Course Intent

- To help building officials and plans examiners to understand what tools are available to them when performing reviews of unusual projects.
- To assist building inspectors as well as to what they should be looking for in the field in relation to unusual structures.

Course Outline

1. Unusual Projects
2. Know Your Limits
3. Submittal Requirements
4. Common Issues
5. Unusual Examples
6. Deep Foundations
111 South Main

- 24-story downtown office building
- 1/3 of footprint cantilevers over adjacent 4-story performing arts center
- 20 stories are suspended and directly supported by a 1,900 ton hat-truss
- 8 miles of steel H-piles support the structure

Temporary cable suspension system was used until hat truss was engaged
Followed a performance-based design approach
Achieved LEED Gold® certification
32-foot tall hat trusses provide skyline lighting

Shipping Containers

- They are becoming quite popular.
- What are some problems with these?
- From single-family units…

Temporary cable suspension system was used until hat truss was engaged
Followed a performance-based design approach
Achieved LEED Gold® certification
32-foot tall hat trusses provide skyline lighting

To multi-story apartments.

Shipping Containers

https://ecoboxfab.com/residential/

https://ecoboxfab.com/projects-in-the-works/
Rack-Supported

- The LFRS for some structures consist of racking and are known as rack-supported buildings.
- Often used with warehouses using automated storage retrieval systems (AS/RS).
- Cladding directly attached to racking.

This Dannon facility is over 100-feet tall and holds up to 7,000 pallets of product.
Up to 120 pallets are capable of being handled by the AS/RS per hour.

Mfr. in Germany:
- Construction documents & calcs had to be translated
- Translated version was still in metric and referenced European standards

High-Ropes Course

- Often referred to as challenge courses.
- Design was based on an ANSI standard → ANSI/ACCT 03 – Challenge Courses and Canopy/Zip Line Tours
- Special inspections are important! (Special Cases)

City Creek

- Large multi-use project across three City blocks
- 4-story below grade parking garages supporting above-grade structures. Grade-level transfer slab was used for all superstructure lateral loads.
City Creek

- City Creek houses multiple high rises, including a 30-story, 375-foot performance-based design high rise.
- The mall spans two city blocks and incorporates a retractable roof and pedestrian sky bridge.

Apple Campus

- Incorporates 14 MW of solar and large fuel cell and battery storage systems.
- Over 3,000 sheets of curved safety glazing wrap the campus. They are the largest curved glass panels used on any building to date.

Apple Campus

- 4.3 million square foot office building, 4 stories above grade and 2 below.
- Entire structure is base isolated.
- Incorporated numerous AMMRs.

NVIDIA

- 500,000 square feet of office space for 2 above grade levels and then 2 levels of below grade parking housing 1,500 parking stalls.
NVIDIA

- Large atrium requiring a significant smoke control design and complicating the means of egress.
- Multiple AMMRs, including design of roof diaphragm to meet Type I construction.

Know Your Limits

- Unusual projects will come our way.
- How will you react?
- Know your limitations and understand what tools you have available to you.
- You don't want to kill a project, but remember your 1st priority → **Life Safety**

2. Know Your Limits

- What do we have in our tool chest?
  - Code Knowledge
  - Modifications
  - Alternate Means & Methods
  - Peer Review
  - Analysis, Testing & Experience Data
**Code Knowledge**

- You know the code. Rely on that understanding.
- Whatever project comes your way, it must meet the intent of code.
- Are you comfortable with the intent of the code?
- If not...
  - Review the commentary
  - Seek an ICC interpretation
  - Ask others for their thoughts

**Modifications**

- **When would you do this?**
  - First, the applicant must request such modification.
  - They should demonstrate that the intent of the code has been accomplished.
  - The *ICC Commentary* states: “…a code violation or the expense of correcting one cannot constitute a practical difficulty.”
  - Once the modification has been granted, the B.O. must record the decision.

** Modifications  

- **IBC 104.10:**
  - “Where there are practical difficulties involved in carrying out the provisions of this code, the building official shall have the authority to grant modifications for individual cases…”
  - “…provided that the building official shall first find that special individual reason makes the strict letter of this code impractical…”
  - “…the modification is in compliance with the intent and purpose of this code…”
  - “…and that such modification does not lessen health, accessibility, life and fire safety or structural requirements.”

**Alternate Means**

- **IBC 104.11**
  - This section applies to “Alternate Materials, Design and Methods of Construction and Equipment”
  - Often referred to as *Alternate Means & Methods*
  - Very similar to a “Modification”, but more often used.
  - They must be approved. Therefore, a formal application must be made.
  - Many jurisdictions have a form for an *Alternate Means & Methods Request (AMMR).*
  - Let’s look at an example…
Alternate Means

- General project info

- Description of code section that cannot be met

- Reason why and description of how the intent will be met

- Typically requires approval from both the B.O. and Fire Marshal
Alternate Means

- **Miscellaneous Items**
  - As with “Modifications”, this must be recorded.
  - Often lumped together with modifications
  - Most jurisdictions assess an additional fee to review AMMRs
  - The responsibility lies with the applicant to show that the intent of the code will be met.
  - We should be focused on **LIFE SAFETY**.

Peer Review

- **Common Example**
  - High-rise buildings having special reinforced concrete core walls
  - ASCE 7 limits the height to 160-feet, or 240-feet with certain limitations
  - The design must therefore follow a performance-based approach
  - The TBI Guidelines are the current standard of practice

Peer Review

- There is a significant difference between a **plan review** and a **peer review**.
  - **Plan Review** → ensure minimum code requirements are met
  - **Peer Review** → reviews performed by subject matter experts
  - Peer reviews can be required by the B.O.
    - To support modifications or AMMs
    - Performance-based design
    - Existing buildings

Peer Review

- **TBI Guidelines**
  - Rather than a design-level earthquake (DE), these structures are analyzed for the maximum considered event (MCE) in addition to the service level event (SLE).
  - It requires a “seismic” peer review panel that typically includes the following:
    - Structural Engineer experienced in the performance-based design of tall buildings
    - Geologist to review the site-specific ground motions
    - Sometimes a representative for the Jurisdiction as well
Peer Review

- **TBI Guidelines**
  - A structural plan review is still performed by the local jurisdiction for gravity and other code-related items
  - Permits are not issued until a letter from the Seismic Peer Review Panel has been provided
  - The owner should submit resumes of persons to be on panel to the Jurisdiction for approval
  - Cost of Seismic Peer Review Panel is covered by the owner

Analysis, Testing, Data

- **Analysis:**
  - Project-specific design and documentation
  - Valid research reports from approved sources *(IBC 104.11.1 & 1703.4.2)*
  - Sufficient technical data should be provided to B.O. *(IBC 1703.4.1)*

- **Testing:**
  - Where available, the applicant should provide the B.O. with *approved* testing showing products applicability
  - Organizations like ICC-ES have acceptance criteria that, if met, allow the B.O. to assume code is met
  - B.O. has the authority to require tests *(IBC 104.11.2)*
    - Tests shall be per this code or recognized standard
    - If no recognized standard, method approved by B.O.
    - Shall be performed by an *approved* agency
    - B.O. shall retain test reports
Analysis, Testing, Data

- **Experience Data:**
  - Research reports showing how well a certain material or type of construction fared in significant event can be quite useful.
  - This is allowed by Chapter 13 of ASCE 7 for nonstructural components but is also valid for structural analysis.
  - This should not be provided as a stand-alone document but should be combined with either analysis or testing measures.
  - Very common in the nuclear industry.

---

3. Submittal Requirements

- **General**
  - Chapter 1 – Construction Documents
  - Statement of Special Inspections
  - Structural Observations
  - What else might we require?

---

Submittal Documents

- Construction Documents
- Statement of Special Inspections (SSI)
- Geotechnical Report
- Other Data
Submittal Documents

- **Construction Documents (IBC 107.2)**
  - Dimensioned & drawn on suitable material
  - Sufficient clarity to indicate that location, nature, and extent of the work proposed and show in detail that it will conform to the provisions of the code
  - Fire Protection Shop Drawings
  - Means of Egress
  - Exterior Wall Envelope
  - Site Plan

Special Inspections

- **What are special inspections?**
  - **IBC § 202:**
    - Special Inspection: “Inspection of construction requiring the expertise of an approved special inspector in order to ensure compliance with this code and the approved construction documents.”
    - Special Inspector: “A qualified person… approved by the building official as having the competence necessary to inspect a particular type of construction requiring special inspection.”

Special Inspections

- **Special Cases (IBC 1705.1.1):**
  - Items that are “in the opinion of the building official, unusual in nature”.
  - This includes…
    - Alternative materials and systems
    - Unusual design applications
    - Specific Manufacturer requirements
  - What are some examples of special cases?

Special Inspections

- **Keep in mind the following...**
  - The Building Code mandated inspections are “minimum” requirements.
  - The Design Professional in Responsible Charge is responsible for developing the special inspection program.
  - Consider the following key components of a program:
    - Qualification Criteria
    - Special Inspections
    - Material Tests
    - Contractor’s Statement of Responsibility
    - Structural Observations
The SSI

- Where special inspections are required a “Statement of Special Inspections” must be submitted (IBC 107.1, IBC 1704.2.3, and IBC 1704.3).
- This **shall** include...
  - Materials, systems and components requiring inspection or testing.
  - Type or extent of each special inspection or test.
  - Additional items per 1705.10, 1705.11, and 1705.12
  - Identify either continuous or periodic inspection.

Contractor Statement

- **Contractor Responsibility** (IBC 1704.4)
  - “Each contractor responsible for the construction of a main wind- or seismic force-resisting system...”
  - “…shall submit a written statement of responsibility to the building official and owner…”
  - “…shall contain acknowledgment of awareness of the special requirements contained in the (SSI).”

Structural Observations

- **IBC § 1704.6:** Required when S.D.C. ‘D’ or $V_{asd}>110$ mph and...
  - Risk Category III or IV
  - Height > 75 feet
  - S.D.C. ‘E’ and > 2 stories
  - **If required by S.E.R.**
  - **If required by B.O.**
Structural Observations

- How do you determine what requires observation?
- The code does not specify, but consider the following recommendations …
  - Foundations
  - Steel Framing
  - Wood Framing
  - Concrete Construction
  - Masonry Construction
  - Anything listed in an AMMR
  - Any above code modifications

4. Common Issues

Seismic Design

- Table 12.2-1: Seismic Force Resisting Systems
  - Bearing Wall Systems
  - Building Frame Systems
  - Moment Resisting Frame Systems
  - Dual Systems
  - Cantilevered Column Systems
  - Steel Systems not meeting detailing requirements
    - Not allowed in SDC D-F
Seismic Design

Table 12.2-1: Seismic Force Resisting Systems

Section 12.2.1.1: Alternative Systems

- Use of seismic force-resisting systems not contained in Table 12.2-1 shall be permitted contingent on approval of AHJ.
  - Independent structural review
  - Substantiating test data
  - Include non-linear dynamics

Seismic Design

Table 12.2-1: Seismic Force Resisting Systems

Section 12.2.1.1: Alternative Systems (cont.)

- Design criteria shall specify limitations on system use
  - Height
  - Connections
  - Detailing
  - Response Modification
  - Overstrength
  - Deflection Amplification
Section 12.2.1.2: SFRS Elements

- Elements must comply with detailing requirements of Table 12.2-1, or the following shall be provided to the AHJ for approval...
  - Description of methodology
  - Justification of applicability
  - Design procedure
  - Requirements for manufacturing
  - Experimental evidence
  - Design review

Combination of LFRS

- Different directions (§12.2.2)
  - Use respective values
- Same Direction (§12.2.3)
  - Horizontal Combination (12.2.3.3)
    - Use most restrictive values (of R)
    - \( C_u \) and \( \Omega_0 \) corresponding to least R
  - Vertical Distribution (12.2.3.1):
    - Lower system has lower R:
      - Upper system can use higher R
      - Lower system for lower R
      - Loads from above increased by ratio of R
    - Upper system has lower R:
      - Lower R for whole building

Two Stage Analysis (§12.2.3.2)

- Flexible upper and rigid lower
- Allowed to be designed as two separate buildings
- Requirements
  - Lower 10x stiffer than upper
  - Period full building ≤ 110% upper
  - Lower building support loads from upper (ratio R)
  - Upper is ELF or Modal
  - Lower is ELF (only)
Seismic Design

- **Inverted Pendulum Structures (§12.2.5.3)**
  - > 50% mass at top of slender cantilever
  - Increase bending moment at top to ½ max moment.

Seismic Irregularity

- **Horizontal Irregularities (Table 12.3-1)**
Seismic Irregularity

- **Seismic Irregularity**

  - **Vertical Irregularities (Table 12.3-2)**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Seismic Forces</th>
<th>Structural Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Overtight Corner Angle</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td>2.</td>
<td>Minimum Vertical Distance</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td>3.</td>
<td>Weight of Structure</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td>4.</td>
<td>Vertical Displacement</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td>5.</td>
<td>Weight of Structure</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td>6.</td>
<td>Vertical Displacement</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td>7.</td>
<td>Weight of Structure</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td>8.</td>
<td>Vertical Displacement</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td>9.</td>
<td>Weight of Structure</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
<tr>
<td>10.</td>
<td>Vertical Displacement</td>
<td>12, 13, and F</td>
<td>A, B, C, D, E</td>
</tr>
</tbody>
</table>

Modal Analysis

- **Modal Analysis**

  - **Table 12.9.1 Pertinent Analytical Procedures**

    | Seismic Design Procedure | Equivalent Seismic Design Force | Structural Analysis Methodology | Structural Analysis Methodology |
    |--------------------------|---------------------------------|------------------------------|---------------------|
    | All earthquake forces    | P                             | S                            | T                  |
    | Overtight Corner Angle   | P                             | S                            | T                  |
    | Minimum Vertical Distance| P                             | S                            | T                  |
    | Weight of Structure      | P                             | S                            | T                  |
    | Vertical Displacement    | P                             | S                            | T                  |
    | Weight of Structure      | P                             | S                            | T                  |
    | Vertical Displacement    | P                             | S                            | T                  |
    | Weight of Structure      | P                             | S                            | T                  |
    | Vertical Displacement    | P                             | S                            | T                  |
    | Weight of Structure      | P                             | S                            | T                  |
    | Vertical Displacement    | P                             | S                            | T                  |

Live Loads

- **Live Loads**

  - **IBC 1607.13.3.1: Landscaped Roofs**
    - Live Load = 20psf
    - Dead Load = weight of “saturated” materials

  - “Sir, it’s quite possible this asteroid is not entirely stable.” – C3PO
5. Unusual Examples

Nonbuilding Structures

- ASCE 7-16, Chapter 15: “Seismic Design Requirements for Nonbuilding Structures”
- Section 15.1.1: “Shall be designed and detailed to resist the minimum lateral forces specified.”

Nonbuilding Structures

- Chapter 15 makes reference to several other standards and publications:
  - AWWA D100
  - AWWA D103
  - API 650 Appendix E
  - API 620 Appendix L
  - ACI 307
  - TMS402/ACI 530/ASCE 6
  - ACI 355.2
  - Etc.
Several Nonbuilding Structures are not covered in ASCE 7...
- Vehicular Bridges
- Electrical Transmission Towers
- Hydraulic Structures
- Buried Utility Lines & Appurtenances
- Nuclear Reactors
- Piers & Wharves

What are they?
- **Self-supporting** structures that carry *gravity loads* and may be required to resist earthquake effects.
- Supported by earth or other structures.
- Similar to buildings in terms of basic structural dynamics and ground motion hazards, but different structural characteristics and performance objectives.
- Often requires additional considerations such as fluid dynamics, networked systems, etc.

Similar to Buildings
- Reference standards or §15.5, but ≥ §12.8
- Select system from Table 12.2-1 or Table 15.4-1
- Design & detailing shall comply w/ referenced sections

Not Similar to Buildings
- Reference standards or §15.6, but ≥ §12.8
- Select system from Table 15.4-2
- Design & detailing shall comply w/ referenced sections

Similar to Buildings → Table 15.4-1:
Nonbuilding Structures

- **Not Similar to Buildings → Table 15.4-2:**

<table>
<thead>
<tr>
<th>Environment Type</th>
<th>Seismic Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
</tr>
<tr>
<td>Not likewise built in</td>
<td>2</td>
</tr>
<tr>
<td>Likewise but not simultaneously built in</td>
<td>2</td>
</tr>
<tr>
<td>Likewise and simultaneously built in</td>
<td>2</td>
</tr>
<tr>
<td>Section 15.4-2.12.2</td>
<td>2</td>
</tr>
<tr>
<td>Section 15.4-2.12.3</td>
<td>2</td>
</tr>
</tbody>
</table>

- **Design Requirements (cont.):**
  - The *period* must be substantiated by analysis.
  - *Importance factor* is based upon the relative hazard and function. It is the largest value of the following:
    - Applicable reference document in Chapter 23
    - Largest value from Table 1.5-2
    - As specified elsewhere in Chapter 15

- **Supported by Other Structures:**
  - Must comply with Section 15.3
  - Three possible outcomes...
    - < 25% of combined weight → Chapter 13
    - > 25% + T < 0.06 seconds → Rigid
    - > 25% + T > 0.06 seconds → Flexible

**Design Loads** = Dead load of structure + weight of operating contents

Drift limitations do not apply, but *rational analysis* must show...
  - Structural stability, and...
  - Components are appropriately attached
Nonbuilding Structures

- **Supported by Other Structures (cont.)**
  - $> 25% + T < 0.06$ seconds $\rightarrow$ Rigid
    - Analysis shall use the combined seismic weight and R-value of the supporting structure.
    - Shall meet the design requirements of Chapter 13 of ASCE 7, but use the response modification factor ($R_p$) obtained from Table 15.4-2 and an amplification factor ($a_p$) of 1.0.

Nonbuilding Structures

- **SEAOC Seismic Design Manual – Volume 1:**
  - Example 55 – Lateral Seismic Force on Nonbuilding Structure
  - Example 56 – Flexible Nonbuilding Structure
  - Example 57 – Rigid Nonbuilding Structure
Podiums

- IBC 510.2 – 510.8: Special Provisions
  - Modify allowable height and area.
  - Each method is independent and separate

- 510.9 – Multiple Buildings
  - Above S-2 Parking
  - Separate Buildings

IBC 510.2

- Podiums (510.2)
  - 3-hr horizontal “lid”
  - Building height
    - Measured from grade plane
    - Smaller of above and below
  - Building area:
    - Above and below separate buildings
  - Above “Lid”:
    - Use groups limited to:
      - A with < 300 occupants each
      - B, M, R, or S

- Below “Lid”:
  - Type I-A construction
  - Any Use Group except H
  - NFPA Sprinkler
  - 2-hr shafts through “lid”
    - Exception 3-hr below and 1-hr above if:
      - Building above not Type I
      - < 4 stories connected
      - Openings above 1-hr rated (not 45 min.)

Parking Below R (510.4)

- S-2 Parking
  - Open or enclosed
  - 1 story above grade
  - Type I or IV

- Group R
  - Any construction type
  - Only count stories above

- Floor between buildings
  - Same construction type as garage
  - Minimum Fire Rating per IBC 508.4

PT Slab fire rating

Footnote k: Interior spans of continuous slabs, beams, and girders shall be permitted to be considered restrained.
**R-1 or R-2 of III-A (510.5)**

- **IBC 510.5:** R1 or R2 of III-A
  - 6 Stories Maximum
  - 75 feet max height
  - First floor above basement:
    - 3-hr fire rated
  - Floor area limited:
    - 3,000 ft² per area
    - Separated by 2-hr Fire Wall

**Open Parking Below R**

- **IBC 510.7:**
  - Parking Garage
    - Open Parking Garage
    - Height and area per 406.5
  - Building above
    - Per Section 503
    - Height and stories include parking
  - Separation
    - Separated per 508.4
    - Separate construction types
    - Fire rating of structural elements supporting building above to be most restrictive
    - Means of egress from building above
      - Separated by 2-hr fire barrier from parking
      - Openings to be 2-hour rated (not 90 min.)

**R-1 or R-2 Type IIA**

- **IBC 510.6:** R-1 or R-2 of Type II-A
  - 100 feet max height
  - Max 9 stories
  - 50 foot separation from
    - Lot Lines
    - Other buildings
  - Exits separated by 2-hr rated Fire Walls
  - First floor assembly is 1-1/2-hr rated

**Type III Construction**

- **Type III (602.3)**
  - Exterior walls:
    - Noncombustible
    - Fire-Retardant-Treated (FRT) wood exterior wall
      - 2-hour rating or less
      - Manufactured lumber cannot be FRT
      - Structural strength of lumber must be reduced per Manufacturer.
  - Interior elements
    - Any material permitted
Exterior Walls

- **IBC 705.6: Ext. Walls – Structural Stability**
  - “Interior structural elements that brace the exterior wall but that are **not located within the plane** of the exterior wall shall per [Table 601](#) for that element.
  - Structural elements that brace the exterior wall but are located **outside** or **within the plane** of the exterior wall per Tables 601 and 602 for the exterior wall.”

Texas Wrap

- **S-2 Type I or II-A**

Exterior Walls

- Parking garage wrapped with Residential Units
- Structural Concerns:
  - Separate Construction Types
  - Expansion Joints
  - Fire Walls
Seismic Design

- **Seismic Gap (§12.12.3)**
  - All portions designed to act as one, or …
  - Separated by a minimum distance
    - $\delta_M = \frac{C_m}{I_p}$
    - $\delta_{MT} = \sqrt{(\delta_{M1})^2 + (\delta_{M2})^2}$

Fire Walls (706)

- **Structural Stability (§706.2):**
  - "…shall have sufficient structural stability under fire conditions to allow collapse of construction on either side without collapse of the wall…"
  - How is this done?
    - 2012 IBC referenced NFPA 221 for double fire walls.
    - 2018 IBC now refers to all examples in NFPA 221 as compliant.

Fire Walls (706)

- **Used to separate portions of buildings**
- "…shall provide a complete separation”.

**Table 503**

- R-1
- Type V-B
- One-Story Sprinklered

"A woman happy in love, she burns the soufflé." – Baron St. Fontanel

Fire Walls (706)

- **NFPA 221:** Three basic types are described
  - Cantilever Walls
  - Tied Walls
  - Double Walls

"Baskin-Robbins always finds out." Dale
Fire Walls (706)

- **Cantilever Fire Walls:**
  - Must be designed for 5psf lateral load
  - No connections between the wall and building frame on either side
  - Flashing must be designed for easy release
  - Foundation must be designed to resist moment from lateral load

"R2 has been known to make mistakes ... from time to time." – C3PO

"Whoa, so this is heat. I love it. Ow, but don’t touch it." – Olaf.

Fire Walls (706)

- **Tied Fire Walls:**
  - Ties roof structures on each side together such that the horizontal pull from the sagging “collapsed” members is carried by the horizontal force resisting system on the other side.

"You almost set me on fire." – Kristoff

"Can you believe they call us criminals when he’s assaulting us with that haircut?" – Rocket Raccoon

“Works best when framing on either side is at the same level and primary members are perpendicular to the wall.”
Fire Walls (706)

- **Tied Fire Walls:**
  - The sagging force, or horizontal pull is calculated as follows:
  - \[ H = \frac{(WL^2)}{(8S)} \]
  - \( H \) = Horizontal pull
  - \( W \) = Dead load of roof
  - \( L \) = Truss or beam span
  - \( S \) = Sag
    - \( S = 0.09L \) for structural steel
    - \( S = 0.07L \) for open-web steel joists
    - \( S = 0.06L \) for wood trusses

- **Double Fire Walls:**
  - Two walls adjacent to each other
  - Each only connected to respective frame
  - Each wall provides required fire rating

Fire Walls (706)

- **Double Fire Walls:**
  - Two walls adjacent to each other
  - Each only connected to respective frame
  - Each wall provides required fire rating

Fire Walls (706)

- **Fire-Resistance Rating (§706.4):**
  - Ratings are based upon occupancy...

<table>
<thead>
<tr>
<th>GROUP</th>
<th>FIRE WALL FIRE-RESISTANCE RATINGS</th>
<th>FIRE-RESISTANCE RATING (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B, E, H-4, I, R-1, R-2, U</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>F-1, H-3, H-5, M, S, I</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>H-1, H-2</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>F-2, S-2, R-3, R-4</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

- In Type II or V construction, walls shall be permitted to have a 2-hour fire-resistance rating.
- For Group H-1, H-2 or H-3 buildings, also see Sections 415.6 and 415.7.

Well, a fake reputation is all a man has.” – Flynn

Firstly, you must find . . . another shrubbery!” – Knights who say Ni

“They’ve encased him in carbonite. He should be quite well protected.” – C3PO
Fire Walls (706)

- **Horizontal Continuity** (§706.5):
  - “…continuous from exterior wall to exterior wall…”
  - Shall extend 18 inches beyond exterior wall
  - As usual, there are several exceptions...

exceptions:

- May terminate at interior surface of combustible sheathing/siding provided the exterior wall has 1-hour rating for at least 4-feet on either side of fire wall. Openings in this area protected for ¼-hour.
- May terminate at interior surface of noncombustible sheathing/finish provided sheathing/finish extends at least 4-feet on either side of fire wall.
- May terminate at interior surface of noncombustible sheathing where the building on both sides of the fire wall is sprinklered.

Fire Walls (706)

- **Vertical Continuity** (§706.6):
  - “…shall extend from the foundation to a termination point at least 30-inches above both adjacent roofs.”
  - Several exceptions...
Fire Walls (706)

- **Exceptions:**
  - **Stepped Buildings:**

- **Exceptions:**
  - **2-Hour Walls:** May terminate at sheathing provided...
    a) Lower roof assembly is 1-hour rated for 4-feet, and...
    b) Openings are not located in roof w/in 4-feet, and...
    c) Each building provided w/ Class 'B' roof covering

- **Exceptions:**
  - **Noncombustible Sheathing:** May terminate at sheathing provided...
    a) Openings are not located in roof w/in 4-feet, and...
    b) Each building provided w/ Class 'B' roof covering

- **Exceptions:**
  - **Type III, IV and V:** May terminate at combustible sheathing provided...
    a) Openings are not located in roof w/in 4-feet, and...
    b) Each building provided w/ Class 'B' roof covering, and...
    c) Sheathing consists of fire-retardant-treated wood for a distance of 4-feet on each side of wall, or...
    d) 5/8-inch Type 'X' gypsum is applied on the underside of the sheathing for a distance of 4-feet on each side of wall.
Fire Walls (706)

- Exceptions:
  - Type III, IV and V: May terminate at combustible sheathing provided…

- Combustible Framing (§706.7):
  - ≥ 4” between adjacent combustible framing members in a concrete or masonry “fire wall”
  - Hollow spaces shall be solidly filled with noncombustible materials

Fire Walls (706)

- Openings (§706.8):
  - Shall be protected per §716.5
  - ≤ 156ft² max. per opening (unless sprinklered), and…
  - ≤ 25% length of wall
  - Not allowed in party walls

- Penetrations (§706.9)
  - Protected per §714

- Duct and Air Transfer (§706.11)
  - Not permitted
    - except not at lot line protect per §717

Sandwich Panels

- Tilt-Up Sandwich Wall Panels are becoming quite common
- Consist of two wythes of concrete and an internal layer of rigid insulation
- Inner wythe is typically the main structural wythe
- Insulation is connected to each wythe by means of connectors installed in a grid-like pattern
Sandwich Panels

- The connectors are an important part of the structural system.
- They often do not provide the connector information.
- Common connector is called Thermomass®.
- **ESR-1746** requires:
  - Calculations supporting the size and spacing of connectors.
  - Continuous special inspections.

Tall Buildings

- Most high-rise projects in recent years utilize reinforced concrete core walls.
- If > 160-feet tall, may not be allowed by ASCE 7.
- Performance-based design should be followed in accordance with an approved guideline/standard.
- The **TBI Guideline** is most common used today.

Design must comply with high seismic force requirements.
- A separate service-level review is also performed.
- Peer review panel should have familiarity with modeling program used.
- A permit should not be issued until the peer review process is complete and a final report from the panel is provided.
Rammed Earth Walls

- Rammed earth wall construction is often found throughout the mid-west and internationally.
- Decorative walls that blend into environment and are energy-efficient

Rammed Earth Walls

- What should be provided?
  - Structural calculations
  - Detailed construction plans
  - Special inspection requirements (formwork, soil gradations, compaction, reinforcement placement, etc.)

Rammed Earth Walls

- Construction commonly consists of:
  - Special soil gradations
  - Reinforcing steel
  - Concrete bond beam at top and at openings
  - Continuous concrete footing
  - Often rigid insulation is provided as well

Straw Bale

- Not specifically covered in body of code, but prevalent throughout the U.S.
- IRC Appendix S provides prescriptive criteria
- Appendices must be adopted but could also be referenced as part of an AMMR
Appendix S provisions include:

- Bale size, tie, moisture content, density, and type of straw requirements
- Finish requirements → typically plaster
- Vapor retarders not allowed!
- Limited to 1-story & ≤ 25-feet tall
- Inspections shall be provided for sill anchors, mesh placement and attachment, and pins for out-of-plane resistance (1/2”Ø placed vertically at 24”o.c.)
- Includes wall bracing provisions
- Can have 1-hour and 2-hour rated walls

If Appendix S cannot be met...

- Engineered design is required
- Unless comfortable in performing needed inspections, B.O. should require special inspections and perhaps even structural observations
ICF

- There are many manufacturers of Insulated Concrete Forms (ICF)
- Only 10 are approved on the ICC-ES website → only one of which complies with 2018 codes
- MFR installation instructions must be provided for review and at inspection

SIP

- Many provisions in the IRC:
  - Limited to 2-stories in SDC ‘C-F’ per IRC R301.2.2.7
  - Manufacturing must comply with ANSI/APA PRS 610.1 (R602.1.11)
  - Limited to walls 60-feet in length when perpendicular to joists and 40-feet when parallel to joists and wall height of 10'-0" (R610.2)
- Not only used in residential...

ICF

- Product locks together and incorporates cross-ties that support reinforcing steel
- If other than Type V construction, must be labeled
- Calculations for foundation or retaining wall design req’d
- Special inspections of reinforcement, plumbness of formwork, bracing of formwork, and concrete materials

SIP

- Minimum thickness per IRC Tables R610.5(1) & (2)
Key connections:

- Spine, or panel-to-panel connection
- Defined in IRC 202
- This is prescriptive attachment, but R610.5.3 allows other approved connections

Key connections:

- Roof framing and diaphragm attachment

Key connections:

- Sill anchorage
- Sill anchors must comply with general IRC provisions
- A capillary break is required at the foundation interface

Tons of information is provided on the website of the Structural Insulated Panel Association (https://www.sips.org/)
- Includes a free SIP Engineering Design Guide
- Each manufacturer typically has their own load design criteria charts
- Need to pay special attention to point loads as the SIPs may not be capable of supporting such loads
Billboards

- Do you ever check the structural design for billboards?
- Are the assumptions they are making correct?
- Significant increases in wind pressures since the UBC

Many times a standard design package is provided by a national sign company
- Pick from tables and select size of pole, foundation, and attachment structure
- Need to verify two key items...
  1. Wind pressure design complies with Chapter 29 of ASCE 7-16
  2. Foundation design is site-specific or complies with IBC 1806

Common failure modes...
1. Failure of plate supporting structure
2. Failure of foundation

IBC 1806:
- Presumptive load bearing values from Table 1806.2
  - Standard to assume 1,500 psf bearing pressure → equivalent to 100 psf/ft of lateral bearing pressure
  - Often times design will consider 200 psf/ft
  - If that is the case → site-specific geotechnical report!
- IBC 1806.3.4 → Provides exception

<table>
<thead>
<tr>
<th>TABLE 1802</th>
<th>PRESUMPTIVE LOAD BEARING VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLASS OF MATERIALS</td>
<td>VERTICAL FOUNDATION PRELOAD (psf)</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Coarse fine sand</td>
<td>12,000</td>
</tr>
<tr>
<td>2. Silty sand and gravel (SW and GP)</td>
<td>6,000</td>
</tr>
<tr>
<td>3. Sand, silty sand, loose sand, silty gravel, and gravel soils (SW, GP, SM, SC, CL, ML, and CH)</td>
<td>2,000</td>
</tr>
<tr>
<td>4. Clay, sandy clay, silty clay, silty silt, and sandy silt (CL, ML, SM, and CH)</td>
<td>1,500</td>
</tr>
<tr>
<td>5. Heavy clay, silt, clay, and silty clay (CL, ML, SM, and CH)</td>
<td>1,500</td>
</tr>
</tbody>
</table>
Shoring

- Many times the shoring design for deep excavation is overlooked.
- It is often thought of as a contractor’s means and methods but should be reviewed & inspected.
- **IBC 1804.1:** Excavations near foundations
  - Shall in no way reduce the vertical or lateral support for any foundation.
  - Two items to consider…
    - Deep excavation shoring
    - Foundation underpinning

---

When do excavations require shoring?

- Shoring Methods
- Soldier piles and lagging
- Soil nailing
- Secant walls
- Sheet piles

---

Do you receive shoring designs?

---

**Fairfax County, VA → Special Inspections**

- Provides recommendations for protecting adjacent properties, including existing public and private streets.
**Shoring**

- Must determine...
  - Types of instruments
  - Accuracy of instrumentation
  - Rate of readings

**Underpinning**

- **IBC 1804.2:** Underpinning
  - Temporary or permanent support to an existing foundation.
  - Conditions requiring:
    - Construction of a new project with a deeper foundation adjacent to an existing building
    - Settlement of an existing structure
    - Change in use of a structure
    - Addition of a basement below an existing structure

- **Settlement of an Existing Structure:**
  - Lowering of water table
  - Poor soils
  - Variable soils
  - Fill soils
  - Footings near slopes
  - Change in structural conditions

- **Underpinning Methods:***
  - Temporary support (maintenance jacking)
    - At completion of the work jacks are replaced with short steel columns and the void is filled.
  - Bracket pile underpinning
    - The steel bracket piles are driven or placed adjacent to the future structure in pre-augured holes which are then backfilled with a lean sand-cement mix.
    - The load is transferred from the structure into the pile through a steel bracket welded to the side of the pile.
Underpinning

General

- There are many different types of deep foundation elements
- Any time we deal with deep foundations, the geotechnical report must provide general recommendations (IBC 1803.5.5)
- Are you comfortable with what has to be provided for each type?

6. Deep Foundations

Common Types

- Auger Cast-in-Place Piles (ACIP)
- Steel Piles
- Helical Piles
- Micropiles
- Rammed Aggregate Piers (RAP)
ACIP

- Cased or uncased
- **Casings - IBC 1810.3.1.6**
  - Shall be of steel
  - Sufficiently strong to resist collapse
  - Sufficiently water-tight to exclude foreign materials
  - Horizontal joints shall be spliced

ACIP

- **IBC 1810.3.5.2:**
  - Cased $\rightarrow$ 8"Ø
  - Uncased $\rightarrow$ 12"Ø
- **IBC 1810.3.9.3:**
  - Reinforcement shall be placed as a unit before filled with concrete

ACIP

- Shear and Moment decrease with depth
Larger amounts of reinforcement where moments and shear are high
Minimum amounts must extend beyond theoretical cutoff points

SDC ‘C’: IBC 1810.3.9.4.1
- 4 vertical bars min.
- Min. Ratio of Steel (\( \rho \))= 0.0025
- Minimum Reinforced Length:
  - 1/3 length of element
  - 10-feet
  - 3 * the width or diameter
  - Where \( \Omega Mn > Mreq \)

SDC ‘D-F’: IBC 1810.3.9.4.2
- 4 vertical bars min.
- Min. Ratio of Steel (\( \rho \))= 0.005
- Minimum Reinforced Length:
  - 1/2 length of element
  - 10-feet
  - 3 * the width or diameter
  - Where \( \Omega Mn > Mreq \)

\( \rho = 0.0025 \)
- #4 ≤ 20”ø
- #5 ≤ 25”ø
- #6 ≤ 30”ø
- #7 ≤ 35”ø

\( \rho = 0.005 \)
- #4 ≤ 14”ø
- #5 ≤ 17”ø
- #6 ≤ 21”ø
- #7 ≤ 24”ø

Site Class ‘A-F’ – min. spacing shall be:
- 0.25 * least dimension, or...
- 6\( d_b \), or...
- Calculated \( s_b \) (\( s_{max} \leq 6 \)-inches; \( s_{min} \geq 4 \)-inches)

Site Class ‘A-D’:
- Distance = 3 * least dimension (from bottom of pile cap)

Site Class ‘E-F’:
- Distance = 7 * least dimension, or...
- Within 7 * least dimension of interfaces with liquefiable layers or soft- to medium-stiff clay
ACIP

- **Seismic Hook: ACI 318**
  - Applies to stirrups, hoops or crossties
  - A hook having a bend not less than 135°, except that circular hoops shall have a bend not less than 90°.
  - Extensions shall be 6d_p, but not less than 3”.

ACIP

- **Unbraced Elements: IBC 1810.1.3**
  - Must be designed as columns
    - Min. Ratio of Steel (ρ) = 0.01
  - Only to point of adequate lateral restraint
    - 5’ below grade (stiff soil)
    - 10’ below grade (soft soil)

### Submittals:
- Review stamp by registered design professional in responsible charge
- Geotechnical recommendations
- Location plan
- Pile cap connection details
- Embedment depth & detailing
- Load test criteria (F.S. ≥ 2.0)
- Special inspections per IBC Table 1705.8
Steel Piles

Materials: IBC 1810.3.2.3
- H-piles → ASTM A6
- Steel pipe → ASTM A252

Protection: IBC 1810.3.2.5
- Caltrans:
  - Most corrosion occurs in fill soils rather than undisturbed soil.
  - Greatest concern for corrosion is the portion of the pile from the bottom of the pile cap down to 3 feet below the lowest ground water elevation.
- Protection Means:
  - Sacrificial metal (corrosion allowance)
  - Protective coatings
  - Cathodic protection

Dimensions: IBC 1810.3.5.3
- H-piles:
  - Flange projections ≤ 14*thickness of web or flange
  - Minimum flange or web thickness ≥ 3/8-inch
  - Nominal depth ≥ 8-inches
- Pipe piles:
  - Nominal diameter ≥ 8-inches
  - Open-ended → 0.34 in² steel per 1,000 ft-lb hammer energy
Steel Piles

- **Splices:** *IBC 1810.3.6*
  - Shall maintain alignment
  - Designed to resist axial, shear and moment
  - Shall be designed to develop ≥ 50% of bending moment

Helical Piles

- Have been used for more than 150 years
- First recorded use was in 1836 to underpin the Maplin Sands Lighthouse in England.
- **Definition (IBC 202):**
  - “Manufactured steel deep foundation element consisting of a central shaft and one or more helical bearing plates. A helical pile is installed by rotating it into the ground. Each helical bearing plate is formed into a screw thread with a uniform defined pitch.”
Helical Piles

- **Common Terminology:**
  - Helix Plate
  - Lead Section
  - Extension
  - Torque Rating
  - Installation Torque

Helical Piles

- **Allowable Axial Load:** *IBC 1810.3.3.1.9*
  - $P_{all} = 0.5*P_{ult}$ → Where $P_{ult}$ is the least of...
    - Sum of bearing plate areas * the ultimate bearing capacity of the soil
    - Ultimate capacity determined from well-documented correlations with installation torque
    - Ultimate capacity determined from load tests
    - Ultimate axial capacity of pile shaft
    - Ultimate capacity of couplings
    - Sum of ultimate capacity of helical bearing plates affixed to pile

Helical Piles

- **Materials:** *IBC 1810.3.5.3.5*
  - Dimensions of central shaft, and...
  - Number, size and thickness of bearing plates...
  - Shall be sufficient to support design loads

- **Installation:** *IBC 1810.4.11*
  - Specified embedment depth, and...
  - Torsional resistance criteria
  - Torque applied ≤ Allowable torque of pile
Helical Piles

- **Submittals:**
  - Review stamp by registered design professional in responsible charge
  - Allowable capacity determination (see previous slide)
  - Location plan
  - Details of connection to foundation
  - The design professional must specify the embedment depth and torsional resistance criteria
  - Load test criteria (F.S. ≥ 2.0)
  - Special inspection criteria (see next slide)

Micropiles

- **First used in Italy in the 1950’s to underpin existing structures damaged during WWII**
- **Definition: IBC 202**
  - “A bored, grouted-in-place deep foundation element that develops its load-carrying capacity by means of a bond zone in soil, bedrock or a combination of soil and bedrock.”
Micropiles

- Small diameter pile (12” max)
- Tailored design for specific need
  - 3-30 tons: Push piles
  - 15-75 tons: Compaction-grouted piles
  - 50-150 tons: Jet-grouted piles
  - 40-100 tons: Post-grouted piles
  - 25-75 tons: Pressure-grouted piles
  - 50-500+ tons: Drilled End-bearing piles

Micropiles

- Designed & Detailed: IBC 1810.3.10
  - Develop load-carrying capacity by means of bond zone with soil or bedrock
  - Reinforcement:
    - ASTM A615 Grade 60 or 75; ASTM A722 Grade 150, or...
    - Steel pipe or tube having 3/16-inch wall thickness
    - Cased ≥ 40% design compression load
    - Uncased = 100% design compression load

Micropiles

- Applications
  - Congested areas
  - Arresting settlement
  - Resist uplift
  - Excavation support (i.e. tie-backs)
  - Underpinning
  - Seismic retrofit
  - Stabilizing slopes

Micropiles

- Installation: IBC 1810.4.10
  - Fluid cement grout pumped through tremie pipe to bottom of element
  - Reinforcing bars shall be inserted prior to withdrawal of temporary casing
  - Casing shall be removed in a controlled manner and grout level shall be monitored
  - If no casing, the diameter shall be verified
  - Bottom shall be cleaned for end bearing piles
  - Subsequent micropiles shall not be drilled near elements until grout has had sufficient time to harden
Micropiles

- **Submittals:**
  - Review stamp by registered design professional in responsible charge
  - Geotechnical recommendations
  - Location plan
  - Details of connection to pile cap
  - Load test criteria (F.S. ≥ 2.0)
  - Special inspections per IBC Table 1705.8

RAPs

- **Geopiers (ESR-1685)**
  - Step 1: Drill hole (10-20’ long, 24-36”ø)
  - Step 2: Form bottom bulb (Uses rammer w/ 45° sides)
  - Step 3: Subsequent Lifts (=12”)
  - Step 4: Footings or placed above Geopier

- **Rammed Aggregate Piers**, commonly referred to as RAPs
  - This is a ground improvement method that uses compacted aggregate to create stiff pier elements.
  - Increases bearing capacity & reduces settlement
  - Can greatly reduce liquefaction potential

- **Geopiers (cont.)**
  - Typically cover 25-35% of the footing area
  - Geopier designer lists the allowable bearing capacity of improved soils
**Geopiers (cont.)**
- Constructed from 6-12" above bottom of footing
- **Special Inspections:**
  - Verify the following…
    - Aggregate properties
    - Type & number of lifts
    - Hole size and depths
    - Top elevations
    - Rammer energy
    - Review load tests on confirmation piers

**Vibro Piers (cont.)**
- Similar to Geopier construction & inspection
- Smaller holes are drilled in softer soils
- Bottom feed option for caving soils
- Fastest and least expensive of all ground improvement methods in cohesive soils

**Settlement Analysis:** *IBC 1810.2.3*
- What is the maximum total and differential settlement we should allow/expect?

<table>
<thead>
<tr>
<th>Settlement Within the Pier Zone (inch)</th>
<th>Settlement Below the Pier Zone (inch)</th>
<th>Total Expected Settlement (inch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.49</td>
<td>0.18</td>
<td>0.58</td>
</tr>
<tr>
<td>0.63</td>
<td>0.26</td>
<td>0.89</td>
</tr>
<tr>
<td>0.52</td>
<td>0.33</td>
<td>0.85</td>
</tr>
<tr>
<td>0.57</td>
<td>0.36</td>
<td>0.93</td>
</tr>
</tbody>
</table>
**RAPs**

- **Submittals:**
  - Review stamp by registered design professional in responsible charge
  - Location plan
  - Material specifications
  - Embedment depth & maximum spacing
  - Settlement calculations
  - Load test criteria (F.S. ≥ 2.0)
  - Special inspections per ESR-1685 (IBC 1704.3)

**Deep Foundations**

- **Summary:**
  - What is required for a complete submittal?
  - What is the min. safety factor? ($P_{ult}$ vs. $P_{as}$)
  - What geotechnical information should be provided?
  - Any particular special inspection requirements?
  - What should be provided on the plans?

**Sample Plan Review Comment:**

RAPs:
The proposed design calls for the use of Geopiers to improve the soil bearing capacity and to limit settlement. A pier location plan must be provided for approval per IBC 1810.4.3 along with engineering calculations that include a settlement analysis per IBC 1810.2.3 and as required by ESR-1685. Because these piers will be installed prior to footings/foundations these items will not be allowed as a deferred submittal and must be submitted for review prior to permit issuance.

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**Any Questions?**

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