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STRUCTURAL VULNERABILITY IN ECUADOR

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Buildings
Code
Research
TO REDUCE SEISMIC RISK
WE MUST REDUCE
STRUCTURAL VULNERABILITY
KEY ASPECTS TOWARDS SEISMIC SAFETY

1. Adequate Architectural seismic configuration
2. Proper structural analysis and design
3. Revision and approval of structural design.
4. Proper construction of structure - seismic detailing
5. Revision of construction – mainly seismic detailing

ECUADORIAN CODE
CODIGO ECUATORIANO DE LA CONSTRUCCION CEC - 2000

EFFECTIVE SINCE MAY 2002
CURRENTLY REWRITEN
1. We are updating the code.

There are several committees that deal with different structural systems or materials.

1. **R/C Buildings Committee.**

The committee for R/C buildings, recommended the adoption of ACI 318-08 S plus an additional section with local recommendations in order to get safer shear design of 5 important elements of frame buildings:

1. Slab – column joints
2. Beam - column joints,
3. shear walls ,
4. Beams
5. columns.
• Chapter 21 is clarified:

• It includes Flat plate systems, in addition to
  • Frame buildings
  • Frame with Shear Wall buildings
  • Frame with diagonal bracing buildings

• It states, for each building system, which elements should yield under a severe earthquake, and how to design for

• General seismic design objective is set in the following graph:
FLAT PLATE BUILDINGS
(without shear walls)

- ACI 318-08 does not give provisions for seismic design of this type of buildings in zone 3 or 4
- Most codes restrict its use to zone 2 at most
- Very poor behavior in past earthquakes

- Despite these facts, more than 50% of buildings use this system

BUILDING CHARACTERISTICS

- 4 to 12 stories
- Columns + Waffle slabs
- Rather small columns
- Integral beams between columns
- No shear walls
- Partitions made of non industrial concrete blocks, and located arbitrarily
ANALYSIS

- Use higher forces
  - CEC 2000: $R = 8$
  - $(R = 10$ Special Moment Frame $)$
- Use effective width of $1/3 \ L$
- Limit Inter story drift to 0.002

TRANSVERSE REINFORCEMENT

- Stirrups shall be designed for the most critical case of 1D or 2D shear.
- In 1D shear, the acting shear $V_u$ shall be computed using the beam probable flexural capacity $M_{n\text{ pr}}$
- In 2D shear, the resultant punching stress shall be computed using the probable flexural capacity when finding $M$ unbalanced.
INELASTIC RESPONSE

• **Objective:**
  • Yielding of slab bars within the effective width

• **Strategy:**
  1. Strong Column - Weak Beam
  2. Strong slab for punching - Weak slab in flexion

1. **Strong Column - Weak Beam**

Sum \( M_{\text{cols}} > 1.4 \) Sum \( M \text{“Beams”} \)

\[
\text{c2} + 3h
\]

• As for M “Beams”
2. Strong slab for punching - Weak slab in flexion

ACI 318-08 + CAPACITY CRITERIA

\[ v_{u \text{punch}} < \phi v_{n \text{punch}} \]

\[ v_{u \text{punch}} = \frac{V_u}{A_c} + \gamma_v \frac{M_{ub} c}{J} \]

\( M_{ub} \) from flexural capacity

\[ v_n = v_c + v_s < 1.59 \sqrt{f'_c} \text{ Kg/cm}^2 \]

If \( v_{u \text{punch}} \leq \phi 1.59 \sqrt{f'_c} \), Design the stirrups

If not, redesign the structure

STIRRUPS DESIGN FOR PUNCHING

• \( Av / \# \text{legs of stirrups} \)
• Legs in tension from shear = \( n \)
• Legs in tension from torsion = 2

\[ M_{ub} \]

• Shear

• Torsión
FRAME BUILDINGS

H beam > 3 h slab

• Beams:
  • When computing Design shear force:
    \[ M_{pr} = 1.2 \times (M_{pr} \times 318) \]
    1.2 due to slab reinforcement

Columns:
• Design shear force for the 1st floor:
  \[ M_{c\ top \ and \ M_{c\ bot} \ are} \ M_{c\ max} = M_{c\ balanced} \]

INELASTIC RESPONSE

• Objective:
• Yielding of beam bars at column faces

• Strategy:
  1. Strong Column - Weak Beam
  2. Strong Joint - Weak Beam
1. Strong Column - Weak Beam

Sum M cols > 1.4 Sum M beams

2. Strong joint - Weak Beam

SHEAR

\[
\frac{hb}{hc} = 1 \\
\frac{hb}{hc} = 0.5
\]

\[
V_n = V_c \\
V_s = 0 \\
V_n = V_c \\
V_s = 0
\]
1. \( \frac{hb}{hc} < 1.5 \)

\[ V_n = V_c + V_s \]

- \( \frac{hb}{hc} = 1 \) \( V_c = V_c^{318} \)
- \( \frac{hb}{hc} = 1.5 \) \( V_c = 0 \)

2. \( \frac{hb}{hc} > 1.5 \)

\[ V_n = V_s \]

- \( V_c = 0 \)

2. Strong joint - Weak Beam

Bar passing through the joint

\[ H_{col} > 20 \ d_{beam} \]

\[ H \ beam > 20 \ d_{col} \]
SHEAR WALL BUILDINGS
(+ Frames)

• Individual
• Coupled

INELASTIC RESPONSE

• Objective:
• Yielding of vertical wall bars at base of wall

• Strategy:
  1. Strong wall in shear - Weak wall in flexion
Design shear force at base $V_u$

\[
V_u = V_u \text{ analysis } (\frac{M_n}{M_u})
\]

\[
\frac{M_n}{M_u} / 1.43
\]

Where $M_n = \text{Wall flexural capacity from a P-M interaction diagram}$

$M_u = \text{Factored design moment}$

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**STRUCTURAL SYSTEMS RECOMMENDED**

- Concrete structural walls
- Frame + shear walls
- Frames
- Avoid flat plate systems w/o shear walls
RESULTADOS MEDICION DE PERIODOS - PUNTO 10
Dynamic Characteristics of a 17th Century Church in Quito, Ecuador

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ABSTRACT

This paper presents the results of a study on the ambient vibration analysis of a historical monument in Ecuador, La Iglesia de la Compañía de Jesus [the Church of the Jesuit Order] was constructed over a period of 80 years, from the mid 16th to the early 17th century and is located in the capital city of Quito. The church has been subjected to natural and human forces only. For this reason, most of the damage inflicted on the structure during seismic loadings occurs in regions that have high tensile stresses.

The church has been repaired many times throughout its history, and has undergone changes in terms of structure as well as additions and upgrades. The behaviour of the structure was originally intended to resist the effects of seismic loads. The building was designed to withstand the earthquake forces only. For this reason, most of the damage inflicted on the structure during seismic loadings occurs in regions that have high tensile stresses.

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Muchas gracias