Seismic Retrofit of a 16-story Non-Ductile RC Building in Downtown L.A.

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Preamble

- In the city of Los Angeles (LA) California, approximately 1,500 buildings have been classified as non-ductile concrete buildings (PEER, 2009)

- Inadequate seismic performance and brittle failure of non-ductile concrete was observed in the 1985 Mexico City, 1994 Northridge, and the 2011 Christchurch New Zealand earthquakes

- In California, non-ductile concrete buildings constructed to building code standards earlier than the code improvements in 1976 are at a particular risk for collapse

- The Los Angeles Department of Building and Safety (LADBS) issued ordinance 183893 “Mandatory Earthquake Hazard Reduction in Existing Non-ductile Concrete Buildings” (2015)

- This ordinance became effective in November of 2015 and is mandatory for the continuous use and adaptive reuse of existing non-ductile concrete buildings, constructed prior to 1977
Non-ductile concrete buildings

- Concrete floors and/or roofs, with or without supporting beams supported by concrete walls and/or concrete columns. Masonry infills may be present within concrete frames.

- Brittle failure with likelihood of shear failure and/or hinging of main structural components leading to collapse.

- Non-ductile characteristics observed in these buildings (Kurama, 1993):
  - Beam bottom (positive) flexural reinf. with short embedment length (typically 6-inches) into the beam-column joint:
    - Beams have insufficient transverse reinf.
    - Beam flexural reinf. cut-off and bend regions according to gravity load requirements
    - Columns with wide spacing of transverse reinforcement
    - Columns with poor confinement of reinf. splices located just above floor level
    - Insufficient or no transverse reinforcement in the beam-column joint
L.A. Ordinance for non-ductile concrete buildings

- Ordinance 183893
- “Mandatory Earthquake Hazard Reduction in Existing Non-ductile Concrete Buildings”
- Effective on November 22, 2015
- Mandatory for continuous use and adaptive reuse of existing non-ductile concrete buildings with permit application prior to January 13, 1977
- Excludes detached single-family dwellings and detached duplexes, and previously retrofitted buildings conforming to LABC provisions
- Timeline for compliance:
  - 2016-2019: Begin the assessment process
  - 2019-2029: Determine retrofit status
  - 2029-2041: Perform building retrofits
L.A. Ordinance for non-ductile concrete buildings

Design criteria:

- Lateral-force resisting system designed to a minimum strength of 75% of the base shear specified in the current LABC seismic provisions
- Elements not designated to be part of the lateral-force resisting system shall be adequate to accommodate seismic displacements due to full (100%) of the design story-drift
- Alternatively, the design criteria can be met using an ASCE 41 approach with the corresponding “Basic Safety Objectives” and ground motions
- Other equivalent methods can be applied if approved by the LADBS
Description of building

- 15-story structure
- Built circa 1927
- Approx. 155 ft × 78 ft
- Non-ductile
- First used as a parking structure
- Repurposed into an office building in 1953
Description of building

GRAVITY SYSTEM:

- RC floors, beams and columns
- Concrete pan-joist floor slabs
- Concrete on mtl deck on steel wide-flange beams floor infills
- Square, circular or interlocking-core cross-section
- Foundation consists of concrete spread footings
Description of building

LATERAL-FORCE RESISTING SYSTEM:
- 8-in thick concrete walls extending full-height of the building
- For lower floors (1st to 8th), on the north side, the solid wall changes to brick infill
Adaptive reuse building modifications

- Accommodate 180 hotel rooms considered a change in use
- An existing mezzanine level will be extended into a new second floor
- Existing parking ramps will be replaced by new ramps.
Seismic retrofit scheme
Analysis procedure

- Selected in accordance to LABC and ASCE7
- Dynamic Modal Response Spectrum
- Linear-elastic frame elements for columns and beams
- Linear-elastic shell elements for RC walls and Floors
- Pin supports were assigned to building base nodes
- Foundation design as a separate second stage
  - Reaction loads from the superstructure
Deformation compatibility

- Existing structural members not part of the LFRS were evaluated for deformation compatibility with 100% of the design story-drift.
- Existing columns were checked for sufficient capacity to develop the capacity of connecting RC girders.
Enhanced building performance

- With the retrofit considered in the analysis, building seismic drifts were considerably reduced, an average of about 70%
FEMA P58 Analysis

- Building modal displacements were used as input for a P58 analysis
- The P58 Simplified Method was applied for estimation of peak story drifts median values
FEMA P58 Analysis

Mean Loss and 90th Percentile Loss Over Intensity

- EXISTING
- RETROFIT

- 20% in 50 years
- 5% in 50 years

Mean Repair Time

- EXISTING
- RETROFIT

- 20% in 50 years
- 5% in 50 years
FEMA P58 Analysis
Concluding remarks

- Retrofit of non-ductile concrete buildings per LADBS 183893 ordinance, considerably reduces probability of damage under earthquakes, e.g. approximately 70% reduction in story drifts case study building

- According to FEMA P58 analysis results, building losses after retrofit are reduced approximately 68%, with retrofit elements designed to sustain 75% of standard code seismic loads for new buildings

- It is noted the contribution, to the total loss, of structural building components considerably reduces for the retrofitted condition
Thank you

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