## Using Opensees for the seismic assessment of existing reinforced concrete buildings

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## Outline

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- 4. Example Application
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#### Introduction

#### **Limitations of Current Seismic Evaluation**

- Current Codes incapable of determining collapse risk
- **Relative importance** of common **deficiencies** not addressed
- High Conservatism in selection of modeling parameters
- Building deficient if single component fails to satisfy the code requirements



## Introduction

#### **ATC-78 Project**

Assessment of Collapse Risk of non-ductile RC structures representative of buildings constructed between 1950-1975

#### **Scope of Study**

- Understand the relative importance of common deficiencies
- Introduce a systematic probabilistic framework in determining the response of old buildings
- Reduce Conservatism in assessment and retrofit of old structures

## **Methodology Overview**







## **Methodology Overview**

## **Challenges of the Methodology**

- Simulation of structural collapse
  - a) Explicit modeling of deterioration of structural members

b) Modeling of brittle type of failures (for example shear or axial failure)

c) Large displacement - non-linear geometric effects taken into account

- Many dynamic analyses are required for proper assessment of seismic behavior
- Introduce a **probabilistic framework** to evaluate collapse risk

## **Modeling assumptions**

- *Earthquake mass* is assumed to be *equally distributed* to the seismic *frames* in x and y direction (lumped mass approach incorporated)
- *Two-dimensional dynamic analysis* is performed
- *Lumped-plasticity approach* to model non-linear material behavior
- *P-Delta effects* are employed in column members to take into account *non-linear geometry*
- The *elastic stiffness* of structural members is *modified* according to the ASCE-41 to implicitly take into account *concrete cracking* and bar slip
- *Joints* assumed to be *rigid* according to ASCE-41

#### **Modeling structural collapse** (controlled by flexure)



# Modeling structural collapse(controlled by shear)Sheiat Spring behavior



(developed by Elwood et al.)

## **Dynamic Analysis**

- Set of 44 ground motions selected far field records (distance from epicenter > 10 km)
- To avoid event bias no more than 2 records taken from any earthquake
- *Ground motions* are *scaled* to increasing earthquake intensity *until collapse*
- Collapse is defined as :

   a) *sidesway collapse* (interstory drift > 10%)
   b) *vertical collapse* (more than 50% of the columns in one story have reached axial failure)
- Probability of collapse (exceedance) is calculated for different S<sub>a</sub>(T<sub>1</sub>) levels

## **Dynamic Analysis**

- **Opensees** structural analysis suite is utilized for the dynamic simultation
- Matlab software is utilized to modify Opensees script during analysis, so that:
  - a) *Scaling of G.M.* is performed
  - b) *Collapse* is tracked in *real-time*
  - c) *Modify solution algorithm* appropriately in real-time
  - d) *Post-processing* of *results* is performed

#### **Ground Motion Scaling**

- *Ground motion intensity*: the *Spectral acceleration* of the individual record at the *fundamental period* of the studied building
- The *intensity of G.M.* is scaled in specified increments until *collapse* is detected
- After collapse is detected the record is scaled down in smaller increment to detect the "exact" failure intensity

## **Solution Algorithm**

- Dynamic Analysis of a structure under extreme earthquake loads can lead to convergence problems in the application of the solution
- Matlab enables modification of Opensees code during analysis:



#### **Post-Processing of Results**



Modify collapse risk using the shape factor

#### **Example Application**

#### **Effect of transverse reinforcement ratio**



## **Conclusions / Summary**

**Opensees** is a powerful tool for simulation of existing buildings because:

- 1. Includes a wide range of elements and materials
- 2. Open source software allows user to modify materials
- 3. Cooperates with other software (Matlab) for pre and post processing of the analyses

## **Conclusions / Summary**

## Thank you!