Additional SNI 201X Provisions (Adopted from ASCE7-10)

Jakarta

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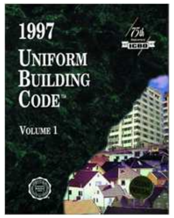
Outline

- Introduction
- Seismic Design Response Spectrum
- Seismic Design Category
- Irregularity
- Redundancy

Introduction

Transition from SNI Gempa 2002 to SNI Gempa 201X

SNI Gempa 2002 → SNI Gempa 201X



Overview on Seismic Response Spectrum

Generating Design Response Spectrum using the new seismic map

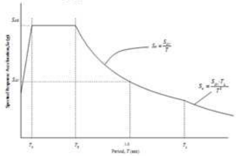


FIGURE 11.4-1 Design Response Spectrum.

Mapped spectral acceleration at MCE level (2500 yr earthquake)

$S_{MS} = F_a S_S$

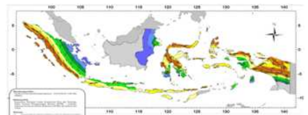
$S_{M1} = F_v S_1$

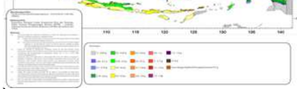
Site coefficients

Spectral acceleration values adjusted from Site Class effects

$S_{DS} = \frac{2}{3} S_{MS}$

$S_{D1} = \frac{2}{3} S_{M1}$





Spectral acceleration at DBE level (500 yr earthquake)

Overview on Seismic Design Category

Seismic Design Category (SDC)

- used to trigger requirements for particular design conditions
- depends on occupancy type and effects of site condition on probable ground shaking intensity

Table 11.6-1 Seismic Design Category Based on Short Period Response Acceleration Parameter

	Risk Category	
Value of S_{DS}	I or II or III	IV
$S_{DS} < 0.167$	A	A
$0.167 \le S_{DS} < 0.33$	B	C
$0.33 \le S_{DS} < 0.50$	C	D
$0.50 \le S_{DS}$	D	D

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

	Risk Category	
Value of S_{D1}	I or II or III	IV
$S_{D1} < 0.067$	A	A
$0.067 \le S_{D1} < 0.133$	B	C
$0.133 \le S_{D1} < 0.20$	C	D
$0.20 \le S_{D1}$	D	D

E: Risk category I, II, III with $S_1 \ge 0.75g$
F: Risk category IV with $S_1 \ge 0.75g$

Example:
Jakarta Bali → SDC D
Soft Soil

Irregular and regular classification

Irregularity

- Structural configuration can significantly affect performance
- Tables provided showing types of irregularities

Table 12.3-1 Horizontal Structural Irregularities

Type	Description	Reference Section	Seismic Design Category Application
1a.	**Torsional Irregularity:** Torsional irregularity is defined to exist where the maximum story drift, computed including accidental torsion with $A_x = 1.0$, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure. Torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	12.3.3.4 12.7.3 12.8.4.3 12.12.1 Table 12.6-1 Section 16.2.2	D, E, and F B, C, D, E, and F C, D, E, and F C, D, E, and F D, E, and F B, C, D, E, and F
1b.	**Extreme Torsional Irregularity:** Extreme torsional irregularity is defined to exist where the maximum story drift, computed including accidental torsion with $A_x = 1.0$, at one end of the structure transverse to an axis is more than 1.4 times the average of the story drifts at the two ends of the structure. Extreme torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	12.3.3.1 12.3.3.4 12.7.3 12.8.4.3 12.12.1 Table 12.6-1 Section 16.2.2	E and F D B, C, and D C and D C and D D B, C, and D
2.	**Reentrant Corner Irregularity:** Reentrant corner irregularity is defined to exist where both plan projections of the structure beyond a reentrant corner are greater than 15% of the plan dimension of the structure in the given direction.	12.3.3.4 Table 12.6-1	D, E, and F D, E, and F
3.	**Diaphragm Discontinuity Irregularity:** Diaphragm discontinuity irregularity is defined to exist where there is a diaphragm with an abrupt discontinuity or variation in stiffness, including one having a cutout or open area greater than 50% of the gross enclosed diaphragm area, or a change in effective diaphragm stiffness of more than 50% from one story to the next.	12.3.3.4 Table 12.6-1	D, E, and F D, E, and F
4.	**Out-of-Plane Offset Irregularity:** Out-of-plane offset irregularity is defined to exist where there is a discontinuity in a lateral force-resistance path, such as an out-of-plane offset of at least one of the vertical elements.	12.3.3.3 12.3.3.4 12.7.3 Table 12.6-1 Section 16.2.2	B, C, D, E, and F D, E, and F B, C, D, E, and F D, E, and F B, C, D, E, and F
5.	**Nonparallel System Irregularity:** Nonparallel system irregularity is defined to exist where vertical lateral force-resisting elements are not parallel to the major orthogonal axes of the seismic force-resisting system.	12.5.3 12.7.3 Table 12.6-1 Section 16.2.2	C, D, E, and F B, C, D, E, and F D, E, and F B, C, D, E, and F

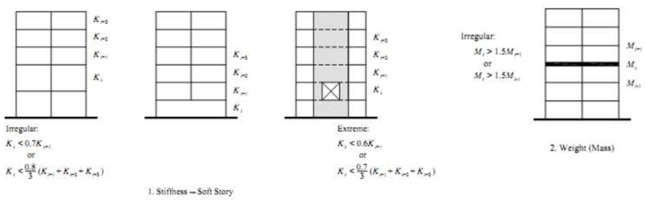
Table 12.3-2 Vertical Structural Irregularities

Type	Description	Reference Section	Seismic Design Category Application
1a.	**Stiffness-Soft Story Irregularity:** Stiffness-soft story irregularity is defined to exist where there is a story in which the lateral stiffness is less than 70% of that in the story above or less than 80% of the average stiffness of the three stories above.	Table 12.6-1	D, E, and F
1b.	**Stiffness-Extreme Soft Story Irregularity:** Stiffness-extreme soft story irregularity is defined to exist where there is a story in which the lateral stiffness is less than 60% of that in the story above or less than 70% of the average stiffness of the three stories above.	12.3.3.1 Table 12.6-1	E and F D, E, and F
2.	**Weight (Mass) Irregularity:** Weight (mass) irregularity is defined to exist where the effective mass of any story is more than 150% of the effective mass of an adjacent story. A roof that is lighter than the floor below need not be considered.	Table 12.6-1	D, E, and F
3.	**Vertical Geometric Irregularity:** Vertical geometric irregularity is defined to exist where the horizontal dimension of the seismic force-resisting system in any story is more than 130% of that in an adjacent story.	Table 12.6-1	D, E, and F
4.	**In-Plane Discontinuity in Vertical Lateral Force-Resisting Element Irregularity:** In-plane discontinuity in vertical lateral force-resisting elements irregularity is defined to exist where there is an in-plane offset of a vertical seismic force-resisting element resulting in overturning demands on a supporting beam, column, truss, or slab.	12.3.3.3 12.3.3.4 Table 12.6-1	B, C, D, E, and F D, E, and F D, E, and F
5a.	**Discontinuity in Lateral Strength–Weak Story Irregularity:** Discontinuity in lateral strength–weak story irregularity is defined to exist where the story lateral strength is less than 80% of that in the story above. The story lateral strength is the total lateral strength of all seismic-resisting elements sharing the story shear for the direction under consideration.	12.3.3.1 Table 12.6-1	E and F D, E, and F
5b.	**Discontinuity in Lateral Strength–Extreme Weak Story Irregularity:** Discontinuity in lateral strength–extreme weak story irregularity is defined to exist where the story lateral strength is less than 65% of that in the story above. The story strength is the total strength of all seismic-resisting elements sharing the story shear for the direction under consideration.	12.3.3.1 12.3.3.2 Table 12.6-1	D, E, and F B and C D, E, and F

Vertical Irregularities

Vertical Irregularities:

- Type 1a: Stiffness-soft story irregularity
- Type 1b: Stiffness-extreme soft story irregularity
- Type 2: Weight (mass) irregularity
- Type 3: Vertical geometric irregularity
- Type 4: In-plane discontinuity in vertical lateral force resisting element
- Type 5a: Discontinuity in lateral strength – weak story irregularity
- Type 5b: Discontinuity in lateral strength – extreme weak story irregularity



Vertical Irregularities

Vertical Irregularities:

- Type 1a: Stiffness-soft story irregularity
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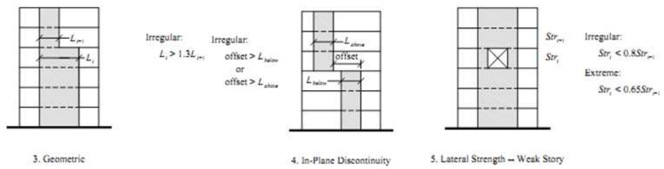
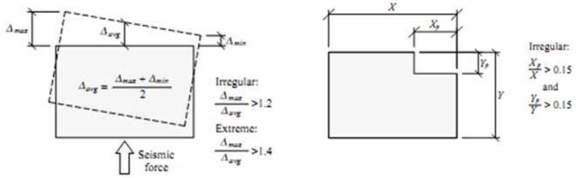


Horizontal Irregularities

Horizontal Irregularities:

- Type 1a: Torsional irregularity
- Type 1b: Extreme torsional irregularity
- Type 2: Reentrant corner irregularity
- Type 3: Diaphragm discontinuity irregularity
- Type 4: Out-of-plane offset irregularity
- Type 5: Nonparallel system irregularity

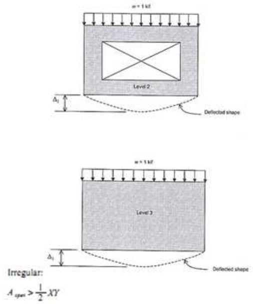


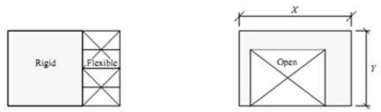
1. Torsional   2. Reentrant corner

Horizontal Irregularities

Horizontal Irregularities:

- Type 1a: Torsional irregularity
- Type 1b: Extreme torsional irregularity
- Type 2: Reentrant corner irregularity
- Type 3: Diaphragm discontinuity irregularity
- Type 4: Out-of-plane offset irregularity
- Type 5: Nonparallel system irregularity



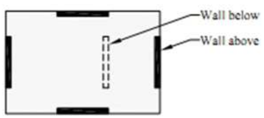


3. Diaphragm discontinuity

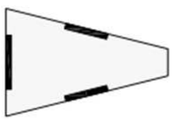
Horizontal Irregularities

Horizontal Irregularities:

- Type 1a: Torsional irregularity
- Type 1b: Extreme torsional irregularity
- Type 2: Reentrant corner irregularity
- Type 3: Diaphragm discontinuity irregularity
- Type 4: Out-of-plane offset irregularity
- Type 5: Nonparallel system irregularity



4. Out-of-plane offset



5. Nonparallel system

Additional requirements for structures w/ irregularities

SDC D

Vertical Irregularities :

- Type 1a: Stiffness-soft story irregularity
- Type 1b: Stiffness-extreme soft story irregularity
- Type 2: Weight (mass) irregularity
- Type 3: Vertical geometric irregularity
- Type 4: In-plane discontinuity in vertical lateral force resisting element
- Type 5a: Discontinuity in lateral strength – weak story irregularity
- **Type 5b: Discontinuity in lateral strength – extreme weak story irregularity**

Horizontal Irregularities:

- Type 1a: Torsional irregularity
- Type 1b: Extreme torsional irregularity
- Type 2: Reentrant corner irregularity
- Type 3: Diaphragm discontinuity irregularity
- Type 4: Out-of-plane offset irregularity
- Type 5: Nonparallel system irregularity

prohibited

Additional requirements for structures w/ irregularities

SDC E & F

Vertical Irregularities :

- Type 1a: Stiffness-soft story irregularity
- **Type 1b: Stiffness-extreme soft story irregularity**
- Type 2: Weight (mass) irregularity
- Type 3: Vertical geometric irregularity
- Type 4: In-plane discontinuity in vertical lateral force resisting element
- **Type 5a: Discontinuity in lateral strength – weak story irregularity**
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Horizontal Irregularities:

- Type 1a: Torsional irregularity
- **Type 1b: Extreme torsional irregularity**
- Type 2: Reentrant corner irregularity
- Type 3: Diaphragm discontinuity irregularity
- Type 4: Out-of-plane offset irregularity
- Type 5: Nonparallel system irregularity

prohibited

Additional requirements for structures w/ irregularities

Structures with 2 stories (9 m height) or more

Vertical Irregularities :

- Type 1a: Stiffness-soft story irregularity
- Type 1b: Stiffness-extreme soft story irregularity
- Type 2: Weight (mass) irregularity
- Type 3: Vertical geometric irregularity
- Type 4: In-plane discontinuity in vertical lateral force resisting element
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Horizontal Irregularities:

- Type 1a: Torsional irregularity
- Type 1b: Extreme torsional irregularity
- Type 2: Reentrant corner irregularity
- Type 3: Diaphragm discontinuity irregularity
- Type 4: Out-of-plane offset irregularity
- Type 5: Nonparallel system irregularity

prohibited
Unless weak story is capable of resisting omega level force

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Additional requirements for structures w/ irregularities

SDC D to F

Vertical Irregularities :

- Type 1a: Stiffness-soft story irregularity
- Type 1b: Stiffness-extreme soft story irregularity
- Type 2: Weight (mass) irregularity
- Type 3: Vertical geometric irregularity
- **Type 4: In-plane discontinuity in vertical lateral force resisting element**
- Type 5a: Discontinuity in lateral strength – weak story irregularity
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Horizontal Irregularities:

- **Type 1a: Torsional irregularity**
- **Type 1b: Extreme torsional irregularity**
- **Type 2: Reentrant corner irregularity**
- **Type 3: Diaphragm discontinuity irregularity**
- **Type 4: Out-of-plane offset irregularity**
- Type 5: Nonparallel system irregularity

25% force increase
for diaphragm and collector connections
Unless omega level force has already been used

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Additional requirements for structures w/ irregularities

Equivalent Lateral Force Analysis is not permitted for Tall buildings with any structural irregularity or Very tall buildings

Table 12.6-1 Permitted Analytical Procedures

Seismic Design Category	Structural Characteristics	Equivalent Lateral Force Analysis, Section 12.8[a]	Modal Response Spectrum Analysis, Section 12.9[a]	Seismic Response History Procedures, Chapter 16[a]
B, C	All structures	P	P	P
D, E, F	Risk Category I or II buildings not exceeding 2 stories above the base	P	P	P
	Structures of light frame construction	P	P	P
	Structures with no structural irregularities and not exceeding 160 ft in structural height	P	P	P
	Structures exceeding 160 ft in structural height with no structural irregularities and with $T < 3.5T_s$	P	P	P
	Structures not exceeding 160 ft in structural height and having only horizontal irregularities of Type 2, 3, 4, or 5 in Table 12.3-1 or vertical irregularities of Type 4, 5a, or 5b in Table 12.3-2	P	P	P
	All other structures	NP	P	P

[a]P: Permitted; NP: Not Permitted; $T_s = S_{D1}/S_{DS}$.

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Redundancy

$$(1.2 + 0.2S_{DS})D + \rho Q_E + L + 0.2S$$
$$(0.9 - 0.2S_{DS})D + \rho Q_E + 1.6H$$

Redundancy factor, ρ

- Desirability in multiple lateral-force-resisting load path
- Belief that excessive loss in story shear strength or development of an extreme torsional irregularity may lead to structural failure
- Verify whether an individual member has a significant effect on the overall system
- Use either 1.0 or 1.3

Redundancy

$$(1.2 + 0.2S_{DS})D + \rho Q_E + L + 0.2S$$
$$(0.9 - 0.2S_{DS})D + \rho Q_E + 1.6H$$

Redundancy factor, ρ = 1.0

- SDC B or C
- Drift calculation and P-delta effects
- Design of nonstructural components
- Design of nonbuilding structures that are not similar to buildings
- Design utilizing overstrength factor, Ω_0
- Diaphragm inertia forces
- Structures with damping systems
- Out-of-plane wall forces and attachments

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Redundancy

$$(1.2 + 0.2S_{DS})D + \rho Q_E + L + 0.2S$$
$$(0.9 - 0.2S_{DS})D + \rho Q_E + 1.6H$$

SDC D to F

Redundancy factor, ρ = 1.3

unless one of the following two conditions is met:

Condition 1 & condition 2

Requirements only applicable to
each story resisting more than 35% of base shear

- includes 87% stories of tall buildings
- Intent is to exclude penthouses and uppermost stories

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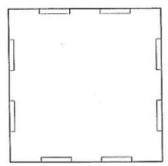
Redundancy

Condition 2

- **No plan irregularities at any level**
- **Sufficient perimeter lateral resisting system**
  - **At least two bays on each side**
  - **Number of bays in shear wall = length/height**
  - **Typically OK for dual systems**



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Redundancy

Condition 1

Table 12.3-3 Requirements for Each Story Resisting More than 35% of the Base Shear

Lateral Force-Resisting Element	Requirement
Braced frames	Removal of an individual brace, or connection thereto, would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Moment frames	Loss of moment resistance at the beam-to-column connections at both ends of a single beam would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Shear walls or wall piers with a height-to-length ratio greater than 1.0	Removal of a shear wall or wall pier with a height-to-length ratio greater than 1.0 within any story, or collector connections thereto, would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b). The shear wall and wall pier height-to-length ratios are determined as shown in Figure 12.3-2.
Cantilever columns	Loss of moment resistance at the base connections of any single cantilever column would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b).
Other	No requirements

Redundancy

Condition 1

Shear walls or wall piers with a height-to-length ratio greater than 1.0	Removal of a shear wall or wall pier with a height-to-length ratio greater than 1.0 within any story, or collector connections thereto, would not result in more than a 33% reduction in story strength, nor does the resulting system have an extreme torsional irregularity (horizontal structural irregularity Type 1b). The shear wall and wall pier height-to-length ratios are determined as shown in Figure 12.3-2.

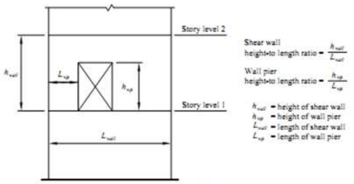


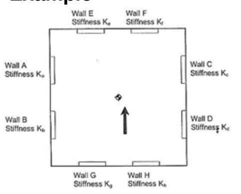
Figure C12.3-4 Shear wall and wall pier height-to-length ratios.

Removal of a shear wall would NOT result in

- More than 33% reduction in story strength
- Extreme torsional irregularity

Redundancy

Example



Stiffness

$K_a = K_b = K_c = K_d = K_e = K_f = K_g = K_h$

Strength

R_n all walls

Geometry

Story height > length of each wall

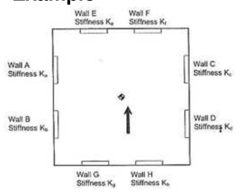
Condition 2

Less than 2 bays on each side → not met

Check condition 1!

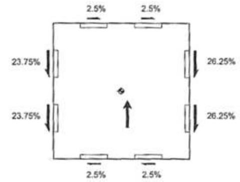
Redundancy

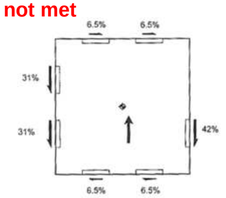
Example



Condition 1 (elastic approach)

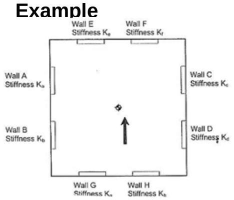
- Determine force distribution based on stiffness
- Remove wall C, determine force distribution
- V_n/V_u = 26.25%V/42%V = 62.5%
- Reduction in story strength = 100%-62.5% = 37.5% > 33%
- not met

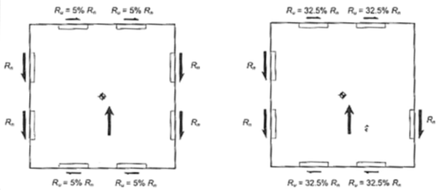




Redundancy

Example



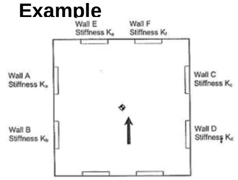


Condition 1 (plastic mechanism approach)

- More consistent w/ principles of seismic design
- Original story shear = $4R_n$
- Remove wall C, story shear = $3R_n$
- $3R_n/4R_n$ = 75%
- Reduction in story strength = 100%-75% = 25% < 33% strength requirement met

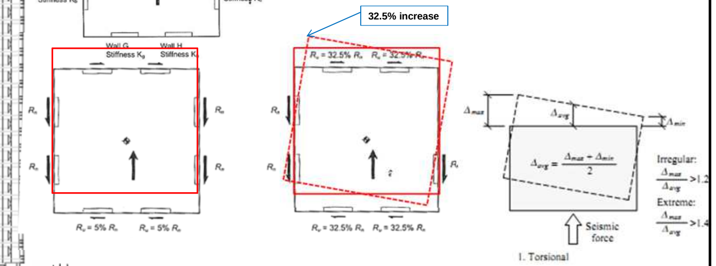
Redundancy

Example



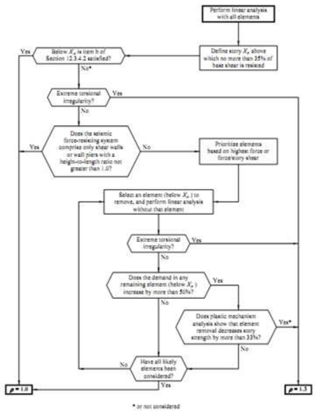
Condition 1 (plastic mechanism approach)

- Check extreme torsional irregularity
- $\Delta_{max}/\Delta_{avg}$ = 1.325 < 1.4
  irregularity requirement met

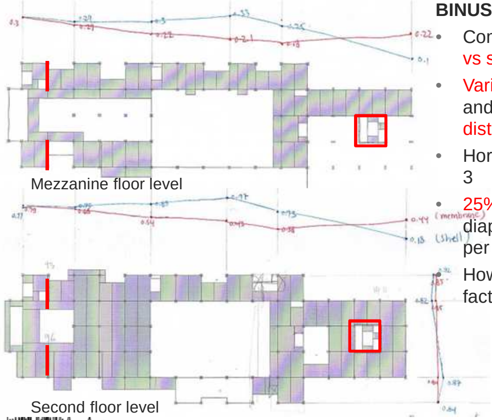


Redundancy

FLOWCHART



DSP Case study



BINUS project

- Comparison study: rigid vs semi rigid diaphragm
- Variation in deformation and in-plane force distribution
- Horizontal irregularity type 3
- 25% force increase in diaphragm connections per code
- How about redundancy factor?

Thank you!

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