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Evaluation of RC Framed Building for Linear and Nonlinear Analysis by using Shear and Flexural Failure Model

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***Abstract*—Conventional method is to analyse the building by linear analysis method. In this method the analysis is done for the elastic zone only and ignoring the strength in inelastic zone. So to predict the behaviour of building in inelastic zone, nonlinear analysis method is used. In nonlinear analysis method, the moment rotation capacity of the building is taken into consideration. Further it accounts the behaviour of the building after cracks takes place. It is possible to build the building with desired performance level. In present project, a comparative study of the building with linear analysis and nonlinear analysis method is done for 5, 10, 15 and 20 storey with all other parameters constants. Nonlinear analysis is carried out first by considering flexural and shears hinges and then by considering only flexural hinges. This study is limited to static nonlinear analysis only.**

From the analysis, pushover curve i.e. base shear Vs. floor displacement curve is obtained. This study also describes the performance of the building for different performance points like intermediate occupancy (IO), life safety (LS) and collapse prevention (CP).

***Keywords*— Nonlinear analysis, Pushover curve, shear and flexural hinges, performance points.**

I. INTRODUCTION

Traditional method is to analyse the building by linear analysis either static or by dynamic. It is force based method. It does not give the actual response of the behaviour of the building. To predict the actual response, nonlinear analysis is must. Nonlinear analysis is displacement based method. It can predict the performance of the building under varying earthquake forces. Nonlinear analysis is of two types: a) Static Nonlinear analysis also known as Pushover analysis b) Dynamic Nonlinear analysis. For low rise building Pushover analysis gives the satisfactory results whereas for high-rise building dynamic nonlinear analysis is adopted.

In general one must design the building for flexural failure (ductile mode of failure). But sometimes due to excessive shear force or inadequate design shear failure antedates the flexural failure. So both types of failure must consider while analysing the building.

The performance of the building is described in terms of performance points. Fig.1 describes the performance points. Those performance points are intermediate occupancy (IO), life safety (LS) and collapse prevention (CP). So the building with load below IO will be functional and ready to occupy immediately, the load below LS will assure the safety of the life but need some repair to serve the function whereas the load below CP will not guarantee the safety of the life but total collapse of the building will not take place. The load exceeding the CP may cause total collapse of the structure.

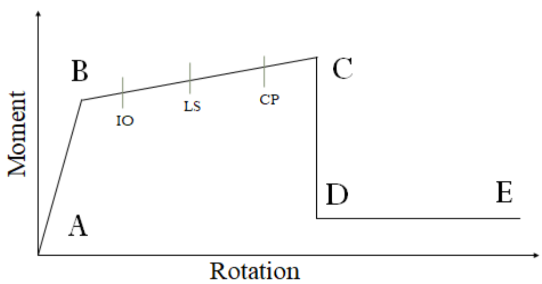

Figure 1: Moment Vs. Rotation relationship

II. AIM AND OBJECTIVE

Objectives of the present study are as follows:

- To model and analyse the building using linear analysis method and nonlinear analysis method.
- In nonlinear analysis method, models of the building are analyse for tow cases:
  - By considering formation of shear and flexural hinges
  - By considering formation of only flexural hinges.
- .Modelling all the building by variation in their heights.
- Obtaining base shear Vs. deformation curve i.e. capacity curve and hinge formation for performance points.

III. METHODOLOGY

In this study, nonlinear analysis of the building with Flexural & Shear hinge and only flexural hinges formation are compared with linear analysis to obtain capacity curve.

Steps adopted are as follows:

Step 1: Selection of the site conditions according to location of building.

Step 2: Selection of building geometry as required and modelling the building for 5, 10, 15 and 20 storeys.

Step 3: Gravity loads consist of dead load, live load, floor finish and wall load for both types of building must be applied.

Step 4: Lateral load for linear analysis are earthquake and wind load whereas for nonlinear analysis pushover loads must be applied.

Step 5: Analyse and designing the model for linear analysis and nonlinear analysis by considering shear and flexural hinges and later by considering only flexural hinges.

Step 6: Obtaining the results in terms of pushover curve and performance points.

IV. MODELLING DATA

Material properties are assigned as per Indian standards. It includes unit weight, modulus of elasticity, etc. They are as follows:

- Concrete grade = M25
- Longitudinal reinforcement = Fe 500
- Transverse reinforcement = Fe 415
- Modulus of elasticity (E) = 5000* (25)^0.5 = 25000 N/mm^2

Table 1: Modelling Data

Plan dimension	20 X 12 m
Length of each storey in X direction	4 m
Length of each storey in Y direction	4 m
Height of each storey	3 m
Thickness of slab	150 mm
Thickness of wall	230 mm
Base location	2 m below ground level
Base joints	Fixed support
Beam size and cover	230 X 500 mm^2 with 40 mm cover
Column size and cover	400 X 600 mm^2 with 40 mm cover
Number of storey considered	5, 10, 15 and 20.
Type of Analysis considered	Linear analysis Nonlinear analysis with only flexural hinges Nonlinear analysis with shear and flexural hinges.
Diaphragm	Rigid
Material Damping	0.05
Codes used	IS 456-2000 IS 1893-2016 IS 875-2015 ASCE 41-13, FEMA-356

Table 2: Loads considered

Dead Load • Concrete (self-weight) • Wall • Reinforcement	 Considering 25 KN/m^3 Considering 20 KN/m^3 Considering 7850kg/m^3
Live load	2 KN/m^2
Floor finish	1.5 KN/m^2
Seismic Load	As per IS 1893-2016.
Wind Load	As per IS 875-2015
Mass source	Dead load, Wall Load, Floor Finish and 0.25 times Live Load

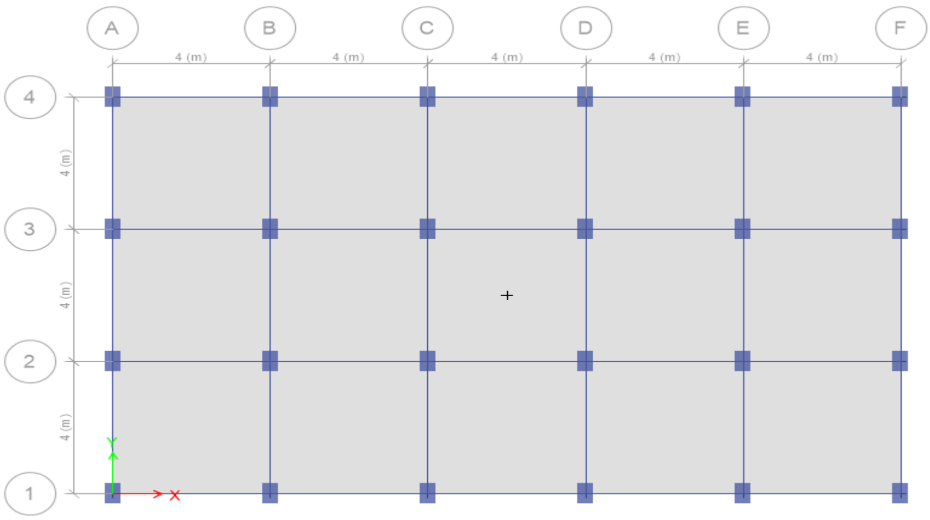

Figure 2: Floor plan

Table 3: Seismic and Wind Parameters

Seismic zone	3
Seismic zone factor	0.16
Site type	2
Importance factor	1
Response reduction factor	5
Wind Speed	44 m/s
Terrain Category	3
Risk Coefficient	1
Topography factor	1

Table 4: Pushover analysis Parameters

Load case type	Nonlinear static
Load applied X axis Y axis	 Acceleration in UX direction with scale factor -1 Acceleration in UY direction with scale factor -1
Load application	Displacement control (400 mm magnitude)
Results obtained	Multiple states

V. RESULTS

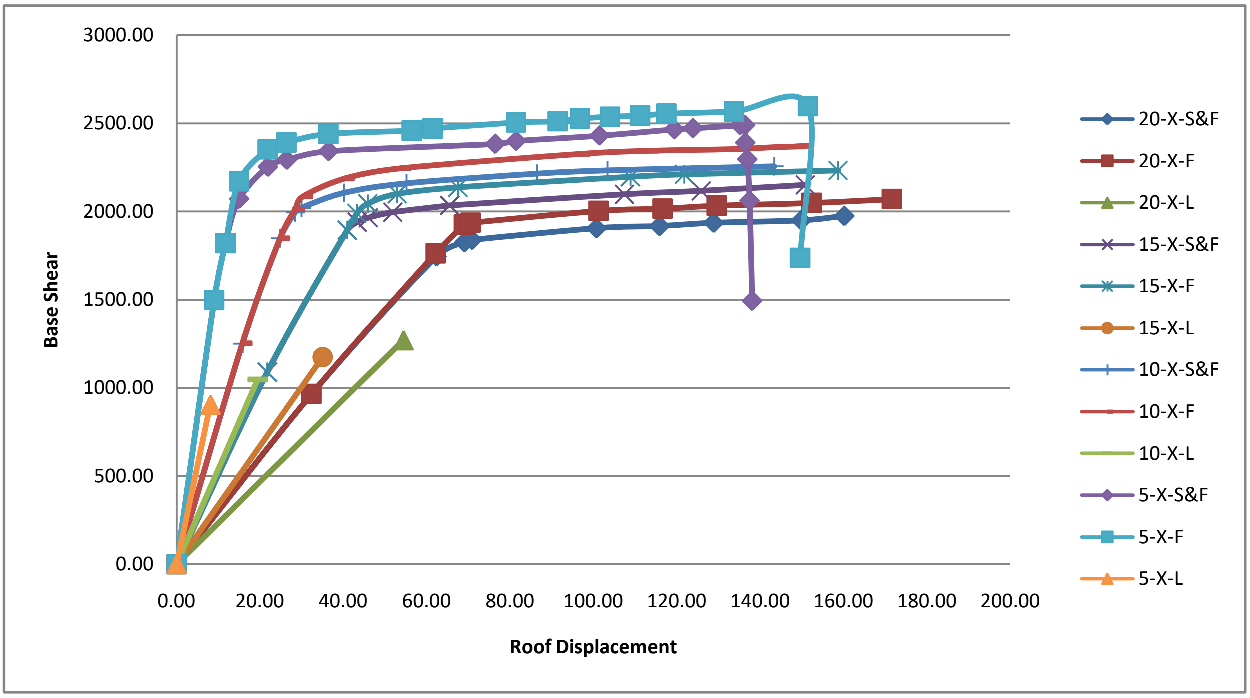

Figure 3: Base shear Vs. Roof displacement curve (X axis)

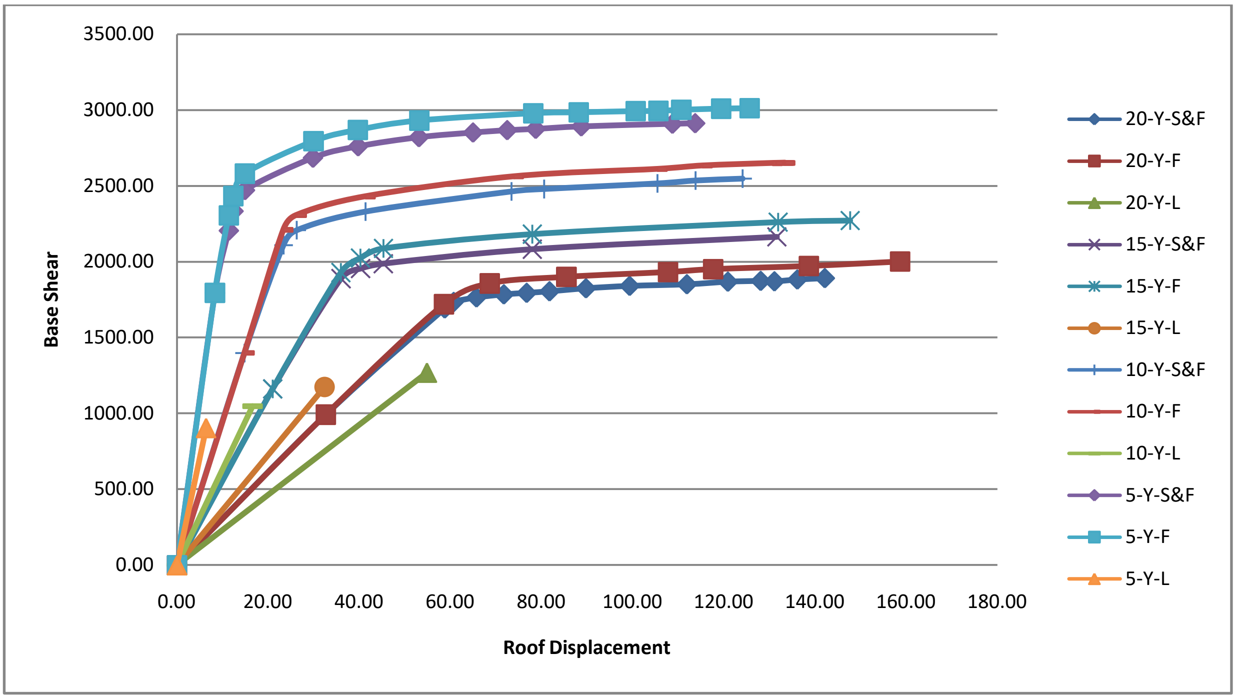

Figure 4: Base Shear Vs. Roof Displacement curve (Y axis)

Table 5: Performance of the building

Sr. No.	Storey	A-IO		IO-LS		LS-CP		> CP	
		Displace-ment	Base shear	Displace-ment	Base shear	Displace-ment	Base shear	Displace-ment	Base shear
1	20(X)-S&F	62.33	1743.96	115.87	1916.56	160.23	1973.76	> 160.23	> 1973.76
	20(X)- F	68.90	1923.93	116.53	2015.51	171.52	2069.15	> 171.52	> 2069.15
	20(Y)-S&F	60.71	1733.77	99.33	1839.91	142.16	1890.84	> 142.16	> 1890.84
	20(Y)- F	68.62	1856.28	107.74	1931.31	158.69	2000.84	> 158.69	> 2000.84
2	15(X)-S&F	40.94	1894.11	107.45	2097.36	150.82	2150.60	> 150.82	> 2150.60
	15(X)- F	43.24	1988.46	108.85	2195.56	158.63	2231.42	> 158.63	> 2231.42
	15(Y)-S&F	35.99	1888.22	77.94	2081.68	131.62	2162.85	> 131.62	> 2162.85
	15(Y)- F	40.23	2023.53	77.94	2180.98	147.68	2270.42	> 147.68	> 2270.42
3	10(X)-S&F	29.91	2020.00	103.37	2232.23	143.37	2255.33	> 143.37	> 2255.33
	10(X)- F	30.28	2083.68	113.37	2342.87	150.37	2371.15	> 150.37	> 2371.15
	10(Y)-S&F	23.36	2110.54	73.41	2463.79	124.09	2548.32	> 124.09	> 2548.32
	10(Y)- F	26.25	2308.24	73.89	2562.30	133.41	2652.26	> 133.41	> 2652.26
4	5(X)-S&F	14.98	2070.36	81.44	2398.96	137.47	2060.20	> 137.47	> 2060.20
	5(X)- F	21.83	2351.36	91.40	2511.12	151.46	2596.12	> 151.46	> 2596.12
	5(Y)-S&F	12.39	2332.78	53.08	2819.77	113.70	2911.74	> 113.70	> 2911.74
	5(Y)- F	14.89	2580.33	53.18	2903.13	125.68	3010.88	> 125.68	> 3010.88

VI. CONCLUSIONS

- Nonlinear analysis gives the capacity curve in various steps. So it is possible to determine the performance of the building under varying loads.
- Linear analysis overestimates the roof displacement by 24.6%, 30.12%, 30.9% and 19.6% for 5, 10, 15 and 20 storey than actual displacement which can be accurately predicted by nonlinear analysis for the same amount of base shear. Hence the building with linear analysis is bulky and so is uneconomical.
- Nonlinear analysis by considering Shear and Flexural hinges gives more realistic results than only Flexural hinges because of considering the effect of the shear hinges. In shear and flexural hinge formation model 1240, 2480, 3722 and 4960 hinges are formed for 5, 10, 15 and 20 storey whereas in flexural hinge formation model 1000, 2000, 3000 and 4000 hinges are formed.
- Nonlinear analysis considering only flexural hinges overestimates the base shear by 3.13%, 3.6%, 4.5% and 4.9% more for 5, 10, 15 and 20 storeys after yielding at collapse point.

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