A PRACTICE-ORIENTED PROBABILISTIC ASSESSMENT OF BUILDING STRUCTURES

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MOTIVATION

Application of probabilistic approaches in everyday practice
Extension of the N2 method by applying the SAC-FEMA probabilistic approach
N2 METHOD

- Pushover analysis of a MDOF model
- Transformation to an equivalent SDOF system and bilinear idealization
- Determination of the NC capacity in terms of (roof) displacement (EDP)
- Determination of the NC capacity in terms of spectral or/and peak ground acceleration (IM)
SAC-FEMA METHOD

Based on research in Stanford by Cornell, Krawinkler and co-authors

\[ P_{LS,x} = \tilde{H} \cdot s_{a,\tilde{C}} \cdot C_H \cdot C_f \cdot C_x \]

Mean vs median hazard

\[ C_H = \exp \left[ \frac{1}{2} \beta_H^2 \right] \]

Randomness

\[ C_f = \exp \left[ \frac{k^2}{2b^2} \beta_{DR}^2 + \beta_{CR}^2 \right] \]

Uncertainty

\[ C_x = \exp \left[ K_x \sqrt{\frac{k^2}{b^2}} \beta_{DU}^2 + \beta_{CU}^2 \right] \]

Idealized hazard curve

\[ H(s_a) = k_0 s_a^{-k} \]

Idealized IDA curve

\[ D(s_a) = \alpha s_a^b \]
ADDITIONAL SIMPLIFICATIONS

- The spectral shape does not change with the intensity of ground motion: $S_a$ can be replaced by $PGA$
- $k = 3.0$ (if a more appropriate value is not known)
- No distinction between mean and median ($C_H = 1$)
- $b = 1$ (equal displacement rule)
- Definition of NC limit state (performance level): the “ultimate” limit state of the most critical important element defines the NC limit state at the level of the structure
- Default (predetermined) values of dispersion measures $\beta$ ($\beta_R = 0.45$)
SIMPLIFIED FORMULA

\[ P_{NC} = 2.5 \ H(\text{PGA}_C) = 2.5 \ k_0 \ \text{PGA}_C^{-3} \]

\( P_{NC} \) is the annual probability of the “failure”

\( H(\text{PGA}_C) \) is the median value of the hazard function at the seismic intensity \( \text{PGA}_C \)

\( \text{PGA}_C \) is the “failure” capacity in terms of peak ground acceleration, i.e. the \( \text{PGA} \) “corresponding” to the displacement capacity (at “failure”) determined by the N2 method

\( k_0 \) is a parameter defining seismic hazard

Only randomness is considered
SPEAR BUILDING
SPEAR BUILDING

![Diagram of Spear Building with dimensions and labels]
TYPICAL CROSS-SECTIONS OF COLUMNS

Test

Column 25/25 cm

Stirrups
Φ8/25 cm

4Φ12

25

ρ₁ = 0.74 %

EC8 H

Column 35/35 cm

Stirrups
Φ8/8.5 cm

4Φ16

4Φ20

35

ρ₁ = 1.7 %
EC8, Soil type C

Elastic spectrum

Design spectrum
PUSHOVER CURVES

- Test
- EC8 H

![Graph showing pushover curves with labels and legend]
DETERMINATION OF SEISMIC CAPACITY (NC)

- Test
- EC8 H
IN2 CURVES

- Test
- EC8 H

![Graph showing performance curves for IN2, comparing Test and EC8 H with NC Capacity.](image-url)
PROBABILITY

Only randomness is considered

\[ P_{NC} = 2.5 \ H(PGA_C) = 2.5 \ k_0 \ PGA_C^{-3} \]

\[ PGA_{475} = 0.25 \ g \times 1.15 = 0.29 \ g \quad \text{(seismic hazard map, soil type C)} \]

\[ H(PGA_{475}) = 0.002 \ (10\% \ in \ 50 \ years) \]

\[ k_0 = H(PGA_{475}) / PGA_{475}^{-3} = 0.046 \]

\[ PGA_C = 0.25 \ g \quad \text{(test building)}, \quad PGA_C = 0.77 \ g \quad \text{(EC8 building)} \]

\[ P_{NC} = 0.78 \times 10^{-2} \quad \text{or 32\% in 50 years} \quad \text{(test building)} \]

\[ P_{NC} = 2.67 \times 10^{-4} \quad \text{or 1.3\% in 50 years} \quad \text{(EC8 building)} \]
DISCUSSION OF RESULTS

- Large increase of stiffness, strength, ductility and “failure” capacity of the code designed building compared to a building not designed for seismic resistance

- Large decrease of the probability of “failure” (1.3 % versus 32 % in 50 years)
DISCUSSION OF RESULTS

\[ PGA_C = 0.77 \text{ g} \]

“The code is too conservative!?”

\[ P_{NC,50} = 1.3 \% \]

“The probability is too high!?”

How high is the tolerable probability?
How safe is safe enough?
CONCLUSIONS

- A simple practice-oriented probabilistic approach has been proposed
- It is based on established methods and usual assumptions used in seismic codes
- Default data on dispersion (randomness and uncertainty) are needed for application
- Data on tolerable probabilities of “failure” and “engineering feeling” for the probabilistic terms have to be developed
THANK YOU!