** | | | |
| Reinforcing steel placement | | ♦ | Verify size, clearances, splices and proper ties. |
| Embedded bolts or plates | ♦ | | |
| Verify required design mix | | ♦ | Verify mix design meets strength and exposure requirements listed on approved plans. |
| Concrete placement/sampling | ♦ | | Includes sampling for air, slump, strength and temperature techniques |
| Inspect formwork | | ♦ | Verify shape, location and member dimensions. |
| Post-installed anchors | ♦ | | In accordance with approved ICC-ES Report. Periodic inspections allowed if stated in ES Report. |
| **COLD-FORMED STEEL CONSTRUCTION (IBC 1705.11.3)** | | | |
| Components of wind- and seismic-force resisting systems. | | ♦ | Verify proper screw attachment, bolting and anchoring of shear walls, braces and holdowns having a fastener spacing ≤ 4"o.c. |
| **OTHER THAN STRUCTURAL STEEL (IBC 1705.2.2)** | | | |
| ***Steel Roof & Floor Deck:*** | | | |
| Material verification of steel deck | | | |
| Roof and deck welds | | | |
| ***Open-Web Steel Joists & Girders:*** | | | |
| Verify end conditions and bridging | | | |
| ***Welding of Reinforcing Steel:*** | | | |
| Verification of weldability (except A706 | | | |
| **STRUCTURAL STEEL CONSTRUCTION (IBC 1** | | | |
| ***Prior to Welding*** *(Table NS.4-1, AISC 360-* | | | |
| Verify welder qualifications & welding | | | |
| Material identification | | | |
| Welder identification | | | who has welded a joint or member. |
| Fit-up groove welds | ♦ | | Verify joint preparation, dimensions, cleanliness, tacking and backing. |
| Access holes | ♦ | | Verify configuration and finish. |
| Fit-up fillet welds | ♦ | | Verify alignment, gaps at root, cleanliness of steel surfaces, tack weld quality and location. |

**SPECIAL INSPECTION SCHEDULE** *(continued)*

| Areas requiring special inspection: | Frequency: Observe | Frequency: Perform | Comments: |
|---|---|---|---|
| **STRUCTURAL STEEL CONSTRUCTION** *(continued)* | | | |
| ***During Welding*** *(Table NS.4-2, AISC 360-16):* | | | |
| Control and handling of welding consumables | ♦ | | Verify packaging and exposure control. |
| Cracked tack welds | ♦ | | Verify welding is not over a cracked tack weld. |
| Environmental conditions | ♦ | | Verify wind speed is within limits as well as precipitation and temperature. |
| WPS followed | ♦ | | Verify items such as welding equipment settings, travel speed, welding materials, shielding gas type/flow rate, preheat applied, interpass temperature maintained, and proper position. |
| Welding techniques | ♦ | | Verify interpass and final cleaning, each pass is within profile limitations, and quality of each pass. |
| Steel headed stud anchors | | ♦ | Verify placement and installation. |
| ***After Welding*** *(Table NS.4-3, AISC 360-16):* | | | |
| Welds cleaned | ♦ | | Verify that welds have been properly cleaned. |
| Size, length and location of welds | | ♦ | |
| Welds meet visual acceptance criteria | | ♦ | |
| Arc strikes | | ♦ | |
| k-area | | ♦ | |
| Backing & welding tabs removed | | ♦ | |
| Repair activities | | ♦ | |
| Document acceptance/rejection of weld | | ♦ | |
| Prohibited | ♦ | | Verify that welds have not been added w/out EOR approval. |
| | | | of embedment prior to placement of concrete. |
| Reduced beam sections (RBS) | | ♦ | Verify contour and finish as well as dimensional tolerances *(see Table J8-1 of AISC 341-16).* |
| Protected zones | | ♦ | Verify that no holes or unapproved attachments are made within the protected zone *(see Table J8-1 of AISC 341-16).* |

Example Review Comment:
The special inspection statement and schedules show outdated requirements. Please update to meet the 2021 IBC special inspection requirements which include steel inspections per AISC 360-16 and AISC 341-16. See IBC 1705.2.1, IBC1705.13.1, and IBC 1705.14.1.

West Coast Code Consultants, Inc. ©

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# Plan Review Items

- ***Remember the WABO white paper***
- ***What should be included in a comment?***
- ***What should not?***
- ***How do we begin?***
- ***How much of our time should be spent reviewing…***
  - The plans?
  - The structural calculations?
  - Anything else?

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# Plan Review Items

***Structural General Notes:***

- Are materials requirements specified?
  - IBC, AWS, AISC, AISI
- Do specific installations meet code?
  - Is weld filler criteria for demand critical welds specified?
- Is extraneous information listed?
- Are there any deferred submittals?
  - Are they allowed?
- Are any special inspections noted?
  - Do they include AISC 360 & 341 requirements?
  - Is a special inspection agreement form required?

Item 15_ comment 52: Please submit the deferred submittal agreement listing all deferred items.

response: Deferred submittal agreement will be submitted by contractor at a later date.

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| VERTICAL LOADS | | | | HORIZONTAL SHEAR | | | |
|---|---|---|---|---|---|---|---|
| DEAD (D) | LIVE (L) | WIND (Wasd) | SEISMIC (0.7*E) | DEAD (D) | LIVE (L) | WIND (Wasd) | SEISMIC (0.7*E) |
| 2.0 KIPS | 1.0 KIPS | ±? KIPS | ±? KIPS | ? KIPS | ? KIPS | ? KIPS | ? KIPS |
| 22.0 KIPS | 130.0 KIPS | ±? KIPS | ±? KIPS | ? KIPS | ? KIPS | ? KIPS | ? KIPS |
| 27.9 KIPS | 131.6 KIPS | ±? KIPS | ±? KIPS | ? KIPS | ? KIPS | ? KIPS | ? KIPS |
| 11.8 KIPS | 62.0 KIPS | ±? KIPS | ±? KIPS | ? KIPS | ? KIPS | ? KIPS | ? KIPS |
| 20.3 KIPS | 46.0 KIPS | ±? KIPS | ±? KIPS | ? KIPS | ? KIPS | ? KIPS | ? KIPS |
| 7.0 KIPS | 57.0 KIPS | ±? KIPS | ±? KIPS | ? KIPS | ? KIPS | ? KIPS | ? KIPS |
| 6.2 KIPS | 2.1 KIPS | ±? KIPS | ±? KIPS | ? KIPS | ? KIPS | ? KIPS | ? KIPS |
| 5.8 KIPS | 1.5 KIPS | ±? KIPS | ±? KIPS | ? KIPS | ? KIPS | ? KIPS | ? KIPS |
| 1.0 KIPS | 1.0 KIPS | ±? KIPS | ±? KIPS | ? KIPS | ? KIPS | ? KIPS | ? KIPS |

DESIGN CRITERIA

WIND AND SEISMIC LOADS PER THE INTERNATIONAL BUILDING CODE 2018 EDITION.

WIND LOAD CRITERIA:
- WIND SPEED – Vasd = ?? MPH (Vult = ??? MPH, RISK CAT. II)
- WIND IMPORTANCE FACTOR – IW = 1.0
- EXPOSURE CATEGORY = C
- TOPOGRAPHIC FACTOR – KZT = 1.0
- GUST RESPONSE FACTOR – G = 0.85
- DIRECTIONALITY FACTOR – KD = 1.0
- PRESSURE EXPOSURE COEFFICIENT – KZ = ?.?? (?? FT – EXPOSURE ?)
- VELOCITY PRESSURE – QZasd = ??.?? PSF

SEISMIC LOAD CRITERIA:
- SEISMIC IMPORTANCE FACTOR – IS = 1.0
- OCCUPANCY CATEGORY = II
- MAPPED ACCELERATIONS – SS=?.???, S1=?.???
- SITE CLASS = D
- DESIGN ACCELERATIONS – SDS=?.???, SD1=?.???
- SEISMIC DESIGN CATEGORY ?
- SEISMIC FORCE-RESISTING SYSTEM – ? (R=2, TABLE 15.4-2)
- BASE SHEAR – V = ?.???W (CS=?.???)
- NON-BUILDING STRUCTURE SIMILAR TO BUILDINGS SECTION 15.5

**LOADS INCOMPLETE**
**ENGINEER TO CALCULATE**
**LOADS BASED ON HEBER CITY, UT**
**ZIP CODE 84032**
**PLANT LOCATION**

SEISMIC LOADS SHOWN IN COLUMN LOAD TABLE ARE 0.7*E FOR USE WITH ALLOWABLE STRESS DESIGN. FOR LRFD, OR WHEN USED WITH LOAD COMBINATIONS PER IBC SECTION 1605, SEISMIC LOADS MUST BE MULTIPLIED BY (1/0.7) TO BECOME 'E' FOR USE WITH STRENGTH VALUES.

THE CALCULATION OF SEISMIC LOAD ASSUMES THE PRESENCE OF FULL DEAD AND LIVE LOADS.

ANCHOR BOLTS SHALL BE A36 MINIMUM. DESIGN OF ANCHORAGE FOR THE BOLTS SHOULD BE EQUAL TO THE FULL STRENGTH OF BOLT.

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# Plan Review Items

***Floor & Roof Framing Plans:***

- Beam & joist sizes, spans, and spacing
- Column sizes
- Braced frame members
- Moment frame members
- Load path connections (anchor bolts, collectors & drag elements, etc.)
- Connection callouts (correct detail references)
- Diaphragm requirements (decking, attachment, shear studs, concrete topping & reinforcing, etc.)

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# Plan Review Items

## *Sections & Details:*

- ***Structural Connections:***
  - Framing details
  - Foundation details
  - Joist-to-Beam
  - Beam-to-Beam
  - Beam-to-Column
  - Column-to-Foundation
  - Column splices
  - Continuity & doubler plates
  - Protected zones & demand critical welds

***This is the opportunity to verify that a complete load path is provided!***

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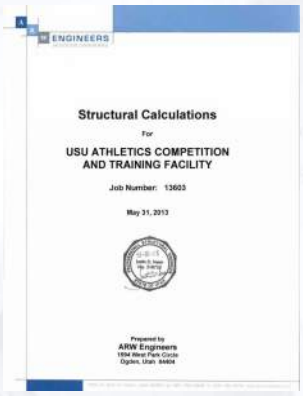
# Plan Review Items

## *Structural Calculations:*

- Remember, it is not our responsibility to verify the mathematical accuracy of the calculations.
- When reviewing plans, note significant structural members and make sure that a calculation is included.




Example Review Comment:
Please provide supporting calculations for the following…
A. The GB7 grade beam specified on sheet S1.02.
B. The footings and retaining walls at ramps shown on sheet S1.04.
C. The retaining walls in the elevator pit area shown on sheet S1.05.

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# Plan Review Items

***Structural Calculations:***

**DESIGN NOTES**

**DESIGN CODES:**

- IBC2015
- ASCE 7-16
- ACI318-14
- NESC 2013

**Outdated codes!**

Example Review Comment:
Page 4 of the calculations refers to the 2015 IBC. Please ensure that the design conforms to the 2021 IBC, and its referenced standards as listed in IBC Chapter 35.

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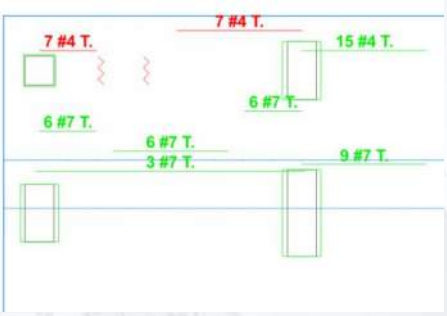
# Plan Review Items

***Sometimes errors are included in calculations:***




Example Review Comment:
Pages 5-91 thru 5-94 of the calculations show a failure at the column located at Grids G-01. Please address.

222

# Plan Review Items

*Is this worthy of a comment?*

**DESIGN SUMMARY**

MAX Bending Ratio = 1.061 : 1 MAX Shear Ratio = 0.058 : 1 DEFLECTIONS

DCR < 1.05, DESIGN OK

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# Inspection Items

- *No matter how good the review, inspection issues will arise.*
- *IBC 110 lists when inspections are required.*
- *Are approved plans onsite?*
- *Is a complete gravity, lateral, and uplift load path provided?*
- *Do member sizes, locations, and their connections match the approved plans?*

224

# Quiz

- ❑ What AISC standards govern the design of steel buildings in addition to the IBC and ASCE 7?
- ❑ List two requirements in relation to demand critical welds.
- ❑ What standard lists prequalified moment connections?
- ❑ What terms does AISC use for the frequency of special inspections?
- ❑ Describe what a protected zone is.
- ❑ What is a doubler plate and when is it required?
- ❑ Joist MFR to provide what at the completion of fabrication?

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# Course Summary

- ❑ ***Verify that a complete gravity, lateral, and uplift load path are provided.***
- ❑ ***Gain general understanding of the requirements included within key structural referenced standards.***
- ❑ ***Learn specific structural requirements for wood, concrete, masonry, and steel included within the IBC and standards.***
- ❑ ***Numerous sample plan review comments.***
- ❑ ***General plan review & inspection considerations for wood, concrete, masonry, and steel construction.***

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# Any Questions?

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chrisk@wc-3.com
http://www.wc-3.com

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