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Collapse Simulation of Slab-Column Moment Frame Building

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Presentation Outline

- Introduction to FEMA P695 Methodology
- ASCE 41 Standard
- Modeling Parameters in ASCE-41
- Building Characteristics
- Modeling Approach
- Effect of Modeling parameters on collapse safety margin for building system

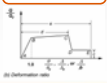
ASCE-41 Standard

Seismic Rehabilitation of Existing Buildings

Rehabilitation Objective → As-Built Information → Rehabilitation Method

Systematic Rehabilitation

Element Modeling Parameters → Analysis of Building Model → Element Acceptance Criteria



FEMA P695 Methodology

Equivalent safety against collapse for buildings with different seismic force resisting systems

Collapse Safety Margin → Design Criteria for Building Codes (i.e. R, C_d, and Ω_0 seismic performance factors)

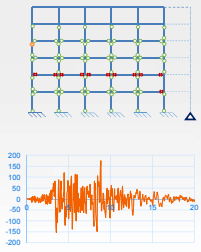
Median Collapse: One-half of the structures have some form of collapse

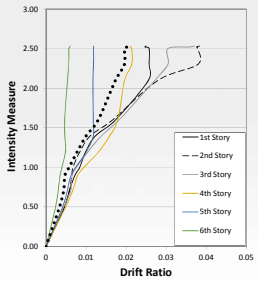
Local Instability | Global Instability

$$\text{Collapse Margin Ratio, } CMR = \frac{SA \text{ Median collapse-level ground motions}}{SA \text{ of } MCE \text{ ground motions}}$$

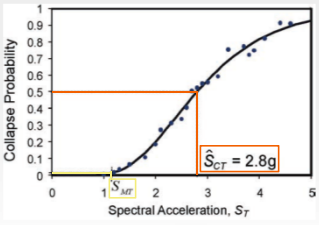
NEHRP: Structure should have a low probability of collapse for *MCE* (1.5 times the design level earthquake)

CMR is established through Incremental Dynamic Analysis





Collapse Fragility Curve



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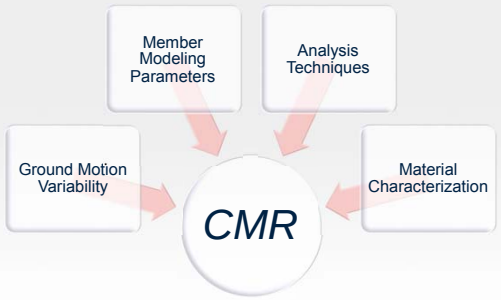
FEMA P695 Methodology



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ASCE 41 Standard

- Seismic rehabilitation
- Rehabilitation objective defined in conjunction with building owner
- Emphasis on element behavior
- Prescriptive rules for modeling components
- Member acceptance criteria

FEMA P695

- Intended for new buildings
- Performance quantified through nonlinear collapse simulations of archetype building models based on MCE
- Emphasis on system behavior
- Calibrated member models
- System Collapse Margin Ratio

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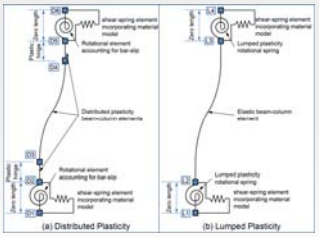
Element Models for Frame Structure



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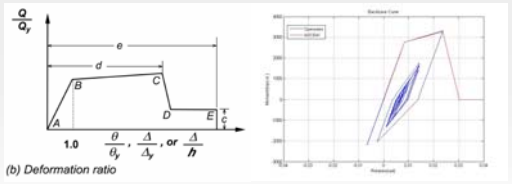
Lumped Plasticity Model for Frame Structure



Moment rotation relationship for nonlinear rotational spring of third story column of Holiday Inn Building

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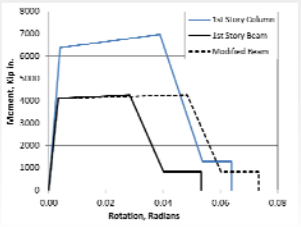
Effect of Modeling Parameters on *CMR*



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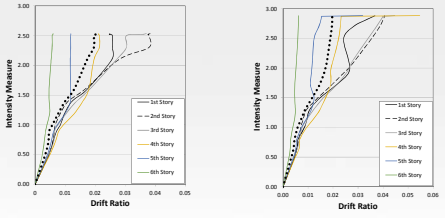
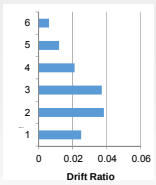
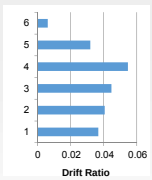
Effect of Modeling Parameters on *CMR*



Effect of Modeling Parameters on *CMR*

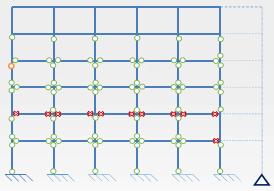


ASCE-41 Beams

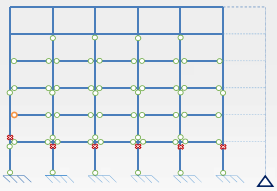


Ductile Beams

Effect of Modeling Parameters on *CMR*



ASCE-41 Beam Modeling Parameters



Ductile Beam Modeling Parameters

Research Plan

- Choose well-known, instrumented, non-ductile building
- Develop nonlinear model using modeling parameters and approaches in ASCE-41
- Perform nonlinear simulations to calculate *CMR*
- Study sensitivity of CMR to modeling parameters

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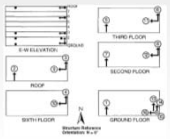
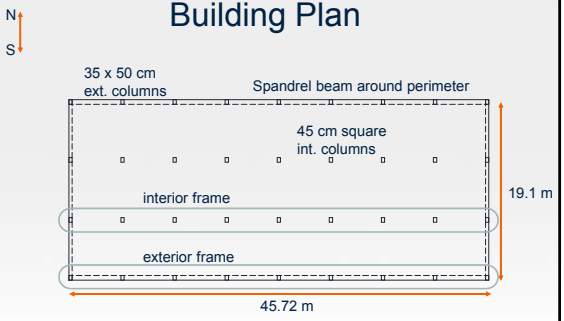
- Compare *CMR* with new construction
- Evaluate *CMR* on the basis of observed damage

Building Description

- Seven-story RC Building in Van Nuys, CA
- Designed in 1965 and constructed in 1966
- Exterior moment-resisting frames
- Interior gravity load flat slab system
- Strong motion records from:
  - 1971 San Fernando
  - 1987 Whittier
  - 1990 Upland
  - 1992 Sierra Madre
  - 1994 Northridge
- Light structural damage during the 1971 San Fernando Earthquake, severe column damage during the 1995 Northridge earthquake.



Building Plan



Modeling Parameters Evaluated

- Effective stiffness criteria for beams and columns
  - Spandrel beams
  - Equivalent beams
- Modeling parameters for beams and columns
  - Shear critical columns
  - Flexure-shear critical columns
  - Beams
- Modeling approach for slab-column moment frames
  - Effective beam-width model
  - Equivalent frame method

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Evaluation Platform

- Opensees analysis program
- Evaluation in E-W direction based on two frames
- Lumped plasticity model
- Modeling parameters for stiffness and plastic deformation adopted from ASCE-41

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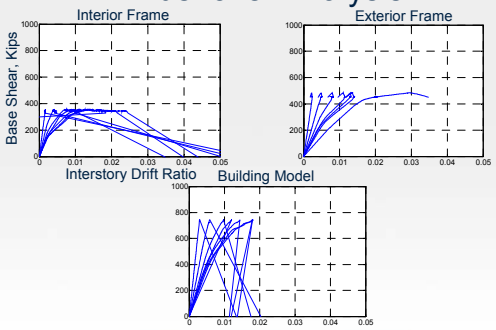
Pushover Analysis



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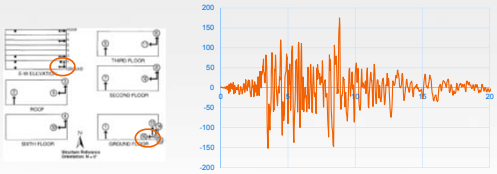
Evaluation Ground Motion

- 1994 Northridge record SE Corner E-W
- PGA 0.45 g



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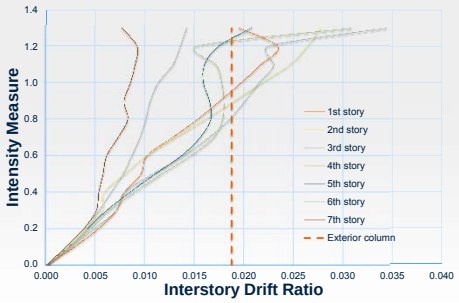
Collapse Simulation Results EW Direction



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Conclusions

- Effective stiffness provisions in ASCE-41 resulted in reasonably accurate estimates of the effective period of the building
- ASCE 41 modeling parameters for columns should be revised to address gap between shear-critical and flexure-shear critical columns
- Nonlinear analyses of the building indicate that the CMR for the Northridge ground motion was approximately 1.3