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.
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.

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:

\[ I_E F_a S_a (0.2) > 0.35 \] (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

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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.

Notes:

- See Article 4.1.9.6
- See Article 4.1.9.15
- See Article 4.1.9.10
- See Sentences 4.1.9.11 (9), (10), and 4.1.9.12 (7)
- See Article 4.1.9.7
- See Appendix A
2 Weight (Mass)

weight of a storey > 150% of weight of an adjacent storey.
(a roof lighter than a floor below is excluded)

3 Vertical Geometric

horizontal dimension of the SFRS in a storey > 130% of that in any adjacent storey.
(one-storey penthouse excluded)
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.

5 Out-of-Plane Offsets

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

7 Torsional sensitivity

if the ratio $B > 1.7$.

$$B = \frac{\delta_{\text{max}}}{\delta_{\text{avg}}}$$

$\delta$ calculated for static loads applied at $\pm 0.10 D_n$
TYPES OF IRREGULARITIES

8. Non-orthogonal systems

SFRS not oriented along a set of orthogonal axes.

IRREGULAR SFRS

SFRS is *irregular* when:

\[ I_E \cdot F \cdot S_a(0.2) > 0.35, \text{ (about } 1/3 \text{ of Vancouver value when } I_E \cdot F = 1) \]

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).
Irregularity Type 8 – “Non-orthogonal lateral force resisting system”

- If $I_E F_a S_a (0.2) > 0.35$ 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.

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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