Non Linear Static Analysis of Multi-storeyed Special Moment Resisting Frames

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Abstract

Nowadays performance based engineering design philosophies are gaining more attention. This study investigates the performance assessment of multi-storeyed moment resisting frames. Push over analysis was used to understand the behaviour of the structures in zone V during an earthquake. Effect of increase in the number of bays and number of stories on seismic performance was studied. Study was carried out for storey heights 3, 3.5 and 4m. 27 building models were created and analysed using ETABS 9.7 software. Parameters like displacement, base shear and time period of these models were chosen for comparison. It was observed that as the number of storey and storey height increased base shear and spectral acceleration is reduced, where as displacement, time period and spectral displacement increased. When number of bays increased base shear and time period increased and spectral acceleration decreased .Analysis shows the location of plastic hinges at performance point of the structures, overall performance of most of the building models lied between the life safety and collapse prevention level.

Keywords— *Pushover Analysis; Base Shear; Spectral Accelerations; Performance Assessment*

I. INTRODUCTION

The sudden release of energy in the earth's crust creates seismic waves which arrive at various instance of time with different intensity levels are called as earthquake. It causes the random ground motion in all directions, radiating from epicenter, which causes structure to vibrate due to which induce inertia forces in them. Many existing structures are seismically deficient due to lack of awareness regarding seismic behavior of structures. Due to this, there is urgent need to reverse this situation and do the seismic evaluation of existing and new structures [1].

Reinforced concrete special moment frames are used as part of seismic force-resisting systems in buildings that are designed to resist earthquakes. When concrete moment frames are selected for buildings assigned to Seismic Design Categories III, IV or V, they are required to be detailed as special reinforced concrete moment frames. Special moment frames may be used in Seismic Design Categories I and II though this may not lead to the most economical design. Both strength and stiffness need to be considered in the design of special moment frames Pushover analysis is an incremental static analysis used to determine the force-displacement relationship, or the capacity curve, for a structural element. Local nonlinear effects are modelled and the structure is pushed until a collapse mechanism is developed in the same building. With increase in the magnitude of loads, weak links and failure modes of the building are observed. At each step, the structure is pushed until enough hinges form to develop a curve between base shear and the corresponding roof displacement of the building and this curve commonly known as pushover curve. This push over curve can be transformed into the capacity spectrum using the structure's originally elastic dynamic properties. Capacity Spectrum method requires that both the capacity curve and the demand curve be represented in response spectral ordinates.The point at which the capacity curve intersects the reduced response curve represents the performance point, at which capacity and demand are equal. Using this method, structures with predictable seismic performance can be produced. The three basic elements of this method are:-

Immediate occupancy (IO): Immediate occupancy level in which relatively little damage of the structure occurs.

Life safety (LS): Life safety level defined as a condition of severe damage, but a state in which margin remains against collapse

Collapse prevention (CP): Collapse prevention level, in which near complete damage of the structure occurs[2].

In the present study effect of increase in the number of bays and number of stories on seismic performance was studied. Study was carried out for storey heights 3, 3.5 and 4m.Non linear static analysis was carried out to understand the response of the building models. The results obtained from the analysis were compared in terms of seismic responses such as base shear, time period, displacement, spectral acceleration and spectral displacement along with the location of plastic hinges at the performance point of all the building structures considered respectively.

II. BUILDING CONFIGURATION

In this study a total of 27 building frames were selected by varying number of stories, number of bays and storey height. A detailed description of all the frames considered has shown in table below.

Table I : General Description and Parameter of the Structures

Beam size	230 mm x 450 mm
Column size	230 mm x 450 mm
Slab thickness	150 mm
Live load	3 KN/m^2
Floor finish	1 KN/m^2
Concrete grade	M25
Steel	Fe 415
Seismic zone	V
Importance factor	1
Response reduction factor	5
Type of soil	Medium soil
No of stories	5,9 and 11
No of bays	6,7

For convenient presentation of results a suitable naming convention has followed.5S6B-SH 3m represents a special moment resisting frame having 5 number of storey with 6 number of bays in both x and y direction with storey height 3m.

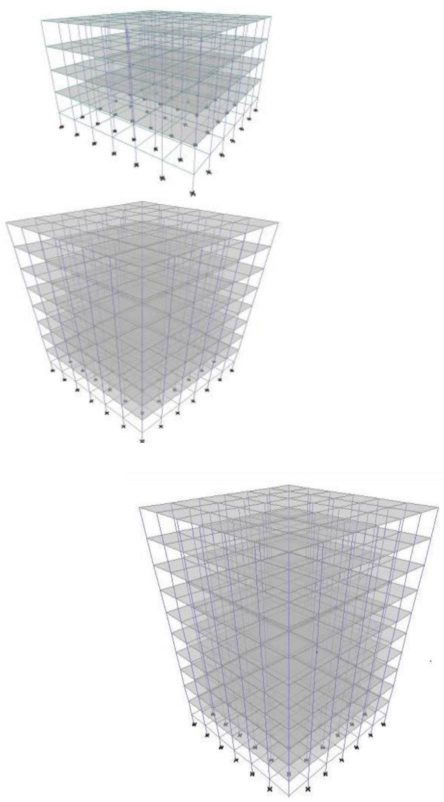


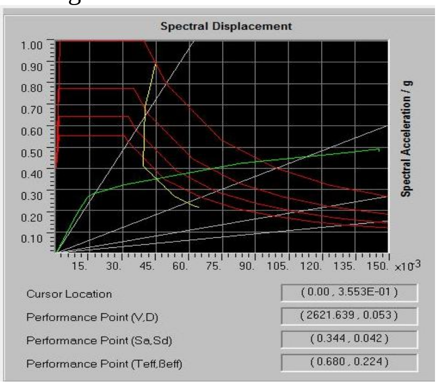
Fig 1. 5S6B , 9S6B and 11S6B Having Storey Height of 3m

III. PUSH OVER ANALYSIS PROCEDURE

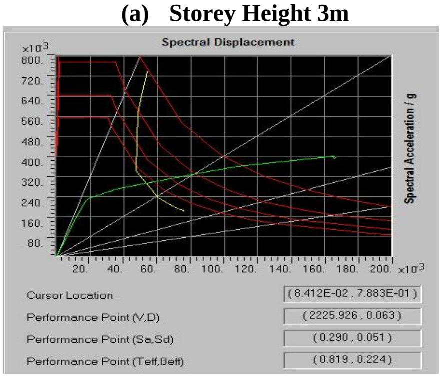
- The three dimensional models were created as per the building configurations using E Tab 9.7 software
- All the material properties, frame sections and load cases are defined and assigned.
- Select all the beams and columns and assign hinge properties as per FEMA -356 to the frame elements. For beams default hinge of flexure (M3) was assigned and for column default hinges of axial force and bending moment (P M2 M3) was assigned.
- Two static pushover cases are defined. Initially gravity load is applied to the structure and then lateral load along longitudinal direction is applied to the structure.
- The static nonlinear, push over analysis was performed to determine the pushover curve and performance point of the building.

IV. RESULTS AND DISCUSSION

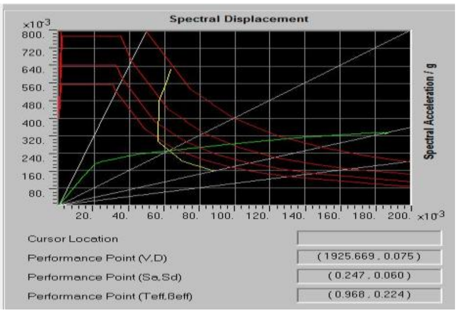
Following figures shows the comparison of performance points of 5S6B on different storey height 3, 3.5 and 4m. Performance point was obtained by intersecting capacity and demand spectrum, where demand curve is shown in yellow colour and capacity curve is shown in green colour. Performance point represents the global behaviour of the structures.



(a) Storey Height 3m



(b) Storey Height 3.5m



(c) Storey height 4m

Fig 2. Comparison of Performance Point

Comparing the above graphs, it was observed that performance point of a 5S6B with storey height 3m shows better performance than 3.5 and 4m.

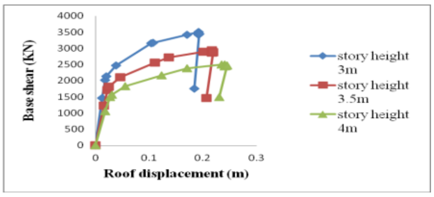


Fig 3. Push over curve

Figure 3 shows the base shear versus displacement graph of 5S6B with different storey heights. From the above graph it can be seen that with increasing the height of storey base shear decreases where as roof displacement increases.

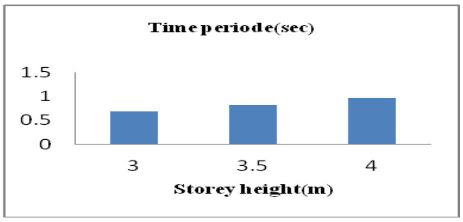
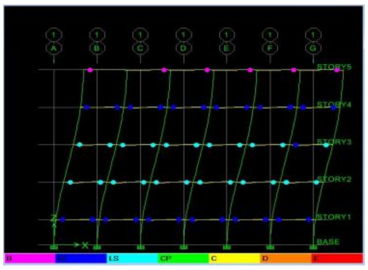
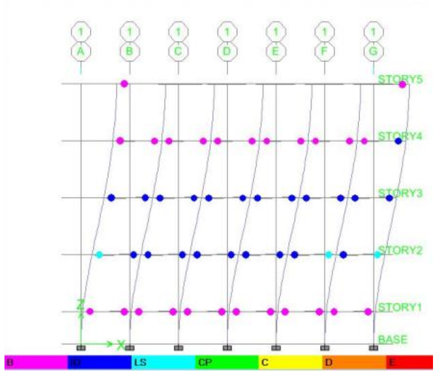


Fig 4. Time period versus storey height

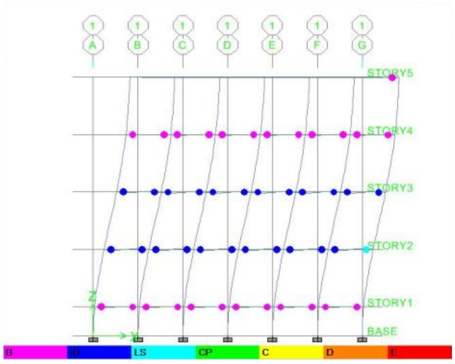
Figure 4 shows the time period versus roof displacement of 5S6B frame. From the above graph it shows that time period required for storey height of 4m is higher while comparing with 3m and 3.5m.



(a) Storey Height 3m



(b) Storey Height 3.5m



(c) Storey Height 4m

Fig 5. Location of Plastic Hinges at Performance Points

The figures showed above gives the location of plastic hinges at their performance points. From the above figures it can be seen that most of the hinges were developed in life safety and collapse occupancy levels.

The table below shows the overall performance of frames under different storey heights and number of stories. The table gives the values of base shear, roof displacement, time period, spectral acceleration and spectral displacement at their performance point.

Table II : Comparison of Performance Points With Different No Stories

Model name	5S6B-SH 3	5S6B-SH 3.5	5S6B-SH 4
Base shear (KN)	2621.639	2225.926	1925.669
Displacement (m)	0.053	0.063	0.075
Spectral acceleration Sa (g)	0.344	0.29	0.247
Spectral displacement Sd (m)	0.042	0.051	0.06
Effective time period T_{eff}(s)	0.68	0.819	0.968
Effective damping β eff	0.224	0.224	0.224

Model name	9S6B-SH 3	9S6B-SH 3.5	9S6B-SH 4

Base shear (KN)	2184.71	1833.577	1580.985
Displacement (m)	0.105	0.128	0.153
Spectral acceleration Sa(g)	0.151	0.125	0.105
Spectral displacement Sd (m)	0.086	0.104	0.126
Effective time period T_{eff}(s)	1.462	1.759	2.15
Effective damping β eff	0.254	0.249	0.259

Model name	11S6B-SH 3	11S6B-SH 3.5	11S6B-SH 4
Base shear (KN)	2065.08	1733.91	1481.03
Displacement (m)	0.134	0.163	0.195
Spectral acceleration Sa(g)	0.115	0.095	0.079
Spectral displacement Sd (m)	0.111	0.135	0.162
Effective time period T_{eff}(s)	1.877	2.329	2.83
Effective damping β eff	0.252	0.264	0.274

From the above tables it can be seen that the performance point of buildings were different under different configuration. As the number of storey and storey height increased base shear and spectral acceleration is reduced, where as displacement, time period and spectral displacement increased. Similarly push over analysis was carried on different number of bays.

Table.III : Comparison of Performance Points With Different No of Bays

Model name	5S7B-SH 3	5S7B-SH 3.5	5S7B-SH 4
Base shear (KN)	3489.49	2955.762	2559.21
Displacement (m)	0.053	0.063	0.075
Spectral acceleration Sa (g)	0.341	0.286	0.244
Spectral displacement Sd (m)	0.043	0.051	0.06
Effective time period T_{eff}(s)	0.689	0.826	0.971
Effective damping β eff	0.226	0.229	0.222

Model name	9S7B-SH 3	9S7B-SH 3.5	9S7B-SH 4
Base shear (KN)	2909.9	2447.99	2100.32
Displacement (m)	0.106	0.128	0.153
Spectral acceleration Sa (g)	0.149	0.124	0.104
Spectral displacement Sd (m)	0.087	0.104	0.127
Effective time period Teff(s)	1.484	1.755	2.161
Effective damping β eff	0.256	0.247	0.259

Model name	11S7B-SH 3	11S7B-SH 3.5	11S7B-SH 4
Base shear (KN)	2749.32	2366.37	1972.301
Displacement (m)	0.135	0.161	0.197
Spectral acceleration Sa (g)	0.114	0.096	0.078
Spectral displacement Sd (m)	0.112	0.133	0.165
Effective time period T_{eff}(s)	1.898	2.278	2.895
Effective damping β eff	0.253	0.259	0.28

Table 3 shows the comparison of performance point with number of bays as 7. It was observed that when number of bays increased base shear and time period increased and spectral acceleration decreased.

V. CONCLUSION

The main objective of the present study was to understand the behaviour of buildings under varying building configurations. A non linear static pushover analysis was used to understand the performance of the structures during an earthquake. From the analysis it was observed that as the number of storey and storey height increased base shear and spectral acceleration is reduced, where as displacement, time period and spectral displacement increased. When number of bays increased base shear and time period increased and spectral acceleration decreased .From this study it can be concluded that reduction in number of storey and increasing the number of bays give better seismic performance with reduced level of damage. Analysis shows the location of plastic hinges at performance point of the structures, overall performance of most of the building models lies between life safety and collapse prevention level, ie the hinges have moderate damage to the structural elements. Pushover analysis showed actual nonlinear behaviour of the structure which helps in performance based seismic design of structure.

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