STRUCTURAL IRREGULARITIES

Proposed Changes and Additions to NBCC 2005

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STRUCTURAL IRREGULARITIES
Background & Overview

- Static lateral force method is based on a regular distribution of stiffness and mass in a structure.
- It becomes less accurate as the structure varies from this assumption.

STRUCTURAL IRREGULARITIES

- Historically – regular buildings perform better in earthquakes than do irregular buildings. Layouts prone to damage are:
  - torsionally eccentric ones.
  - "in" or "out" or plane offsets of the lateral system.
  - cut-off lateral load elements – particularly coming down the building.
  - those with a weak storey.

STRUCTURAL IRREGULARITIES

- Irregularities defined in code address:
  - mass and/or stiffness irregularities by requiring a dynamic analysis for "taller" buildings in "higher" seismic zones (short period buildings tend to be first mode dominated – static method not bad).
  - offsets etc… treated by requiring a dynamic analysis for "taller" buildings **and** prescribing some system limitations.
  - post disaster buildings – limit irregularities (basically in "higher" zones – only mass irregularities and non-orthogonal system allowed).

TYPES OF STRUCTURAL IRREGULARITIES

1 Vertical stiffness irregularity
2 Weight (mass) irregularity
3 Vertical geometric irregularity
4 In-plane discontinuity
5 Out-of-plane offsets
6 Discontinuity in capacity (weak storey)
7 Torsional sensitivity
8 Non-orthogonal systems

IRREGULARITY TRIGGER

When:

$I_E \cdot F_a \cdot S_a(0.2) > 0.35$ (i.e., 2.4 times Calgary value when I_E and F_a are unity) + any one of the 8 irregularity types.

the building is considered as *irregular.*

IRREGULARITY DEFINITIONS

Type

Notes

Irregularity type

Definition

Structural Irregularities
Forming Part of Sentence 4.1.9.5(1)

Type	Irregularity Type and Definition	Notes
1	**Vertical Stiffness Irregularity** **This is considered to exist when the lateral stiffness of the SFRS in a storey is less than 70% of any adjacent storey, or less than 80% of the corresponding average stiffness of the three storeys above or below. One-storey penthouses need not be considered.**	(1) (3) (6)
2	**Weight (mass) Irregularity** Weight irregularity shall be considered to exist where the weight, W, of any storey is more than 150 percent of the weight of an adjacent storey. A roof that is lighter than the floor below need not be considered.	(1)
3	**Vertical Geometric Irregularity** Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the SFRS in any storey is more than 130 percent of that in an adjacent storey. One-storey penthouses need not be considered.	(1) (2) (3) (6)
4	**In-plane Discontinuity in vertical lateral force-resisting element** An in-plane offset of a lateral load-resisting element of the SFRS or a reduction in lateral stiffness of the resisting element in the storey below.	(1) (2) (3) (6)
5	**Out-of-Plane Offsets** Discontinuities in a lateral force path, such as out-of-plane offsets of the vertical elements of the SFRS.	(1) (2) (3) (6)
6	**Discontinuity in Capacity - Weak Storey** A weak storey is one in which the storey shear strength is less than that in the storey above. The storey shear strength is the total strength of all seismic-resisting elements of the SFRS sharing the storey shear for the direction under consideration.	(3)
7	**Torsional Sensitivity- to be considered when diaphragms are not flexible.** Torsional sensitivity shall be considered to exist when the ratio B calculated according to Sentence 4.1.9.11(9) exceeds 1.7.	(1) (3) (4) (6)
8	**Non-orthogonal Systems** A "Non-orthogonal System" irregularity shall be considered to exist when the SFRS is not oriented along a set of orthogonal axes.	(5) (6)

Notes

Notes:	**To Table 4.1.9.5A - Additional Requirements for Irregular Structures**
(1)	See Article 4.1.9.6
(2)	See Article 4.1.9.15
(3)	See Article 4.1.9.10
(4)	See Sentences 4.1.9.11 (9), (10), and 4.1.9.12 (7)
(5)	See Article 4.1.9.7
(6)	See Appendix A

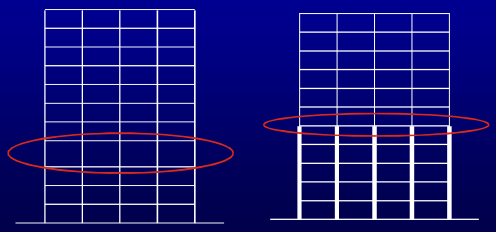
TYPES OF IRREGULARITIES

1 Vertical Stiffness

lateral stiffness of the *SFRS* in a storey:

< 70% of that in any adjacent storey, or

< 80% of the average stiffness of the 3 storeys above or below.

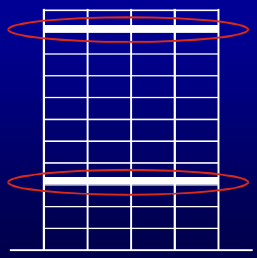


TYPES OF IRREGULARITIES

2 Weight (Mass)

weight of a storey > 150% of weight of an adjacent storey.

(a roof lighter than a floor below is excluded)

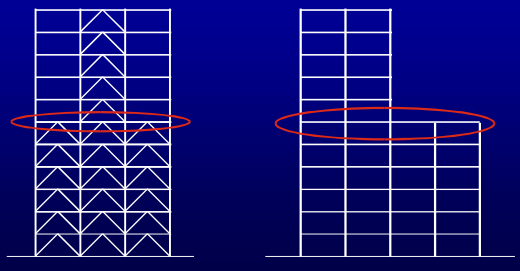


TYPES OF IRREGULARITIES

3 Vertical Geometric

horizontal dimension of the *SFRS* in a storey > 130% of that in any adjacent storey.

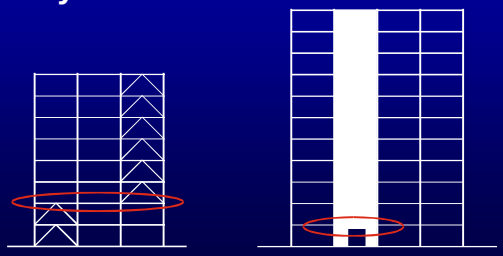
(one-storey penthouse excluded)



TYPES OF IRREGULARITIES

4 In-Plane Discontinuity

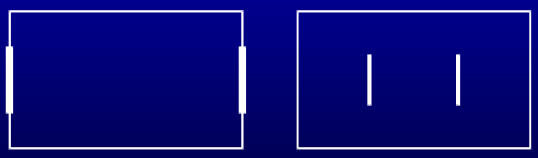
- **in-plane offset of an element of the SFRS,**
  or
- **reduction in lateral stiffness of an element in the storey below.**



TYPES OF IRREGULARITIES

5 Out-of-Plane Offsets

discontinuity of lateral force path
e.g., out-of-plane offsets
of the elements of the *SFRS.*



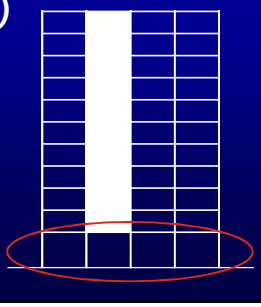
Bottom Floors **Top Floors**

TYPES OF IRREGULARITIES

6 Discontinuity in Capacity - Weak Storey

storey shear strength less than that in the storey above.

(Storey shear strength = total of all elements of the SFRS in the direction considered)



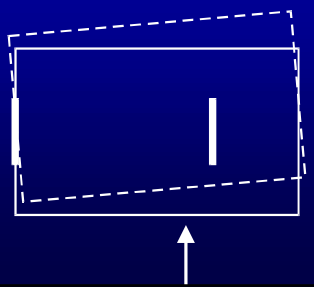
TYPES OF IRREGULARITIES

7 Torsional sensitivity

if the ratio B > 1.7.

B = δ_{max} / δ_{avg}

δ calculated for static loads applied at $\pm$ 0.10 D_n

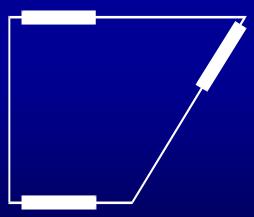


Plan

TYPES OF IRREGULARITIES

8 Non-orthogonal systems

SFRS **not oriented along a set of orthogonal axes.**



Plan

IRREGULAR SFRS

SFRS is *irregular* when:

$I_E \cdot F \cdot S_a(0.2) > 0.35$, **(about 1/3 of Vancouver value when** $I_E = F = 1$**)**

with any one of the 8 irregularity types.

Stiffness of non-structural components shall not be included to make an irregular SFRS regular.

Method of analysis – dynamic required except that static analysis may be used if **any** of the following apply:

- $I_E F_a S_a(0.2) < 0.35$
- Regular structure with h < 60 m and with T < 2.0 s
- Irregular structure (except type 7, torsion) with h < 20 m and with T < 0.5 s

IRREGULAR SFRS

- Irregularity type 6 (weak storey) not permitted unless $I_E F_a S_a(0.2) < 0.2$ and forces multiplied by $R_d R_o$
- Post-disaster buildings shall not have any of the following irregularities:
  - types 1 (vert. stiffness), 3 (vert. geom.), 4 (in-plane discont.), 5 (out-of-plane offsets) or 7 (torsion) if $I_E F_a S_a(0.2) > 0.35$; type 6 (weak storey).

IRREGULAR SFRS

Irregularity Type 8 – "Non-orthogonal lateral force resisting system"

- If $I_E F_a S_a(0.2) \geq 0.35$ then:
  - pick any orthogonal set of axes.
  - analyse for 100% of base shear along each axis concurrent with 30% of the base shear along the other axis.

IRREGULAR SFRS

If $I_E F_v S_a(1.0) > 0.25$ and T > 1.0 s, walls shall be continuous from the ground to the top level and shall not have irregularity types 4 (in-plane discont.), 5 (out-of-plane offsets).

Note: **$S_a(1.0) = 0.25$ is 6 times Calgary value**


The End