Comparison of Non-Linear Static & Dynamic Capacity of an existing Seven Storied RC Building

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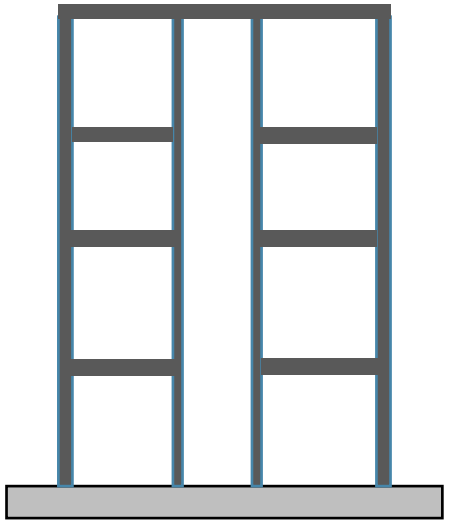
Outlines

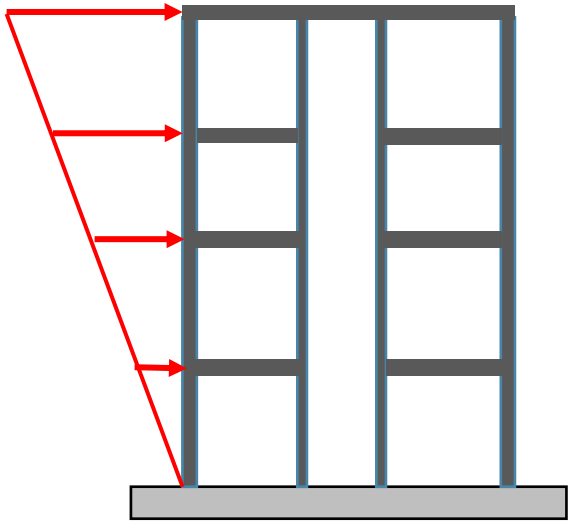
- Background
- Objective
- Literature Review
- Numerical Modelling
- Results & Analysis
- Conclusions

Background

Nepal earthquake: a disaster that shows quakes don't kill people, buildings do

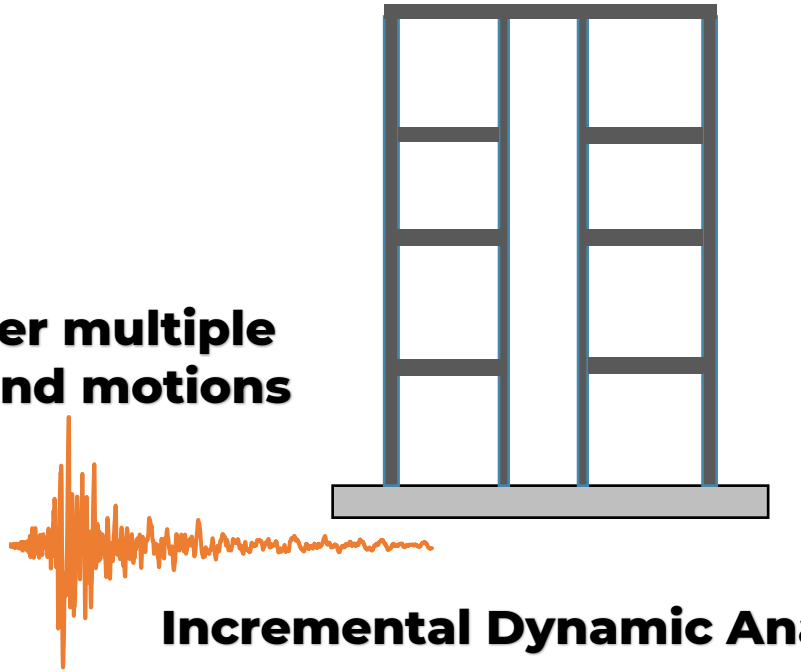


Existing Building



Pushover Analysis

Under multiple Ground motions

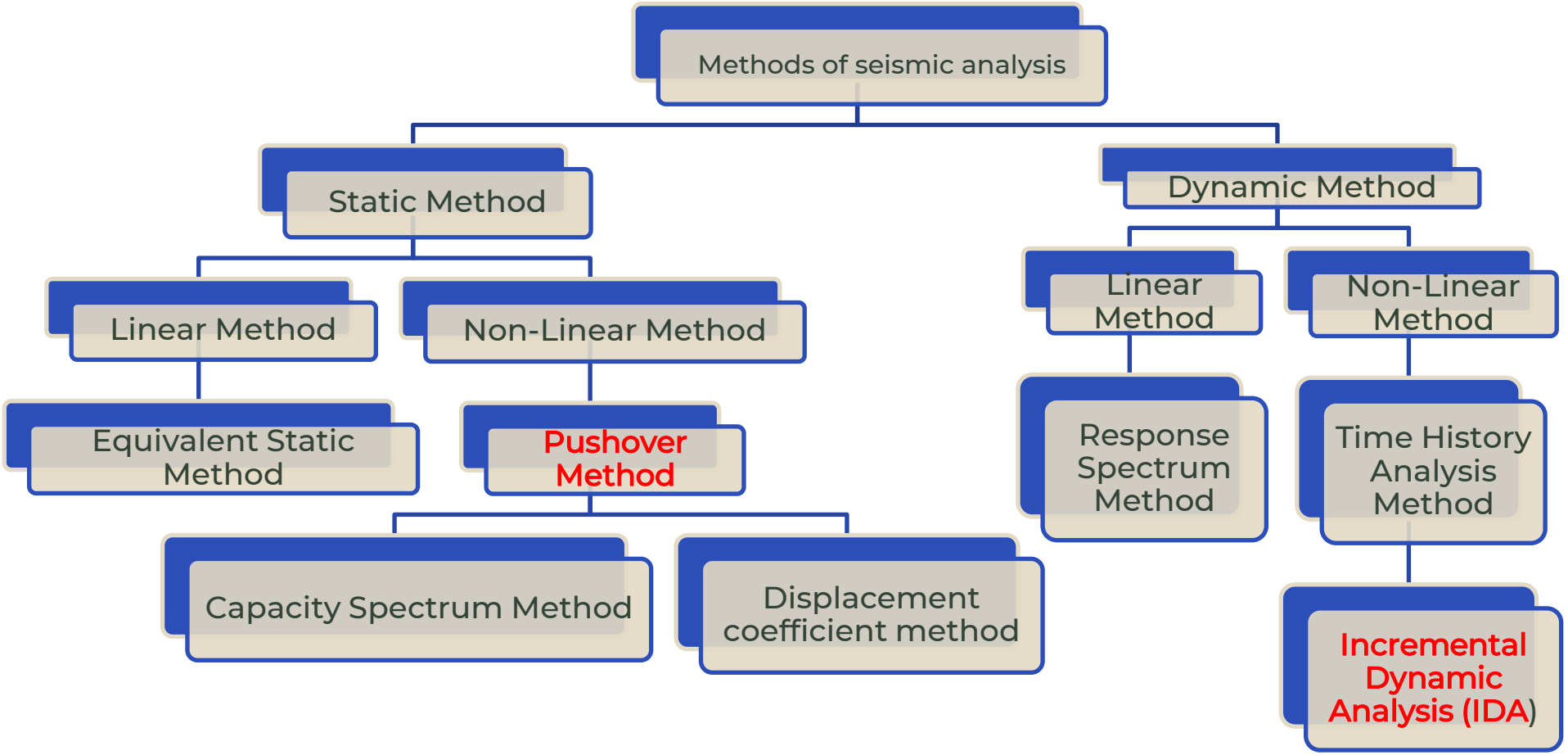


Incremental Dynamic Analysis

Objective

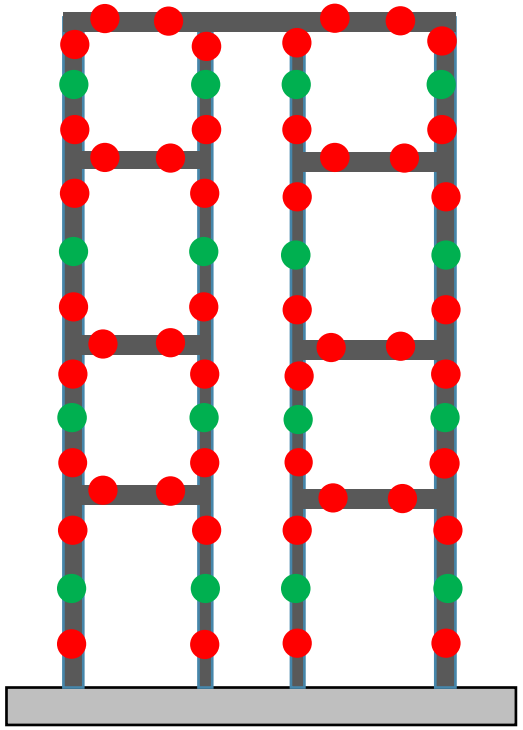
- To collect an existing building plan & make a model on the SAP2000 program.
- To perform non-linear static analysis (pushover analysis) of the building.
- To perform incremental dynamic analysis (IDA) of the building.
- To perform a comparative study of the capacity curve and damage state of pushover and incremental dynamic analysis.

Literature Review



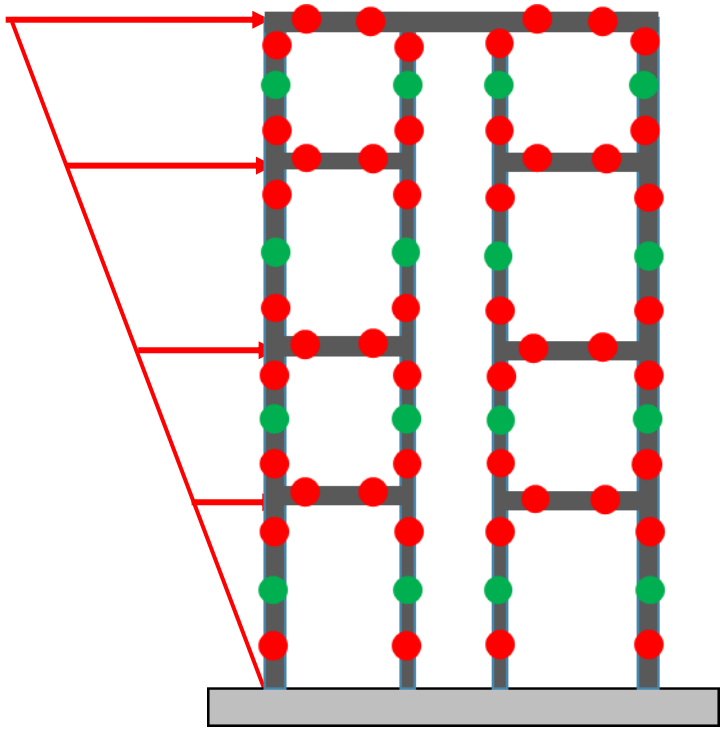
Literature Review

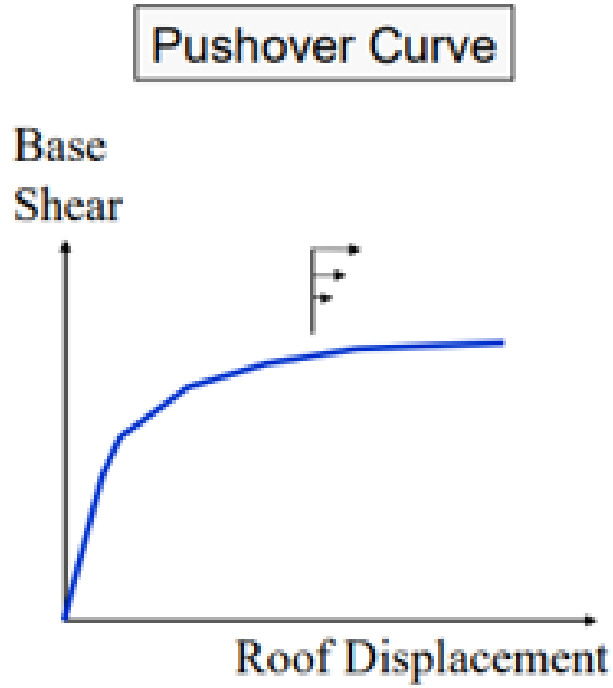
Pushover Analysis



● = Flexural Hinge

● = Shear Hinge





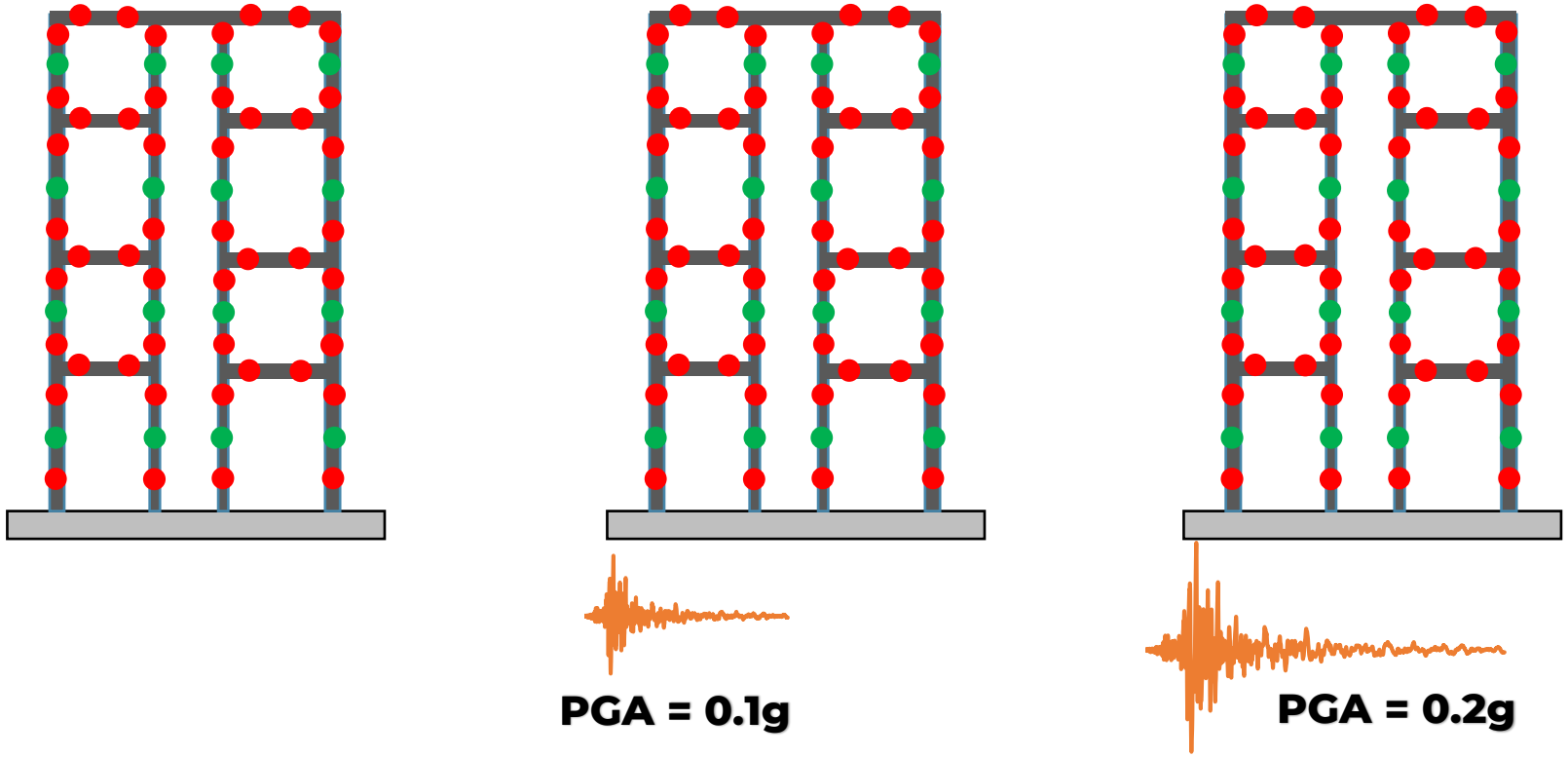
Step 1 : Assign hinges to the model

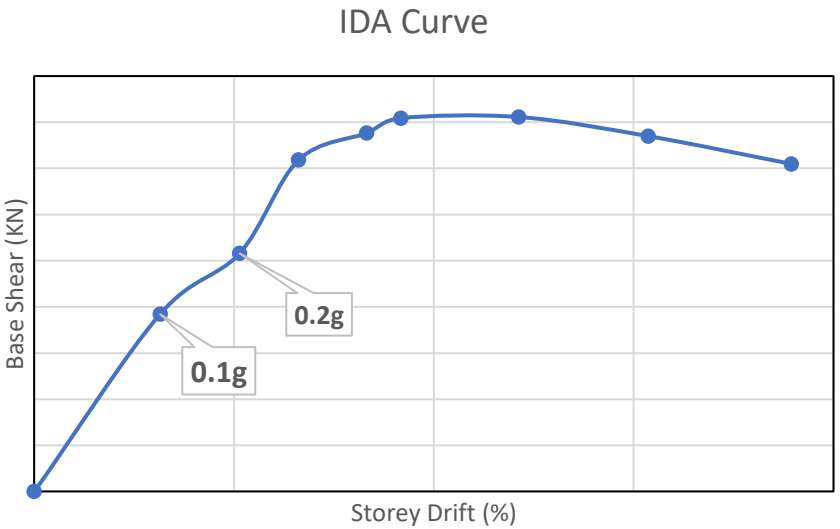
Step 2 : Monotonic triangular load pattern application

Step 3 : Nonlinear analysis to obtain pushover curve

Literature Review

Incremental Dynamic Analysis (IDA)



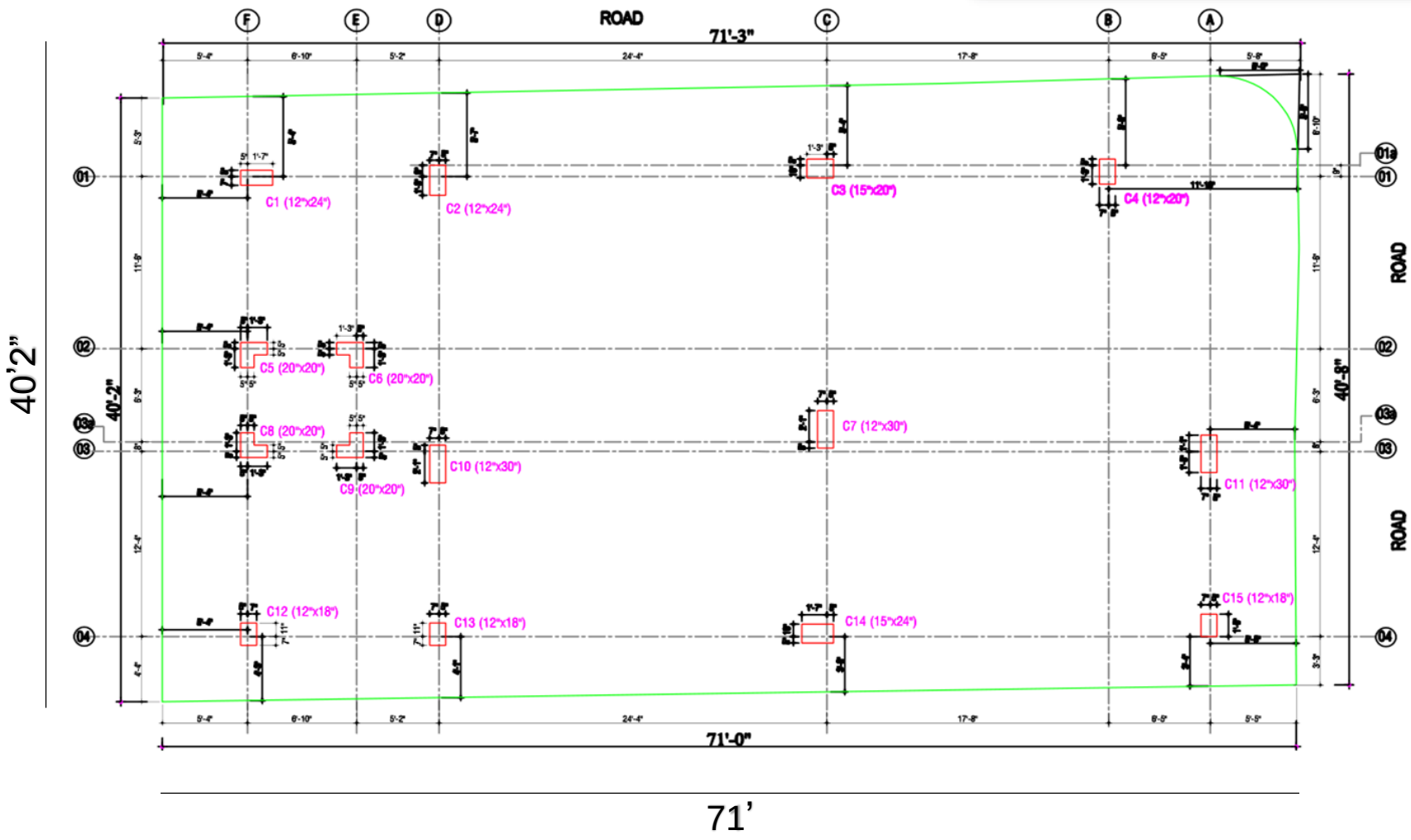


Step 1 : Assign hinges to the model

Step 2 : Scale up & down to the ground motions

Step 3 : Nonlinear analysis to obtain IDA curve

Numerical Modelling of an existing RC building



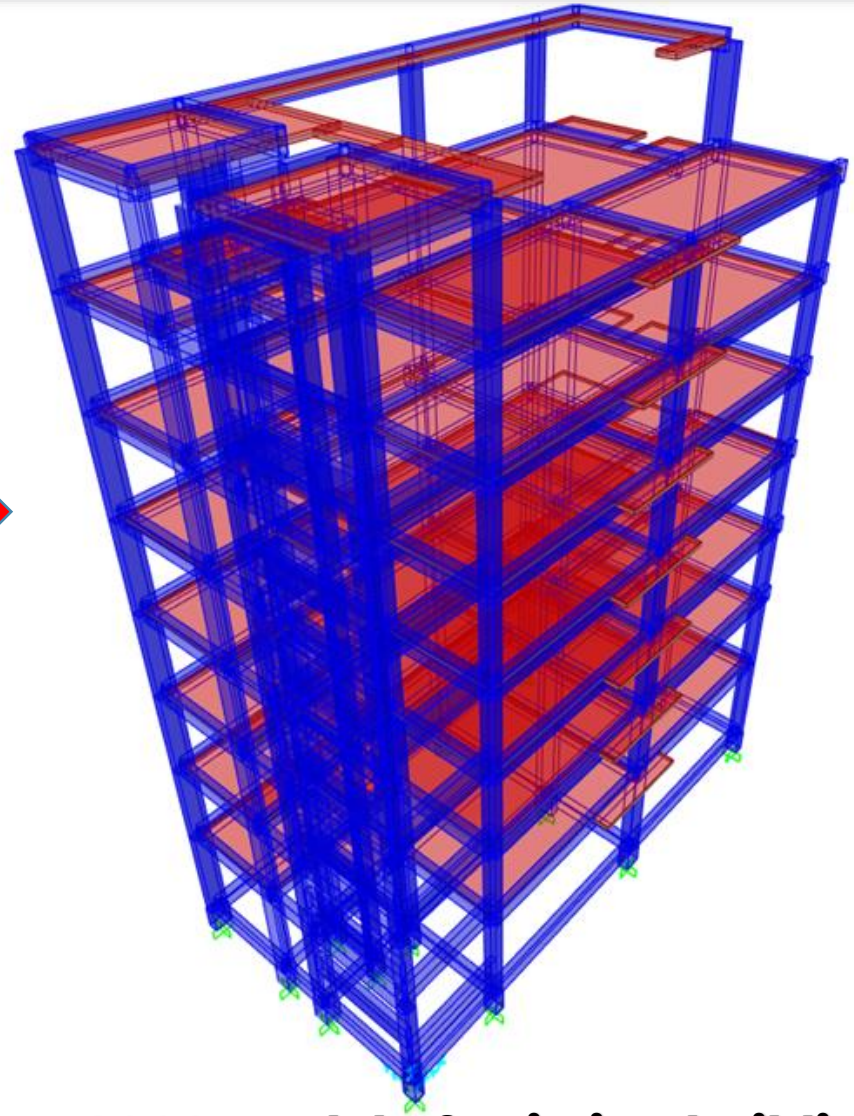
Information	Corresponding data
Project Name	(G+6) 07 Storied Residential Building
Project Location	Dhaka
f'c (Column)	3500 psi
f'c (Other Members)	3000 psi
fy	72.5 ksi
Seismic Zone	II

Column Layout

Numerical Modelling of an existing RC building

Loads	Value
FF	20 psf
PW	25 psf
LL	40 psf

Elevation view of existing building

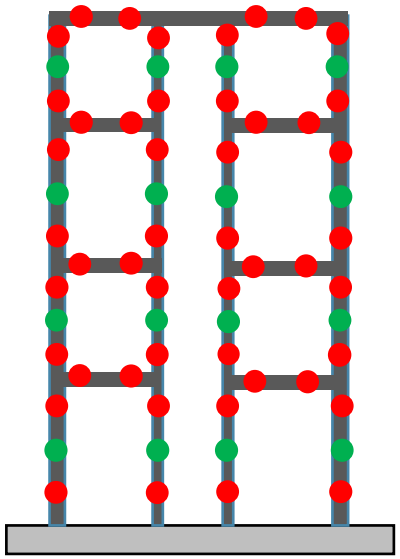


SAP2000 model of existing building

Numerical Modelling of an existing RC building

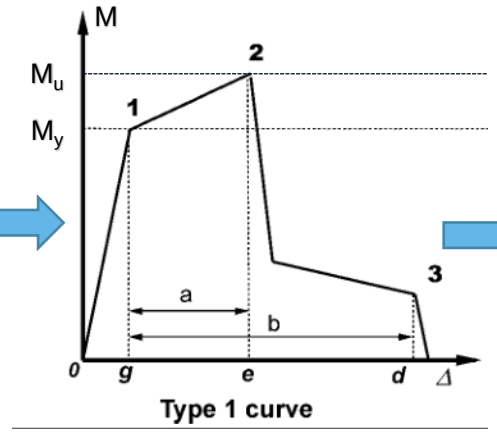
Details of Pushover Analysis in SAP2000

Plastic Hinge Definition and Assignment

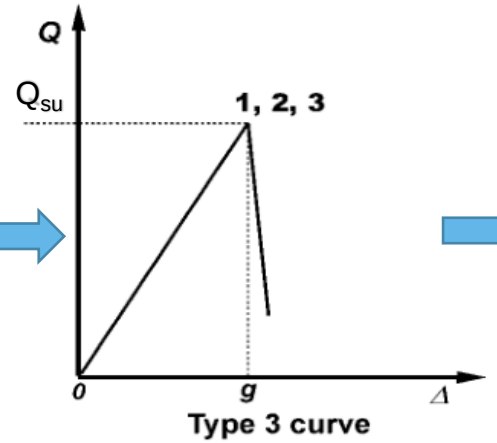


● = Flexural Hinge

● = Shear Hinge



Type 1 curve



Type 3 curve

JBDPA (2001) formula used for calculating ultimate moment of columns:

$$M_u = \{0.8a_t \cdot \sigma_y \cdot D + 0.12b \cdot D^2 \cdot F_c\} \cdot \left(\frac{N_{max} - N}{N_{max} - 0.4b \cdot D \cdot F_c}\right)$$

JBDPA (2001) formula used for calculating ultimate moment of Beams:

$$M_u = 0.9a_t \cdot \sigma_y \cdot d$$

JBDPA (2001) formula used for calculating shear capacity of Columns:

$$Q_{su} = \left\{\frac{0.053p_t^{0.23}(18 + F_c)}{\frac{M}{Q \cdot d} + 0.12} + 0.85\sqrt{p_w \cdot \sigma_{wy}} + 0.1\sigma_0\right\} \cdot b \cdot j$$

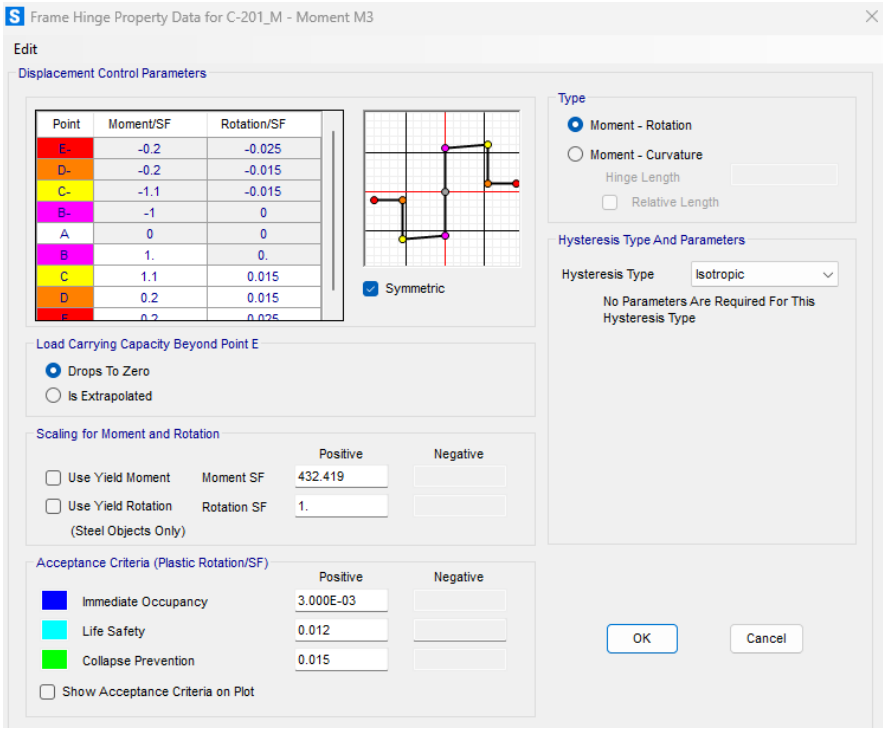
Typical behavior curve for flexural and shear hinges (FEMA 356)

Numerical Modelling of an existing RC building

Hinge Assignment

Table: Yield Moment calculation of columns at Second Floor

Column Notation	No. of bars	Bar dia (mm)	Total reinforcement area, ag (mm^2)	Total area of tensile reinforcing bars, at (mm^2)	Axial Force (N)	Ultimate flexural strength, Mu (N-mm)	Yield Moment, My (KN-mm)
C-201	16	16	3216	1407	488474.34	4.757E+08	432.419
C-202	4	20	1256	1633	933469.39	3.117E+08	283.353
	12	16	2412				

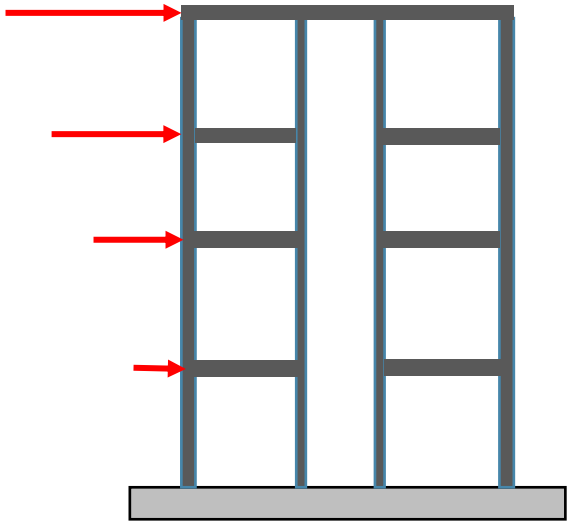


Yield Moment is obtained dividing the ultimate moment by 1.1

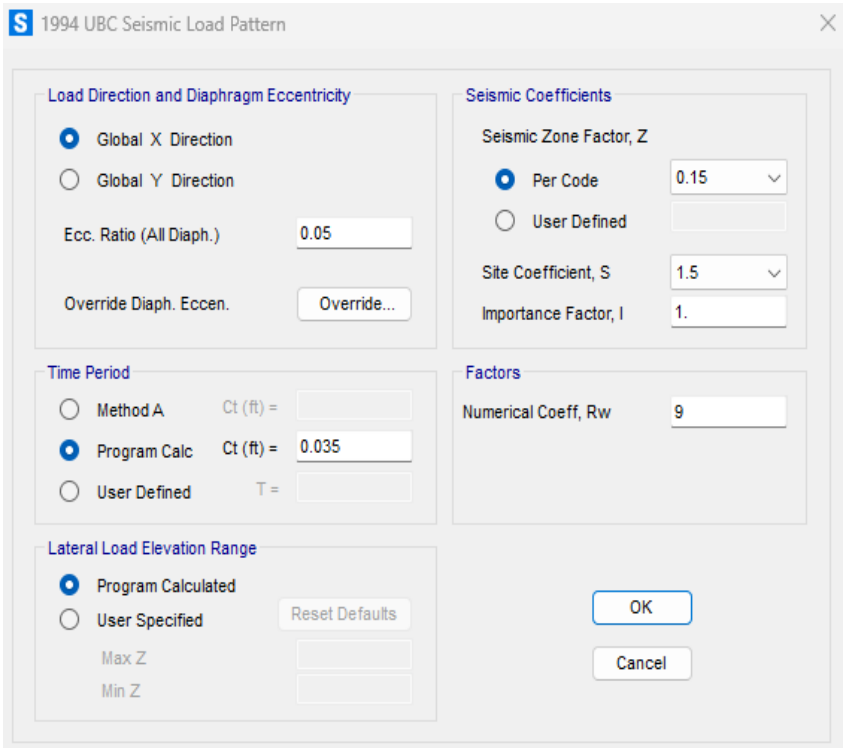
Numerical Modelling of an existing RC building

Load Cases for Pushover Analysis

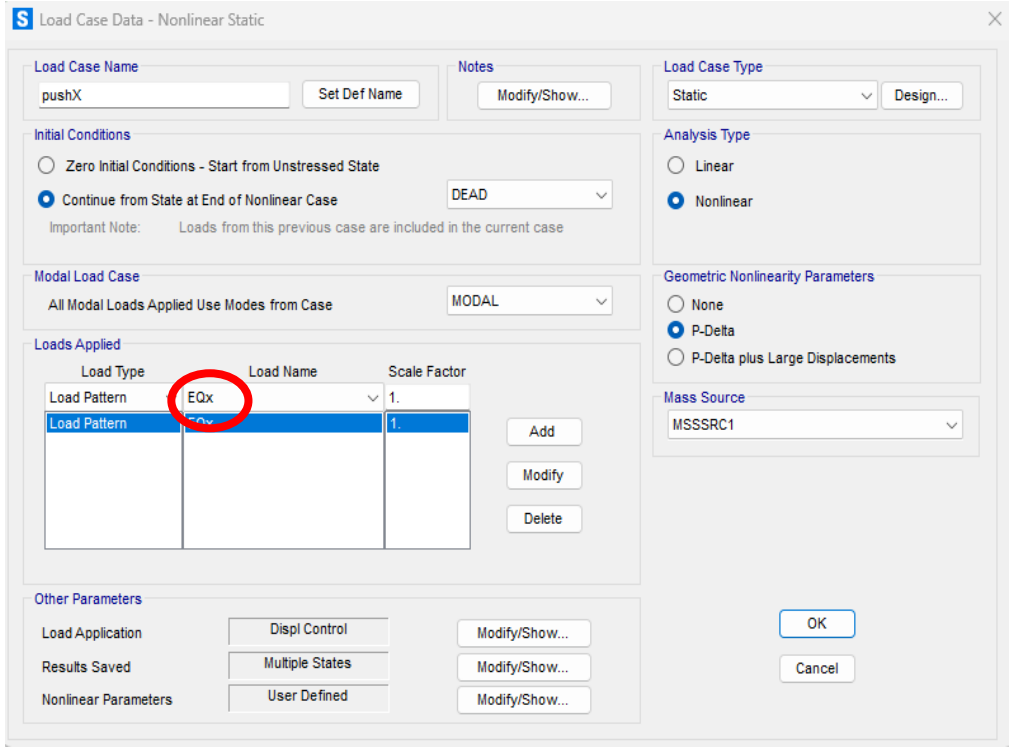
EQx load



Earthquake load case (Eqx)



Pushover load case

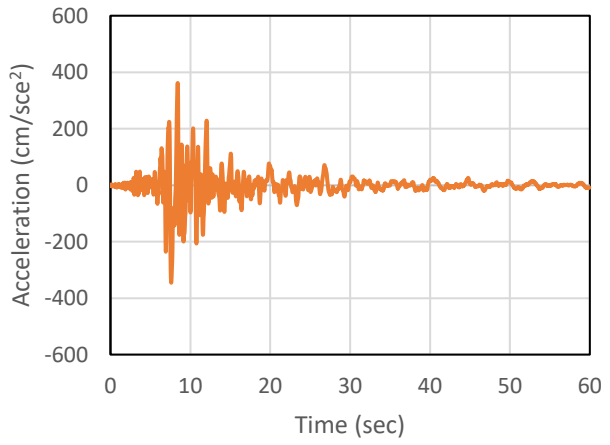


Load Cases for Pushover analysis Y direction is defined in a similar manner

Numerical Modelling of an existing RC building

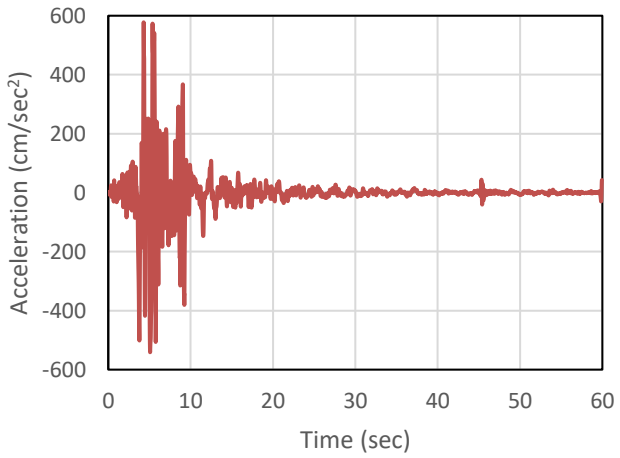
Details of Incremental Dynamic Analysis in SAP2000

Ground motions used for the IDA



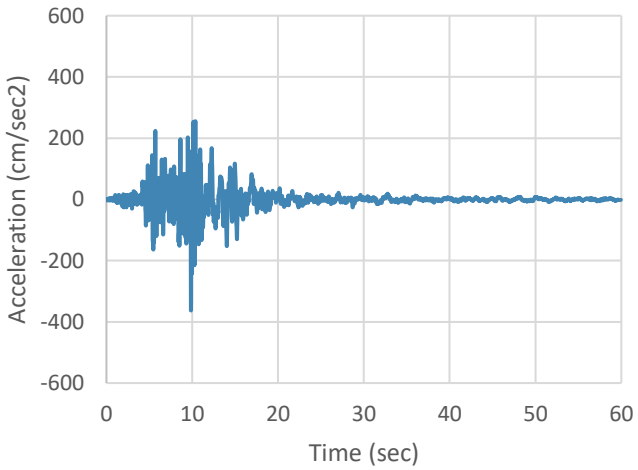
Hollister Earthquake

PGA = 361.787 cm/sec^2
= 0.3688 g



Newhall Earthquake

PGA = 575.1675 cm/sec^2
= 0.5863 g



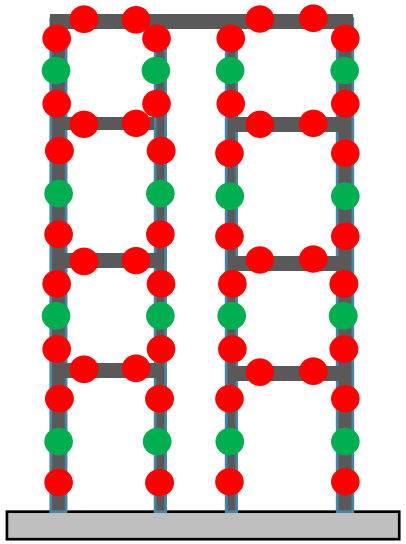
Santa Monica Earthquake

PGA = 362.127 cm/sec^2
= 0.3691 g

Newhall has the highest PGA among three earthquake

Numerical Modelling of an existing RC building

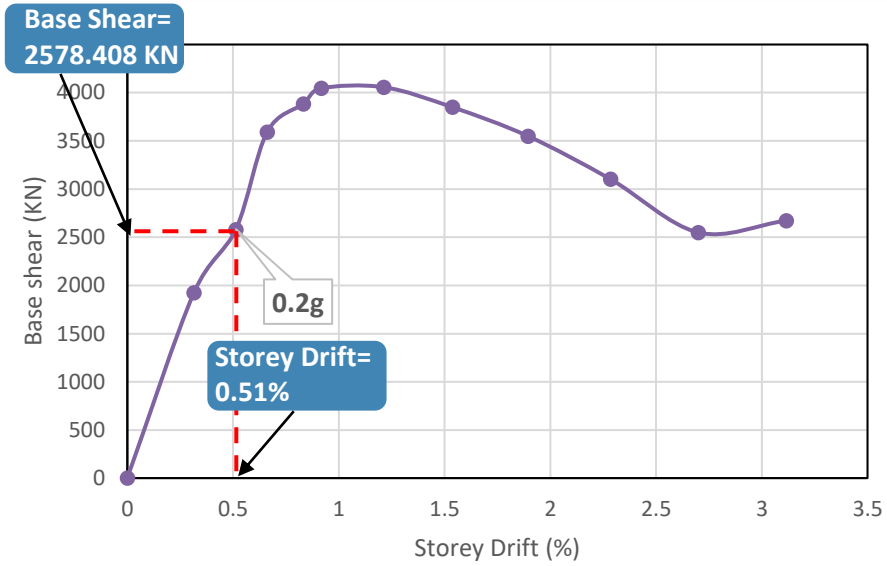
Scale Factor

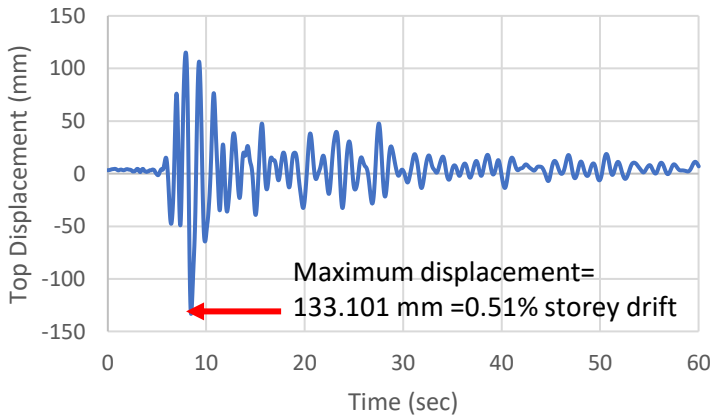


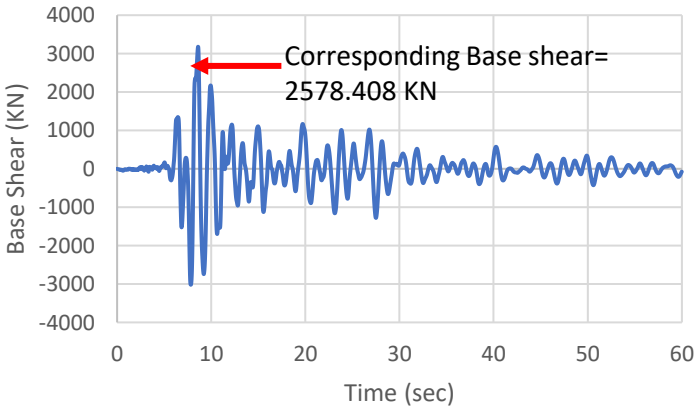
PGA = 0.2g

Scale Factor for Hollister Earthquake

	Peak Acceleration	Scale Factor $(\frac{\text{Required Peak}}{\text{Peak Ground Acceleration}})$
Original Time History	0.3688g	1
Scaled Time History	0.1g	0.271
	0.2g	0.542
	0.3g	0.813
	0.4g	1.085
	0.5g	1.356
	0.6g	1.627
	0.7g	1.898
	0.8g	2.169
	0.9g	2.44
	1.0g	2.711



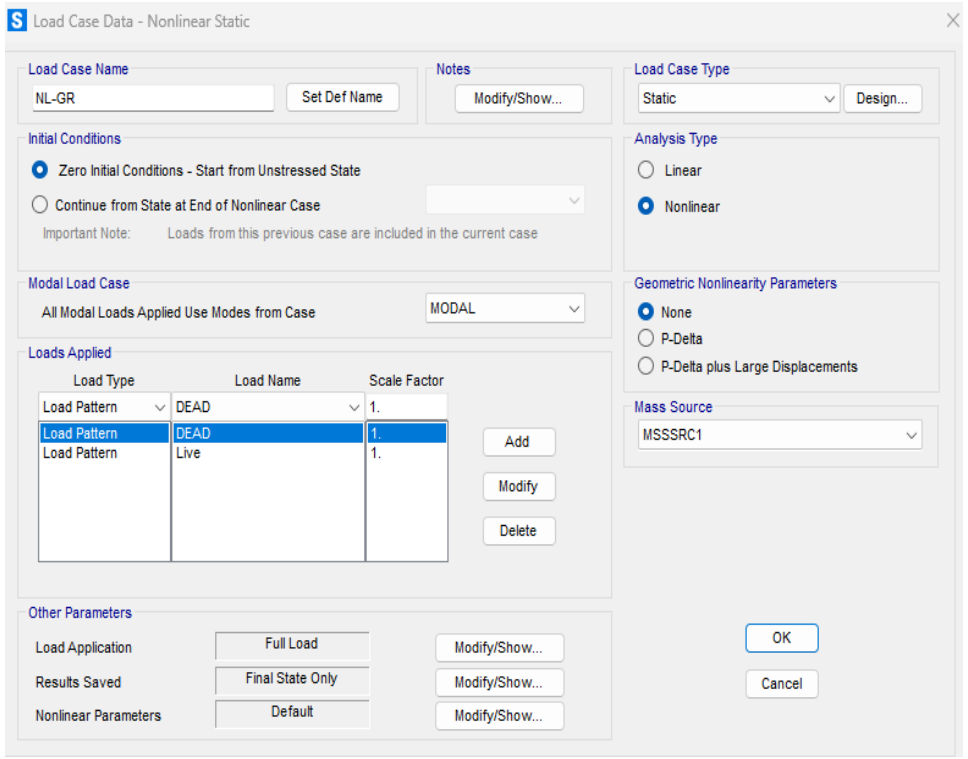




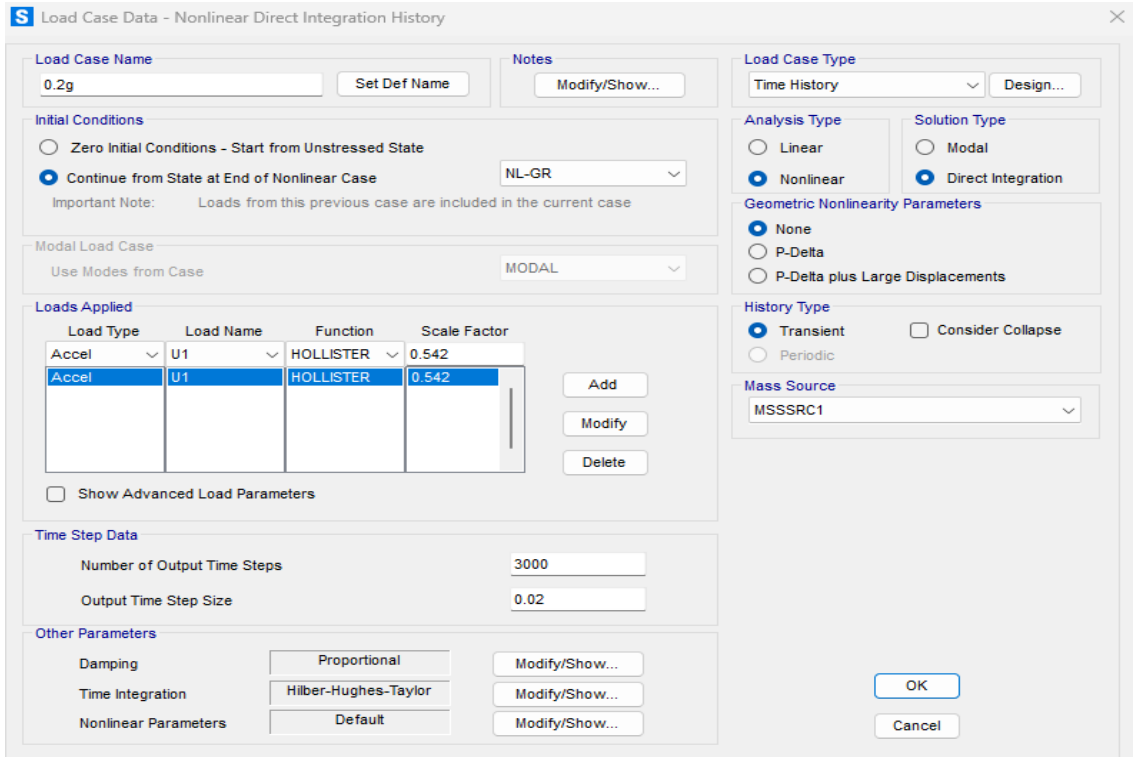
Numerical Modelling of an existing RC building

Load Cases for IDA

Non-linear gravity load cases



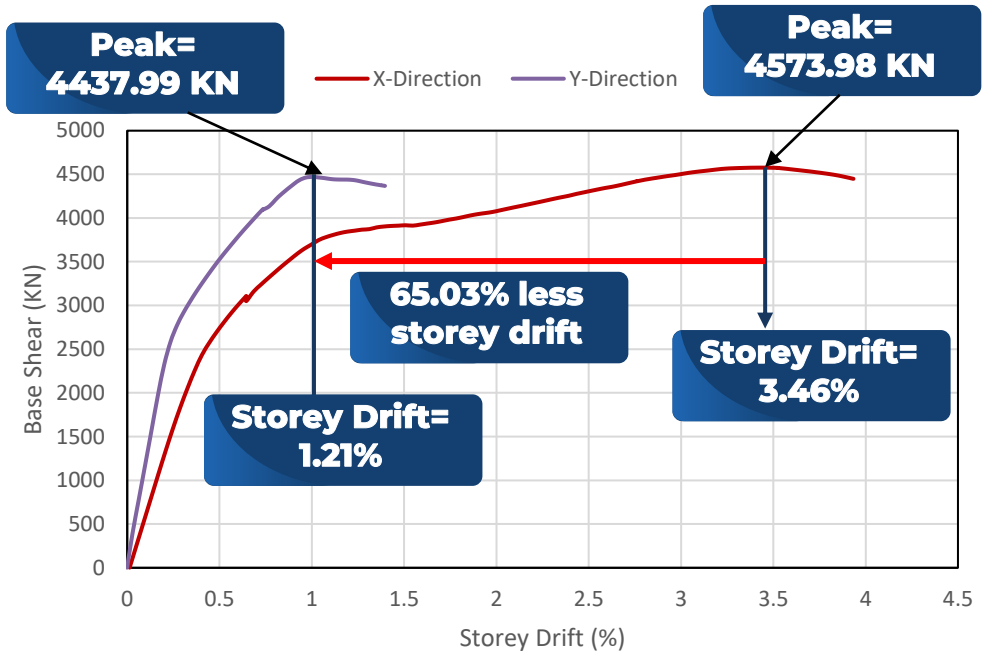
Non-linear Time history load case for a specific scaled ground motion



Results & Analysis

Results & Analysis

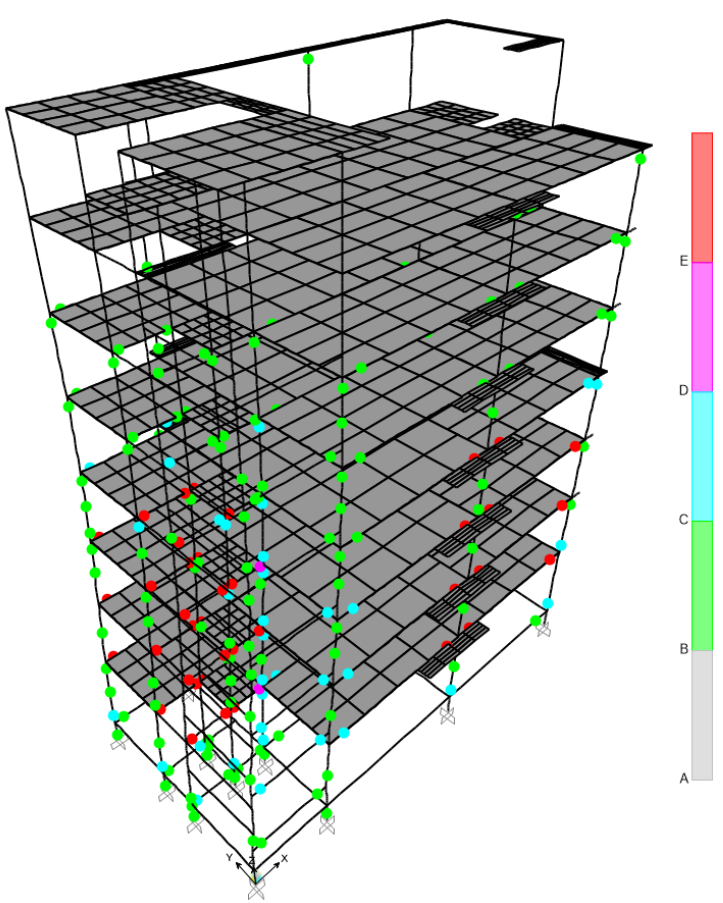
Pushover Analysis



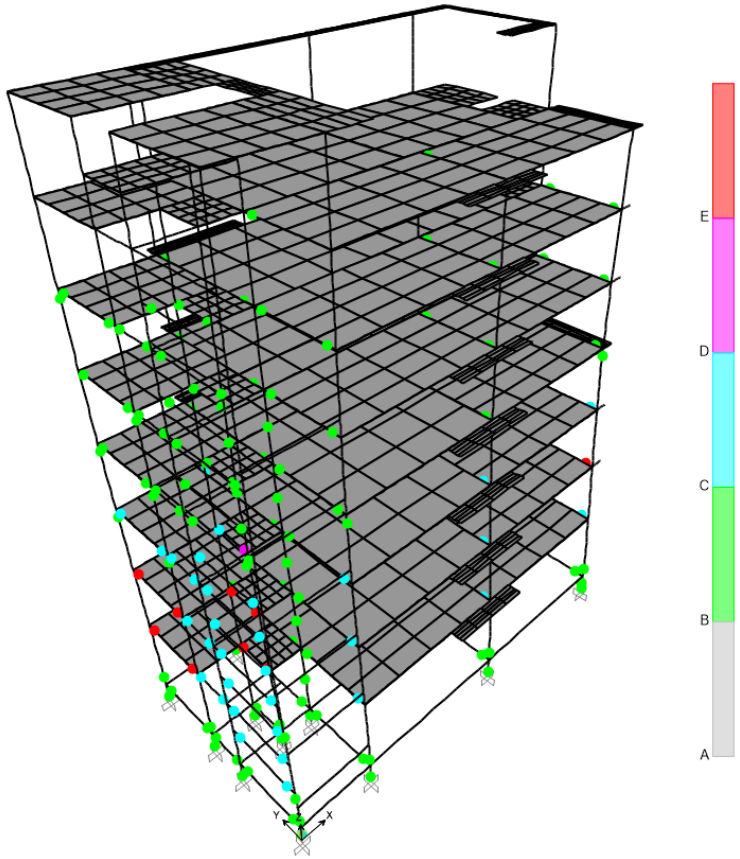
Nearly Same Lateral Capacity

More ductile behavior X-direction

More damage in X-direction as more deformation occurs



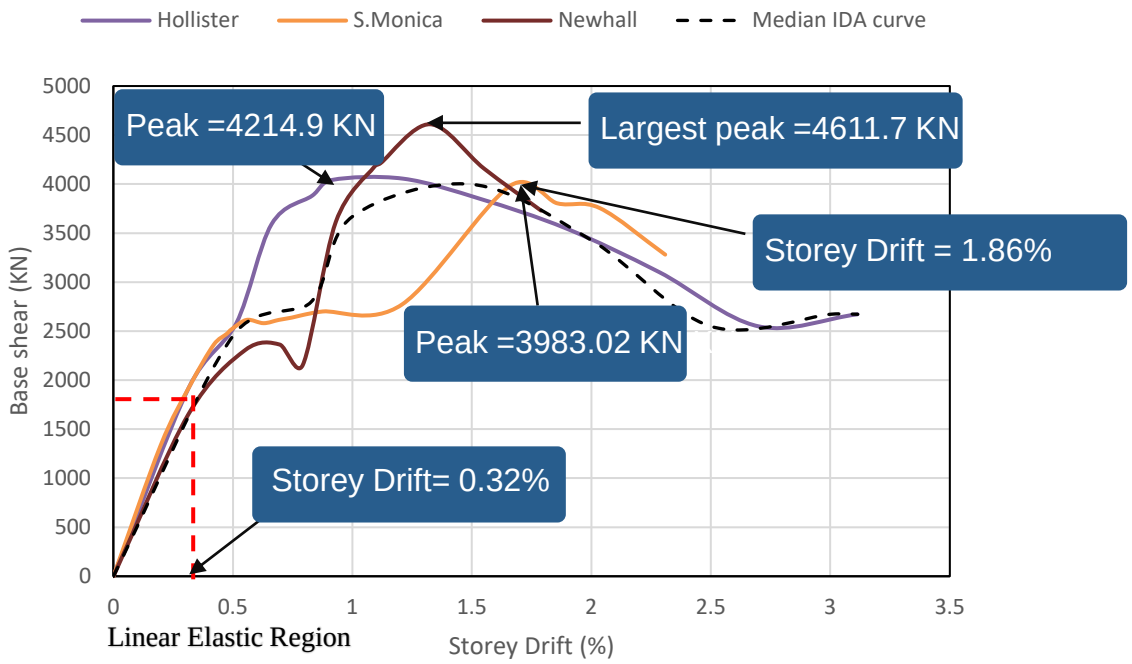
Pushover Analysis (X-direction)



Pushover Analysis (Y-direction)

Results & Analysis

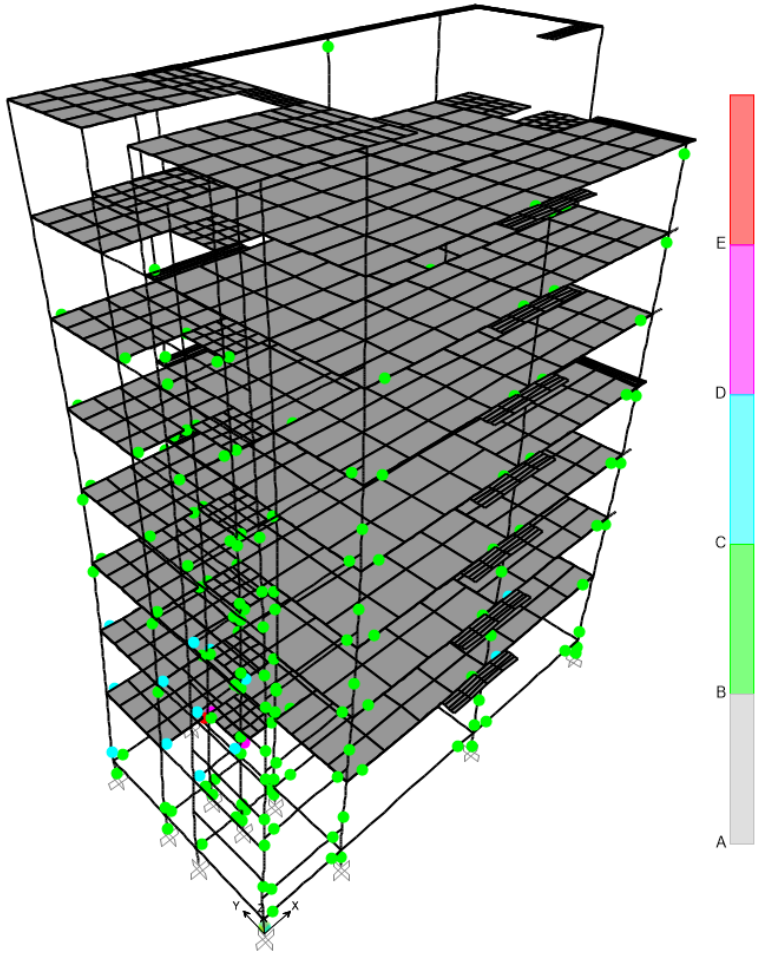
Incremental Dynamic Analysis



Same Linear Elastic Region till 0.32% storey drift

Newhall Earthquake have 9.41% and 15.78% more lateral capacity than Hollister and Santa Monica Earthquake

Santa Monica Earthquake resist 53.72% and 39.85% more storey drift than Hollister and Newhall Earthquake before dropping it's capacity



Damage states of Hollister Earthquake

Results & Analysis

Comparison of capacity curve between Pushover and Incremental Dynamic Analysis

Initial Stiffness

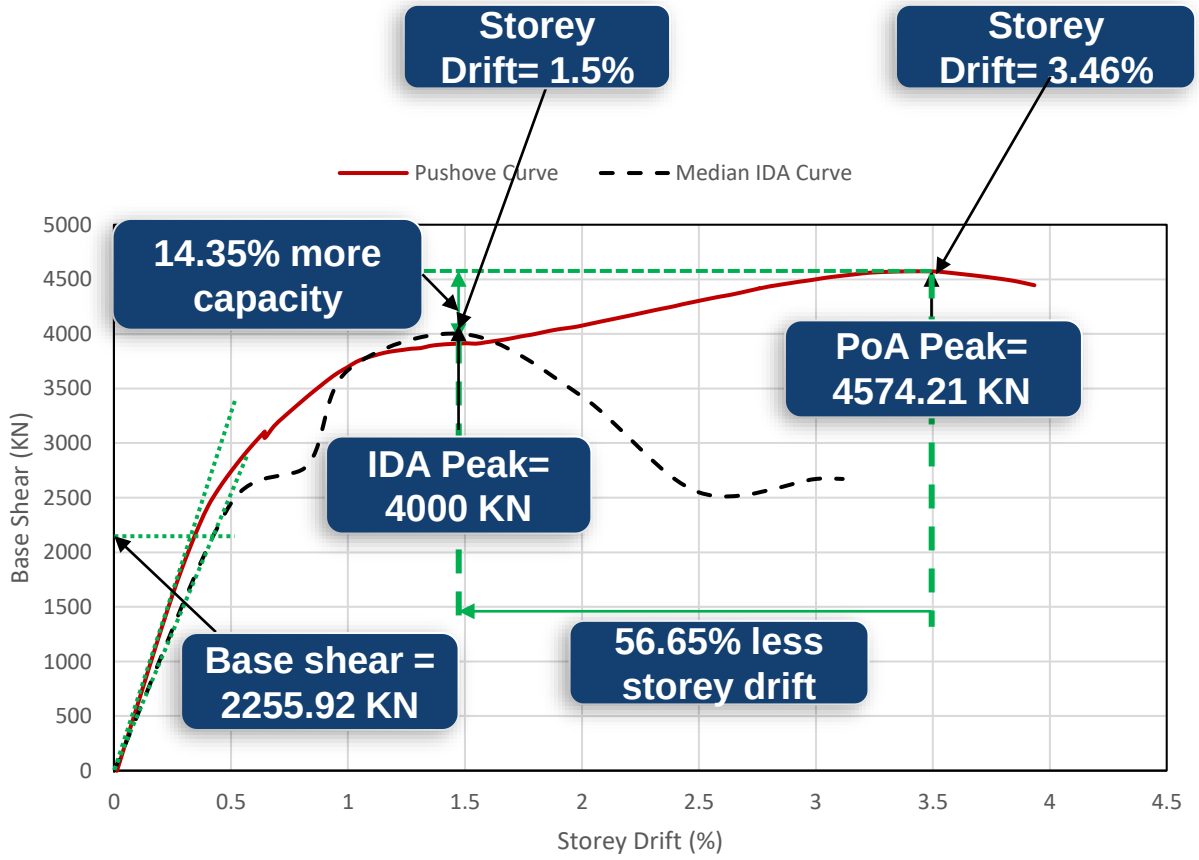
The building shows almost similar elastic properties under pushover and IDA

Maximum Resistance

The building shows more resistance under static loading

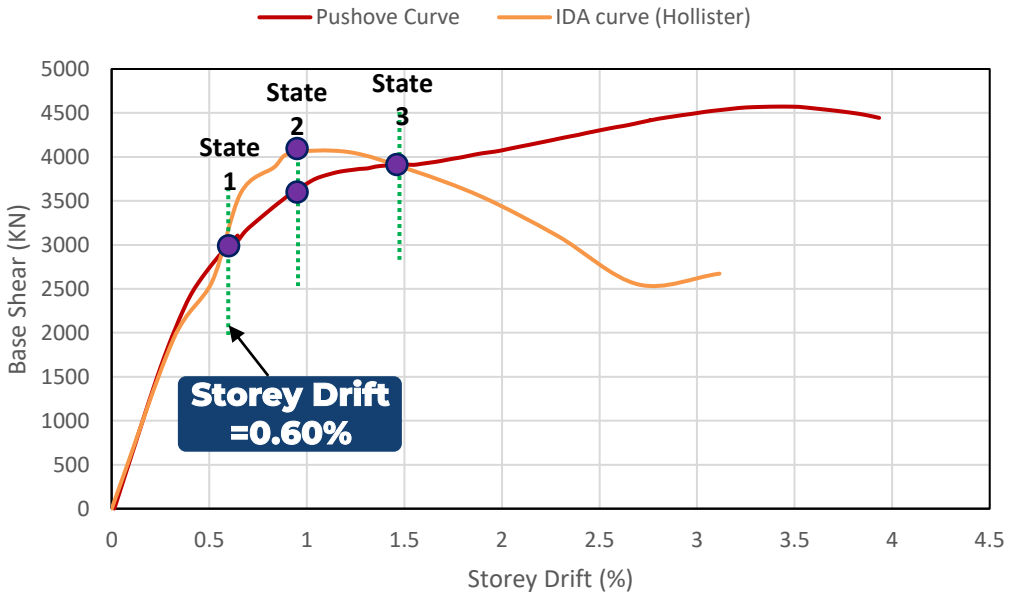
Ductility

Pushover curve shows more ductile behavior

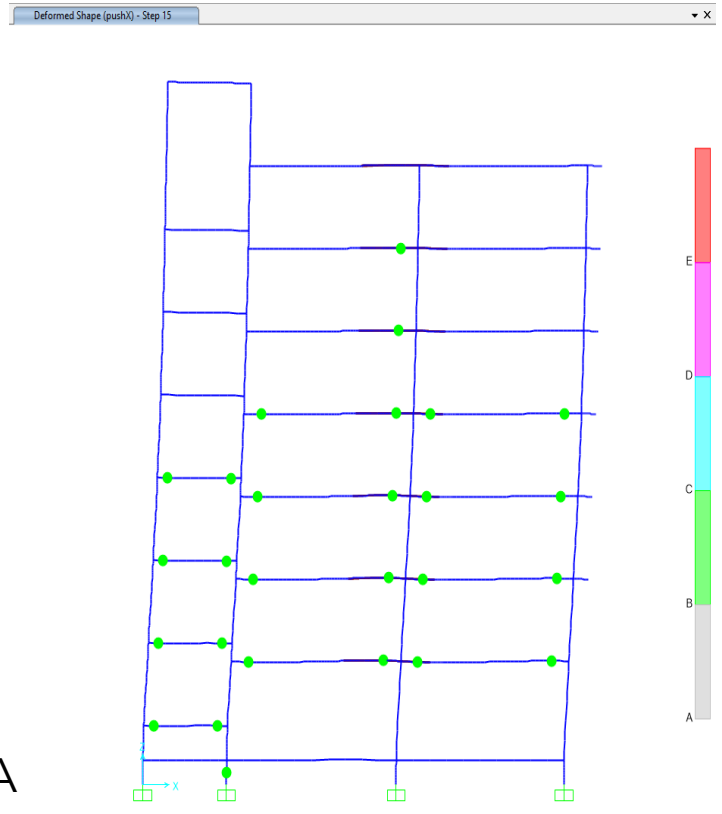


Results & Analysis

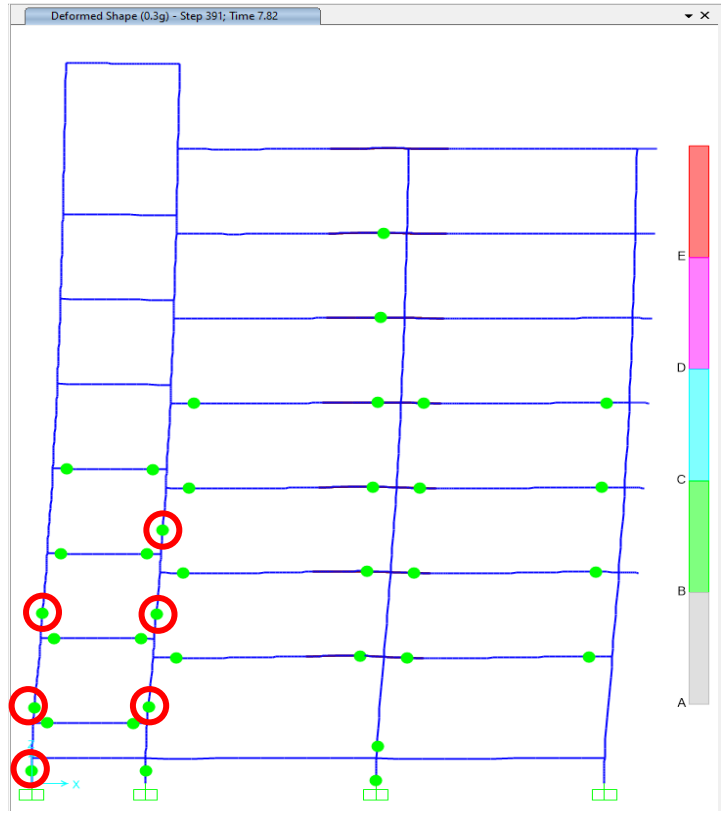
Comparison of damage states between Pushover and Incremental Dynamic Analysis



Hinge formation of **State 1**



Pushover Analysis



Incremental Dynamic Analysis (Hollister Earthquake)

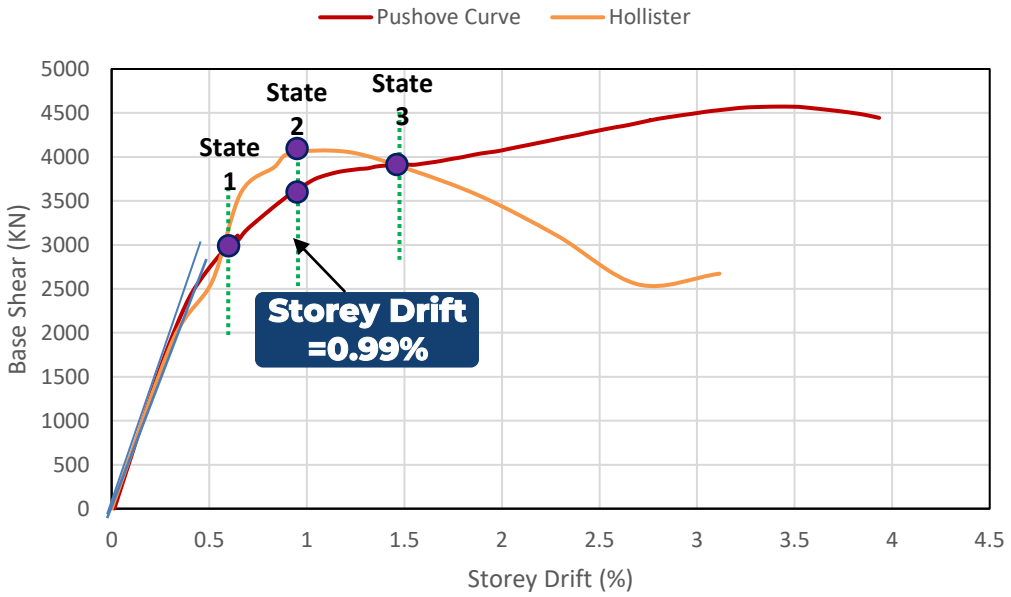
O =Additional hinges formed during IDA

O =More damaged hinge during IDA

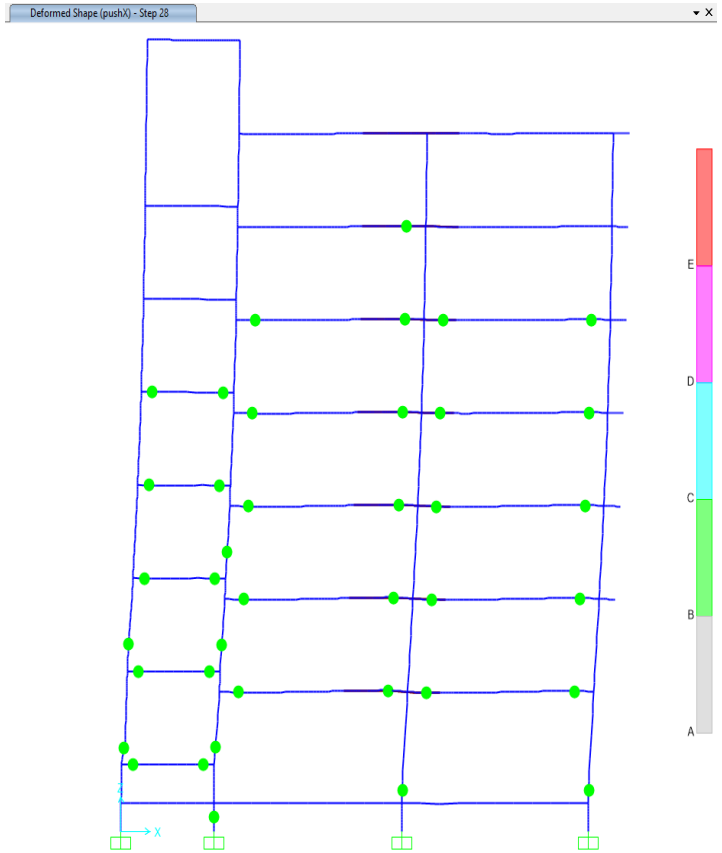
More hinge formation is observed at state 1 between pushover analysis & IDA

Results & Analysis

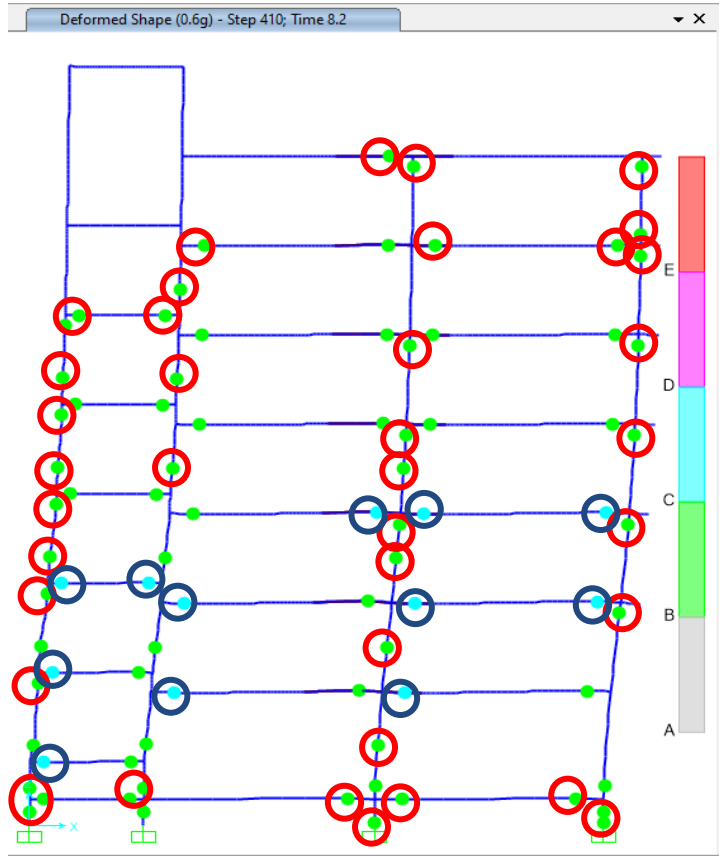
Comparison of damage states between Pushover and Incremental Dynamic Analysis



Hinge formation of **State 2**



Pushover Analysis



Incremental Dynamic Analysis

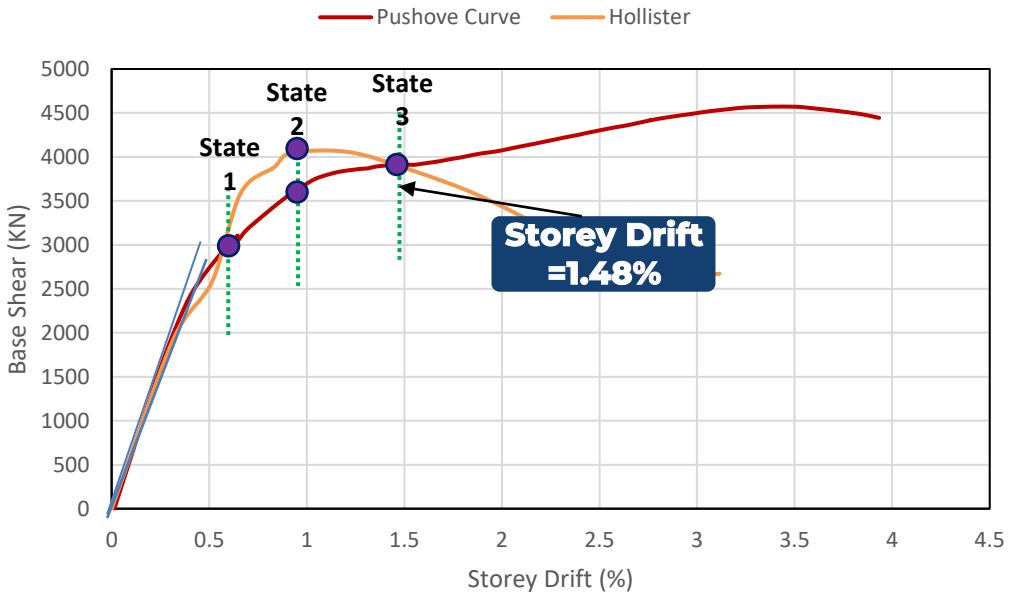
=Additional hinges formed during IDA

=More damaged hinge during IDA

More hinge formation is observed with increase of storey drift in IDA than pushover analysis

Results & Analysis

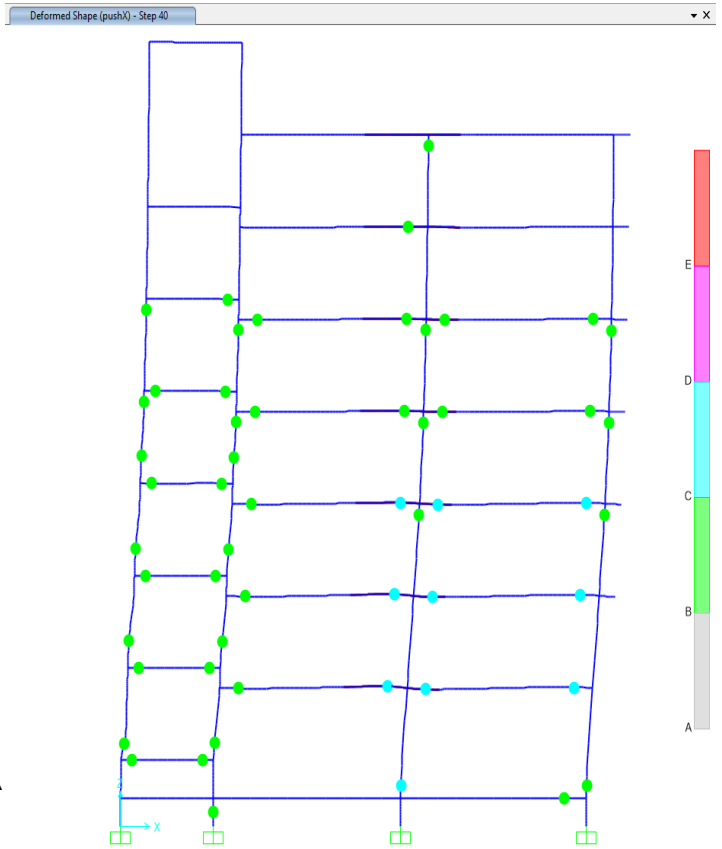
Comparison of damage states between Pushover and Incremental Dynamic Analysis



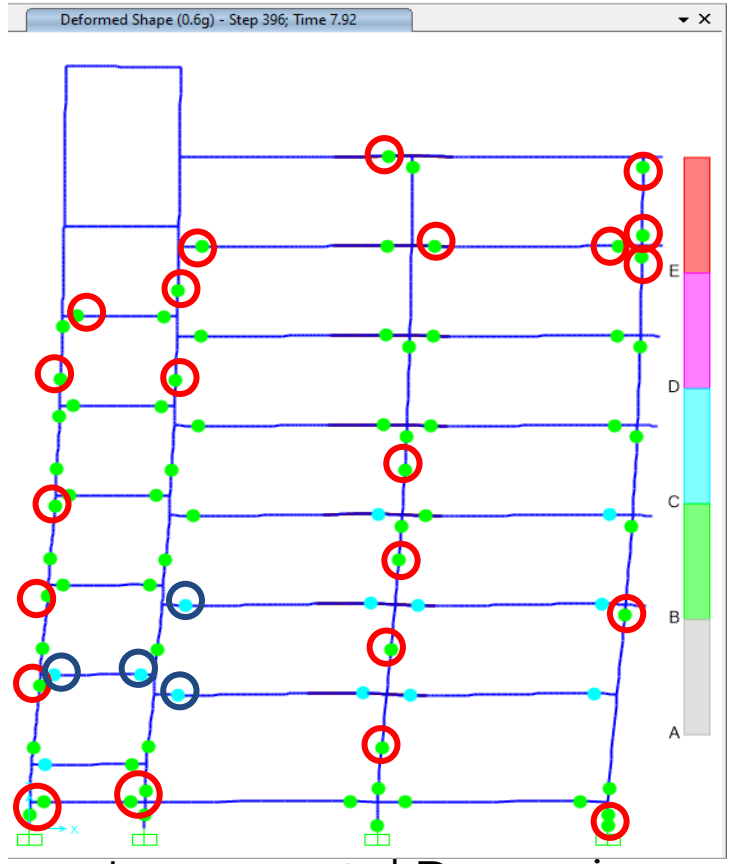
=Additional hinges formed during IDA

=More damaged hinge during IDA

Hinge formation of **State 3**



Pushover Analysis

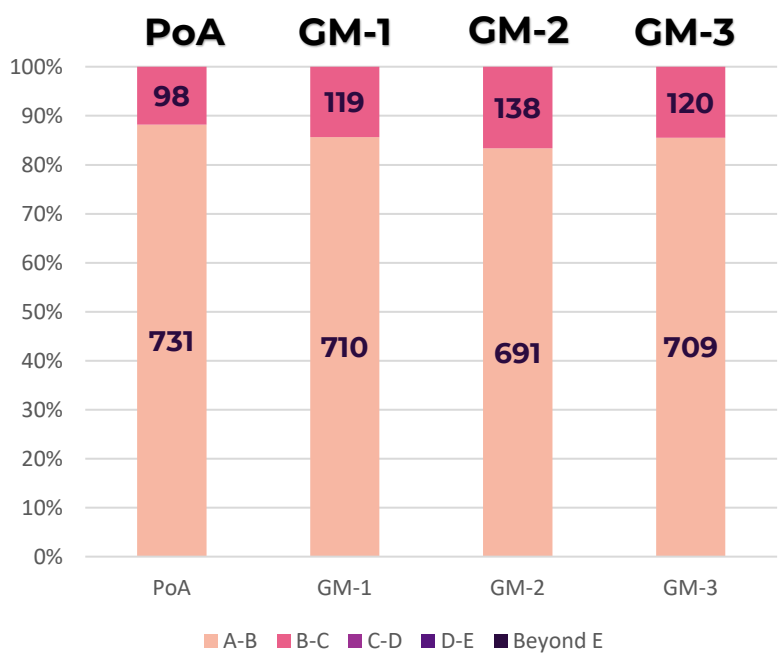


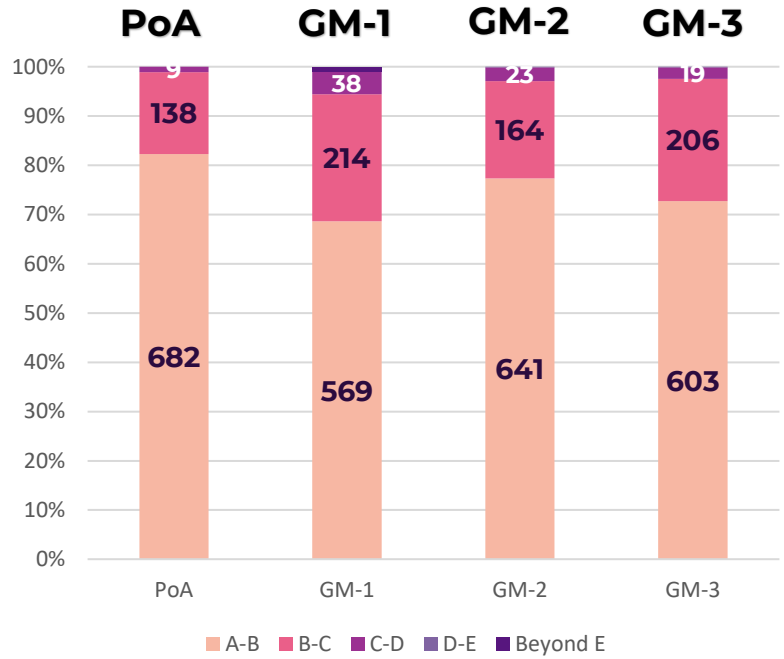
Incremental Dynamic Analysis

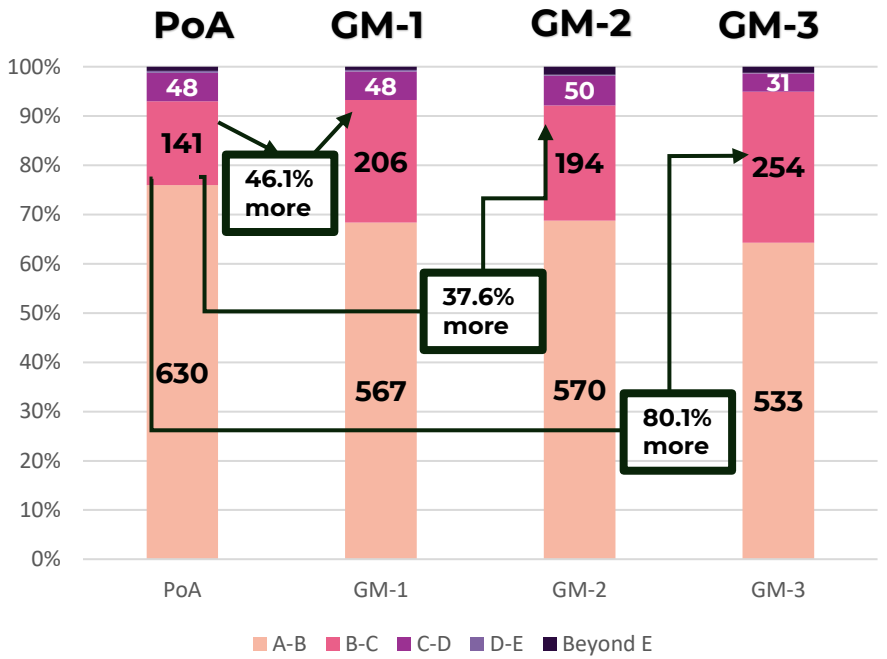
More hinge formation is observed with increase of storey drift in IDA than pushover analysis

Results & Analysis

Comparison of damage states between Pushover and Incremental Dynamic Analysis



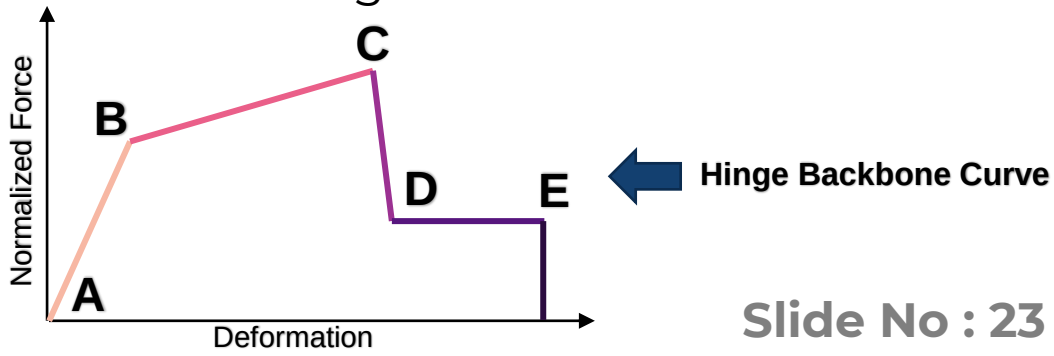




Hinge formation of **State 1**

Hinge formation of **State 2**

Hinge formation of **State 3**



At near peak state, IDA shows 54.6% more damages at B-C from Pushover analysis

Conclusions

1

Numerical Model Generation in SAP2000

A numerical model of an existing building has been developed in SAP2000 to perform Pushover and Incremental Dynamic Analysis

Both Capacity curves are similar considering initial stiffness however varies in ductility and strength

2

- Strength: PoA shows 14.35% larger than IDA
- Ductility: IDA shows 56.65% less than PoA

Damages are concentrated more in case incremental dynamic analysis

At near peak state, IDA shows 54.6% more damages at B-C from Pushover analysis

3

THANK YOU

Question and Answer Session