Seismic Design Using the 2006 IBC and ASCE 7-05

John Hooper, S.E.
Magnusson Klemencic Associates

Special Thanks to the Structural Engineers Association of Washington for use of their material

Overview

2006 International Building Code

- Uses ASCE 7-05 as primary structural reference
  - No required modifications to ASCE 7
  - A few alternates to ASCE 7
- References materials standards for structural design
- Contains geotechnical investigation requirements
- Contains analysis, design, detailing, and installation requirements for foundations
- Contains detailed inspection, testing, and observation requirements for structural and nonstructural systems
ASCE 7-05: Significant Changes
- Completely reorganized
- Updated seismic hazard maps (available online)
- Seismic Use Group eliminated
  (Occupancy Category used directly)
- Revised structural systems and limitations
- New redundancy factor
- New simplified design procedure--not covered in this presentation

Seismic Hazard Maps Online
- $S_s$ and $S_r$, Hazard Curves, Uniform Hazard Spectra
  - Location-specific values for various building codes
  - Hazard curves and uniform hazard spectra by location

Seismic Design Criteria
Seismic Design Options

• 2003 IBC
  – IBC Sections 1614 through 1623 based on and referring to ASCE 7-02, with several modifications
  or
  – ASCE 7-02 Sections 9.1 through 9.6, 9.13, and 9.14 without IBC modifications to ASCE 7-02
• 2006 IBC
  – IBC Section 1613 based on and referring to ASCE 7-05, with several alternates
  – SDC permitted to be determined based on IBC or ASCE 7 (same procedure for both)

IBC Alternates to ASCE 7 Provisions

• No IBC modifications to ASCE 7, just alternates
  – Section 1613.6.1 Flexible diaphragm assumptions
  – Section 1613.6.2 Additional seismic-force-resisting systems for seismically isolated structures
• Otherwise, use ASCE 7-05
• Use IBC for modifications to materials standards (IBC Chapters 19-23)

ASCE 7-05 Seismic Reorganization – Goals

1. Improve clarity and use
2. Reduce depth of section numbering from 6 max typical to 4 max typical
   (i.e., Sec. 9.5.2.5.2.2 is now Sec. 12.5.3)
3. Simplify table and figure numbering
   (i.e., Table 9.5.2.5.1 is now Table 12.6-1)
4. Create logical sequence of provisions aim at the structural engineering community
5. Improve headings and clarify ambiguous provisions
ASCE 7-05 Reorganization

1. Changed major subjects to Chapters rather than Sections (similar to the IBC)
2. Replaced Chapter 9 with Chapters 11-23
3. Incorporated detailing references into system table
4. Put the chapters into a logical sequence
5. Rewrote ambiguous headings
6. Rewrote sections to eliminate ambiguity
7. Provided Cross Reference Table C11-1...02 to 05

Seismic Design Criteria

ASCE 7-05 Section 11.1 Purpose

“...specified earthquake loads are based upon post-elastic energy dissipation in the structure, and because of this fact, the requirements for design, detailing, and construction shall be satisfied even for structures and members for which load combos w/o EQ exceed those with EQ...”

Chapter 11 Seismic Design Criteria

11.1 General
11.2 Definitions
11.3 Notation
11.4* Seismic Ground Motion Values
11.5* Importance Factor
11.6* Seismic Design Category
11.7 Design Requirements for Category A
11.8** Geologic Hazards & Geotechnical Investigation

*Use ASCE 7 or IBC Section 1613
**Don’t use; use IBC Chapter 18 instead
Seismic Hazard

• Same method as 2003 IBC
  – Response spectrum ordinates are mapped
  – Near-fault effects are included in basic maps
  – Data is “location-specific”
  – Soil effects still handled separately
• Updated – 2002 USGS Seismic Hazard Maps
  – Minor differences, depending on location
• Soil factors same as 2003 IBC

Seismic Hazard Maps

• MCE Spectral Accelerations: $S_h$, $S_I$

http://eqhazmaps.usgs.gov

What is MCE?

• Maximum Considered Earthquake
  – (NOT maximum credible earthquake OR maximum capable earthquake)

• Ground motion that is the lesser of:
  – 2% probability of exceedance in 50 years (2475 yr m.r.i.)
  – 150% of median acceleration from characteristic earthquakes on known faults, but only if this is greater than 150% of “zone 4” (no consistent m.r.i.)
Summary of Ground Motion

- Maps → $S_S$, $S_J$
- Site class, $S_S$, and $S_J$ → $F_a$, $F_v$
- $S_{MS} = F_a S_S$ → $S_{M1} = F_v S_J$
- $S_{DS} = 2/3 S_{MS}$ → $S_{D1} = 2/3 S_{M1}$ → Design

Design Response Spectrum

Geotechnical Considerations

- Site Class (IBC Sec. 1613.5.5 or ASCE 7 Ch. 20)
  - Based on shear wave velocity, SPT blow count, or shear strength
- Identify site hazards (Sec. 1802.2.6)
  - SDC ≥ C
  - Surface faulting
  - Liquefaction, slope instability
- Seismic wall pressures (Sec. 1802.2.7)
  - SDC ≥ D
  - For design purposes treat these loads as “E” not “H”
Site-Specific Ground Motion

- Site response analysis (ASCE 7 Chapter 21)
  - Required for determining \( F_a \) and \( F_v \) in Site Class F
  - Soil layers above rock modeled and analyzed to quantify amplification of rock motion

- Ground motion hazard analysis
  - Required for seismically isolated structures with large ground motion

Time Histories

- Rules in ASCE 7-05 Section 16.1.3.2
  - Address selection, scaling, period range
  - Design process depends on number of motions used

Occupancy Category and Importance Factors

<table>
<thead>
<tr>
<th>Occupancy Category</th>
<th>Description</th>
<th>Importance Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Agricultural, temporary, storage</td>
<td>( I_e = 1.0 )</td>
</tr>
<tr>
<td>II</td>
<td>Not Occupancy Category I, III or IV</td>
<td>( I_e = 1.0 )</td>
</tr>
<tr>
<td>III</td>
<td>Substantial hazard to human life: &gt; 300 people in “covered structures whose primary occupancy is public assembly”; &gt; 250-person school or day care; &gt; 500-person college; &gt; 50-resident health care (no surgery); &gt; 5,000 occupants; jail, detention</td>
<td>( I_e = 1.25 )</td>
</tr>
<tr>
<td>IV</td>
<td>Essential facilities: surgery or emergency health care; fire, rescue, police, emergency vehicle, shelters, aviation control towers, etc.</td>
<td>( I_e = 1.50 )</td>
</tr>
</tbody>
</table>
Drift Limits

Depend on:
• Occupancy category
• Structural system (masonry or not masonry)
• Building height and nonstructural component design

### Impact of Occupancy (strength and drift)

<table>
<thead>
<tr>
<th>OC</th>
<th>Description</th>
<th>F/F typical</th>
<th>∆/∆typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>Not III or IV (&quot;typical&quot;)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>III</td>
<td>Substantial hazard to human life:</td>
<td>1.25</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td>&gt;300 people in &quot;covered structures whose primary occupancy is public assembly&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;250-person school or day care</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;500-person college</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;50,000-person college</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;5,000 occupants</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>essential facilities:</td>
<td>1.5</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>surgery or emergency health care, fire, rescue, police, emergency vehicle, shelters, aviation control towers, etc.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Seismic Design Category (SDC)

• IBC Tables 1613.5.6(1) and 1613.5.6(2)
• Function of seismic hazard, site class, and occupancy category
• Controls system selection, analysis, design, and detailing
• Can be based just on S_{DS} in certain conditions
  – IBC Section 1613.5.6.1
  – Short period for analysis and design
  – Rigid diaphragm or short diaphragm span
Seismic Design Category

- SDC E: OC I, II, III where $S_1 \geq 0.75$
- SDC F: OC IV where $S_1 \geq 0.75$

Seismic Design Category A

- Minimum lateral force for integrity/stability
- Lateral load path (connections between parts)
- Anchorage of concrete/masonry walls

- ALL requirements appear in ASCE 7-05 Section 11.7 – no other seismic requirements apply

Load Combinations

- IBC addresses:
  - $D, L, L_r, S, R, H, F, T$
  - $W, E$
- Don’t use ASCE 7 Chapter 2 or Section 12.4.2.3
- ASCE 7 referenced for:
  - $P$ (ponding), $F_a$ (flood)
- Recognize that not all loads are maximum simultaneously
Seismic Load Combination

Complications

• Strength design v. ASD
• ASD: basic v. alternative

• Redundancy factor, \( \rho \)
• Overstrength factor, \( \Omega_0 \)
• Vertical EQ effects, \( 0.2S_{25}D \)

Redundancy Factor

Redundancy Defined

• Unnecessary repetition
  – For the sake of “engineering economy,” some designers have used fewer, larger elements
  – At times this has resulted in poor seismic performance; the repetition was necessary

• Duplication or repetition of elements … to provide alternative functional channels in case of failure

American Heritage Dictionary
Advice for Investment (and structures)

- Conventional wisdom: “Diversify; don’t put all your eggs in one basket.”
- Andrew Carnegie: “Concentrate; put all your eggs in one basket, and watch that basket.”

1997 UBC – 2003 IBC: Questions

- Redundancy or reliability?
- What degree of redundancy? (How many baskets do you have?)
- How big is the building? (Is your basket big or small?)

\[ \rho_i = 2 \frac{A}{r_{exc} \sqrt{A}} \]

ASCE 7-05: Answers

- We want redundancy (multiple elements)
  - Use multiple smaller baskets
  or
  - Make the basket stronger
- Either a building is redundant or it is not: \( \rho = 1.0 \) or \( 1.3 \)
- Building size doesn’t matter
Where Does Redundancy Matter?

- Seismic-force-resisting system strength for buildings
- So, \( \rho = 1.0 \) for:
  - Seismic Design Category B or C
  - Drift and P-delta effects
  - Nonstructural components
  - Most nonbuilding structures
  - Members designed for \( \Omega_0 \) forces
  - Prescriptive diaphragm loads
  - Structures with damping systems

Determining the Redundancy Factor

- Pass prescriptively?
- Linear analysis
- Extreme torsion? [Yes / No]
- Only squat walls? [Yes / No]
- Prioritize
- Remove element
- Extreme torsion? [Yes / No]
- Excessive strength loss? [Yes* / No]
- Likely elements considered?

Redundancy: Prescriptive (\( \rho = 1.0 \))

- Regular in plan at all levels
- At least two bays of SFR framing at perimeter on each side in each direction (where \( V_{\text{nx}} > 0.35V \))
- Plan
- Count shear wall “bays” as \( L/h \) (2L/h for light-framed)
Redundancy: By Calculation

(ASCE 7-05 Section 12.3.4.2, item a)

- Where $V_{\text{story}} > 0.35 V$, consider loss of seismic resistance:
  - Braced frames: lose any single brace
  - Moment frames: lose moment resistance at both ends of any single beam (or base of any single cantilever column)
  - Shear walls: lose any single wall or wall pier with height-to-length ratio greater than 1.0

- Criteria:
  - No extreme torsion: reduction in story strength $\leq 33\%$

Wall Height-to-Length Ratios

- Shear wall
  $h_i/L_{w_i}$
- Wall pier
  $h_{wp}/L_{wp}$
- Consider loss where
  $h_i/L_{w_i} > 1.0$
  $h_{wp}/L_{wp} > 1.0$

System and Analysis Requirements
Seismic Design Using the 2006 IBC and ASCE 7-05

Systems Factor Table (ASCE 7-05)

- 83 choices for systems
- Systems added
  - Precast Shear Walls
  - Buckling-restrained Braced Frames
  - Steel Plate Shear Walls
- Systems deleted
  - Ordinary Steel CBFs (from Bearing Wall and Dual Systems groups)
- Systems renamed
  - Inverted Pendulum Systems and Cantilevered Column Systems
  - Added additional system types in Cantilevered Column Systems group (e.g., Timber Frames)

- Column added for detailing requirements section references
- 2006 IBC adds exception to relax limitations for ordinary steel CBFs and MFs for some seismically isolated structures
- Miscellaneous changes to factors and footnotes
Irregularities

- Only 1 change to irregularity types
  - Extreme Weak Story vertical irregularity added

Vertical Structural Irregularities

- Weak Story: Strength A < 80% Strength B
- Extreme Weak Story: Strength A < 65% Strength B

Additional reference sections have been added to tables. Some do not change provisions and simply provide additional clarity. Some are references to new requirements (e.g., the Horizontal Irregularity Type 1a reference to 12.7.3).
Analysis Procedures

• Modal Response Spectrum Analysis Procedure
  – Provisions reduced in extent by deleting most of the mathematics from provisions
  – Provisions revised to indicate that resulting forces, not drifts, are subject to 85% of ELF procedure lower bound

ASCE 7-05 Base Shear Equations

\[ V = C_s W \]

Where \( C_s \) = seismic response coefficient
ASCE 7-02 Base Shear Equations

\[ C_s = \frac{S_{ds}}{R/I} \]
\[ \leq \frac{S_{dl}}{T(R/I)} \]
\[ \geq 0.044S_{ds} \]
\[ \geq 0.5S_I \quad \text{for SDC E and F} \]

Also, for regular structures with \( \leq 5 \) stories and with \( T \leq 0.5 \) seconds, \( C_s \) may be based on \( S_s = 1.5g \) and \( S_I = 0.6g \).

ASCE 7-05 Base Shear Equations

\[ C_s = \frac{S_{ds}}{R/I} \]
\[ \leq \frac{S_{dl}}{T(R/I)} \quad \text{for } T \leq T_{L1} \]
\[ \leq \frac{S_{dl}T_{L1}}{T^*(R/I)} \quad \text{for } T > T_{L1} \]
\[ \geq 0.01 \]
\[ \geq 0.5S_I \quad \text{for } S_I \geq 0.6g \]

Also, for regular structures with \( \leq 5 \) stories and with \( T \leq 0.5 \) seconds, \( C_s \) may be based on \( S_s = 1.5g \).

ASCE 7-02 vs. ASCE 7-05

<table>
<thead>
<tr>
<th>ASCE 7-02</th>
<th>ASCE 7-05</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ C_s = \frac{S_{ds}}{R/I} ]</td>
<td>[ C_s = \frac{S_{ds}}{R/I} ]</td>
</tr>
<tr>
<td>[ \leq \frac{S_{dl}}{T(R/I)} ]</td>
<td>[ \leq \frac{S_{dl}}{T(R/I)} \quad \text{for } T \leq T_{L1} ]</td>
</tr>
<tr>
<td>[ \geq 0.044S_{ds} ]</td>
<td>[ \leq \frac{S_{dl}T_{L1}}{T^*(R/I)} \quad \text{for } T &gt; T_{L1} ]</td>
</tr>
<tr>
<td>[ \geq 0.5S_I \quad \text{for SDC E and F} ]</td>
<td>[ \geq 0.01 ]</td>
</tr>
</tbody>
</table>

WA emergency change (app); ASCE 7-05 Supplement No. 2

17
Combinations of Framing Systems

- Provisions reformatted and expanded
- Separate subsections for:
  - Combinations of framing systems in different directions
  - Combinations of framing systems in same direction

Combinations of Framing Systems

- Systems in Different Directions
  - No real changes
  - Clarifies that individual system factors apply in their respective directions
Combinations of Framing Systems

- Systems in Same Direction
  - Provisions split into those for vertical and horizontal combinations

Combinations of Framing Systems

- Systems in Same Direction – Vertical Combinations
  - Two-stage equivalent lateral force procedure for vertical combinations in 2003 IBC now included in ASCE 7-05

Combinations of Framing Systems

- Systems in Same Direction – Vertical Combinations
  - Two-stage equivalent lateral force procedure
    - No longer required that both flexible upper portion and the rigid lower portion be regular structures
    - For the requirement that lower portion be at least 10 times stiffer than upper portion, stiffness no longer specified as “average story” stiffness
Combinations of Framing Systems

- Systems in Same Direction – Horizontal Combinations

Plan View

In ASCE 7-05, possible to have different values of *R* on independent lines in the same direction providing:

- Occupancy Category I or II
- ≤ 2 stories
- Light-frame construction or flexible diaphragms

Diaphragms, Drift and Deformation

Seismic Design Using the 2006 IBC and ASCE 7-05

Diaphragm Flexibility

- Important for the purposes of distribution of story shear and torsional moment, affecting design displacements
- Where diaphragms are not flexible,
  - the distribution of lateral forces shall consider the effect of the inherent torsional moment (*M*<sub>t</sub>) (12.8.4.1)
  - the design shall include the inherent torsional moment (*M*<sub>t</sub>) plus the accidental torsional moments (*M*<sub>ta</sub>) (12.8.4.2)
  - structures assigned to SDC C,D,E,F with Type 1a or 1b torsional irregularity shall account effect by multiplying (*M*<sub>ta</sub>) with the torsional amplification factor (*A*<sub>x</sub>) (12.8.4.3)
Diaphragm Flexibility

- Torsional Amplification Factor, $A_x$ (Figure 12.8-1)

Structural analysis shall explicitly consider stiffness of the diaphragm unless idealized as flexible or rigid
- Flexible Diaphragm (12.3.1.1)
- Rigid Diaphragm (12.3.1.2)
- Calculated Flexible Diaphragm (12.3.1.3)

Flexible Diaphragm (12.3.1.1)
- Constructed of wood structural panels or untopped steel deck
- Vertical elements are steel or composite steel and concrete braced frames, or concrete, masonry, steel, or composite shear walls.
- Wood structural panels or untopped steel decks in one- and two-family residential buildings of light-frame construction

Note: 2006 IBC – 1613.6.1 Alternatives provides an option
Diaphragm Flexibility (12.3.1)

• Rigid Diaphragm (12.3.1.2)
  – Concrete slab or concrete filled metal deck
  – Span / Depth ≤ 3
  – No horizontal irregularities

Diaphragm Flexibility (12.3.1)

• Calculated Flexible Diaphragm (12.3.1.3)
  – Maximum in-plane deflection is more than twice the average story drift of vertical elements

Story Drift Limit (12.12.1)

• $\Delta \leq \Delta_a$ (Table 12.12-1)
  – Story Drift Determination
    • 12.8.6 – Equivalent Lateral Force (ELF)
    • 12.9.2 – Modal Analysis
    • 16.1 – Linear Response History
  – SDC – C,D,E,F with horizontal torsional irregularity (1a or 1b), story drift ($\Delta$) must be computed using deflections along edges of structure
Seismic Design Using the 2006 IBC and ASCE 7-05

Allowable Story Drift, $\Delta_a$

(12.12.1)

<table>
<thead>
<tr>
<th>Structure</th>
<th>$\Delta_a$</th>
<th>$\Delta_{a/\rho}$</th>
<th>$\Delta_{a/\rho}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redundant story drift</td>
<td>0.010%</td>
<td>0.010%</td>
<td>0.010%</td>
</tr>
<tr>
<td>Other story drift</td>
<td>0.015%</td>
<td>0.015%</td>
<td>0.015%</td>
</tr>
</tbody>
</table>

Reasons:
- Redundancy helps a moment frame structure to attain comparatively large deflection without significant strength loss. Therefore, penalty should not be confined to design strength only, but also to drift allowances.

Moment Frames in SDC: D - F

(12.12.1.3)

- Design story drift ($\Delta$)
  - $\Delta \leq \Delta_{a/\rho}$
  - $\rho$ = Redundancy Factor = 1.0 or 1.3 (12.3.4.2)

Reason:
- Redundancy helps a moment frame structure to attain comparatively large deflection without significant strength loss. Therefore, penalty should not be confined to design strength only, but also to drift allowances.

Story Drift Determination

(12.8.6)

- Deflections of level x, $\delta_x$, to be used for $\Delta$, are determined by:
  $\delta_x = C_d \delta_{xe} / I$

  - $C_d$ : deflection amplification factor (Table 12.2-1)
  - $\delta_{xe}$ : deflections determined by elastic analysis
  - $I$ : importance factor (11.5.1)
Story Drift Determination

(Figure 12.8-2)

Modal Response Parameters (12.9.2)
- The value for story drifts shall be computed using properties of each mode and the response spectra defined in code divided by the quantity \( R / I \). The value for displacement and drift quantities shall be multiplied by the quantity \( C_d / I \).

\[
\frac{I}{R} \times \frac{C_d}{I} = \frac{C_d}{R}
\]

Scaling Values of Combined Response (12.9.4)
- Where the combined response for the modal base shear \( V_t \) is less than 85% of the calculated base shear \( V \) using the ELF procedure, the forces, but not the drifts, shall be multiplied by:

\[
0.85 \frac{V}{V_t}
\]
12.12.3 Building Separation. All portions of the structure shall be designed and constructed to act as an integral unit in resisting seismic forces unless separated structurally by a distance sufficient to avoid damaging contact under total deflection ($\delta_x$) as determined in Section 12.8.6.

- “Portions of the structure”?
- “Avoid damaging contact”?
- “Total deflection ($\delta_x$)”?

Building Separations? - Examples

[Diagram showing building separations and calculations]

Maximum Inelastic Displacements

<table>
<thead>
<tr>
<th>Level</th>
<th>$\delta_{M1}$ (in.)</th>
<th>$\delta_{M2}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>7.60</td>
<td>----</td>
</tr>
<tr>
<td>3</td>
<td>5.50</td>
<td>3.75</td>
</tr>
<tr>
<td>2</td>
<td>2.60</td>
<td>1.75</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Source: 2006 IBC Structural/Seismic Design Manual - Volume 1, SEAOC, ICC

Ex 1) Separation within the same Structure

$\delta_M = \delta_{M1} + \delta_{M2}$

$\delta_M = 5.50 + 3.75 = 9.25$ in.

[Diagram showing building separations and calculations]

Maximum Inelastic Displacements

<table>
<thead>
<tr>
<th>Level</th>
<th>$\delta_{M1}$ (in.)</th>
<th>$\delta_{M2}$ (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>7.60</td>
<td>----</td>
</tr>
<tr>
<td>3</td>
<td>5.50</td>
<td>3.75</td>
</tr>
<tr>
<td>2</td>
<td>2.60</td>
<td>1.75</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Source: 2006 IBC Structural/Seismic Design Manual - Volume 1, SEAOC, ICC
2006 IBC and ASCE 7-05 makes no distinction between an “internal” separation in the same building and the separation between two “adjacent” buildings on the same property. It is silent with respect to separation between adjacent buildings.

Ex 2) Separation from an adjacent building on the same property

2a) 2006 IBC and ASCE 7-05

\[ \delta_M = \delta_{u,1} + \delta_{u,2} \]
\[ \delta_M = 5.50 + 3.75 = 9.25 \text{ in.} \]

2b) 2003 IBC – 1620.4.5

\[ \delta_M = \sqrt{(\delta_{u,1})^2 + (\delta_{u,2})^2} \]  
\[ = \sqrt{(5.50)^2 + (3.75)^2} = 6.66 \text{ in.} \]

• Exception: Smaller separations shall be permitted when justified by rational analyses based on maximum expected ground motions.

Summary

• Diaphragm Flexibility
  – Flexible or Rigid Idealization, Semi-rigid
  – Can impact many of the design and detailing requirements
• Drift and Displacements
  – Allowable Drifts
  – Building Separations
  – Moment Frames in SDC - D, E, F \[ \Delta \leq \Delta_{\rho} \]
• Diaphragm Forces
  – Horizontal and vertical irregularities can impact diaphragm connection forces
  – Clearer format
• Collector elements and connections (SDC – C, D, E, F)
  – Designed for the load combinations with overstrength factor \( \Omega \) (with exception)
• Structural walls and their anchorage
  – Dependent on SDC’s and diaphragm flexibility
  – Wall material