

## **Pushover Analysis Of RCC Building With Soft Storey At Different Levels.**

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**Abstract:** Due to increase in population, parking spaces is big issue for the apartments in the cities. Hence new trend for utilize the ground storey for a parking. Also for office spaces or conference hall etc, soft story at different levels of structure are constructed. In the past earthquake has shown that the buildings with simple and uniform configurations are subjected to less damage. Regularity and continuity of stiffness in the horizontal planes as well as in vertical direction is very important from earthquake safety point of view. A building with discontinuity is subjected to concentration of forces and deformations at the point of discontinuity which may leads to the failure of members at the junction and collapse of building. Open first storey is a typical feature in the modern multistory constructions in urban India. Such features are highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes. Though multistoried buildings with open (soft) ground floor are inherently vulnerable to collapse due to earthquake load, their construction is still widespread in the developing nations like India. Social and functional need to provide car parking space at ground level and for offices open stories at different level of structure far out-weighs the warning against such buildings from engineering community. With ground soft storey for office space open floor is required on different levels of building. In present thesis we are concentrating on finding the best place for soft stories in high rise buildings. With the availability of fast computers, so-called performance based seismic engineering (PBSE), where inelastic structural analysis is combined with seismic hazard assessment to calculate expected seismic performance of a structure, has become increasingly feasible. With the help of this tool, structural engineers too, although on a computer and not in a lab, can observe expected performance of any structure under large forces and modify design accordingly. PBSE usually involves nonlinear static analysis, also known as pushover analysis. Hence in this study vulnerability of RCC building with soft storey at GL along with at intermediate floor using nonlinear static analysis. In this project thesis the modeling is done with software SAP 2000 for the analysis. The RCC symmetrical building having G+10 storey consider for study. The performance of the building studied considering second floor, fifth floor and eighth floor along with ground floor as a soft storey. To find out performance points of building with soft storey at these levels with push over analysis is carried out and also analyze the seismic performance of the building by retrofitting with shear wall.

**Keywords**—Performance Based Seismic Engineering, Push over analysis, SAP 2000, Soft Storey.

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### **I. Introduction**

Buildings are classified as having a “soft storey”, if that level is less than 70% as stiff as the floor immediately above it, or less than 80% as stiff as the average stiffness of the three floors above it. Often, open-ground-storey buildings are called soft-storey buildings, even though their ground storey may be soft and weak. Generally, the soft or weak storey usually exists at the ground storey level, but it could be at any other storey level. Soft storey buildings, having first storey's much less rigid than the storey's above are particularly susceptible to earthquake damage because of large, unreinforced openings on their ground floors. Behavior of soft storey building to seismic forces has to be critically examined considering various geometrical and seismic parameters.

Reinforced-concrete framed structure in recent time has a special feature i.e. the ground storey is left open for the purpose of parking etc. Such building are often called open ground storey buildings or building on stilts. Open ground storey system is being adopted in many buildings presently due to the advantage of open space to meet the economical and architectural demands. But these stilt floor used in most severely damaged or, collapsed R.C. buildings, introduced ‘severe irregularity of sudden change of stiffness’ between the ground

storey and upper stories since they had in filled bricks walls which increase the lateral stiffness of the frame by a factor of three to four times. In such buildings the dynamic ductility demand during probable earthquake gets concentrated in the soft storey and the upper storey tends to remain elastic. Hence the building is totally collapsed due to soft storey effect.

Fig. 1.1 Shows the soft storey at ground floor, no infill walls are provided at ground storey and fig. 1.2 shows soft stories at different floors used for office spaces



Fig 1.1 Example of a soft storey at the ground floor



Fig 1.2 Example of soft storey at different levels

### 1.1 Soft Storey

The building in which the ground storey consists of open space for parking area is known as stilt building and the parking storey is called as stilt Floor or Soft-Storey. When sudden change of stiffness takes place along the building height, the storey of which the drastic reduction of stiffness is observed is known as soft storey. A Soft storey building is a multi-story building with wide doors, large unobstructed commercial spaces, or the ground storey is left open for the purpose of parking , i.e. columns in the ground storey do not have any partition walls (of either masonry or RC) between them.

□ As per IS-1893:2002 (part I)

An Soft Storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storey's above.

□ Extreme Soft Storey

An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above.

### 1.2 Soft Storey Behavior

Many building structures having parking or commercial areas in their first stories, suffered major structural damages and collapsed in the recent earthquakes. Large open areas with less infill and exterior walls and higher floor levels at the ground level result in soft stories and hence damage. In such buildings, the stiffness of the lateral load resisting systems at those stories is quite less than the stories above or below. In Fig.1.3, the lateral displacement diagram of a building with a soft storey under lateral loading is shown.

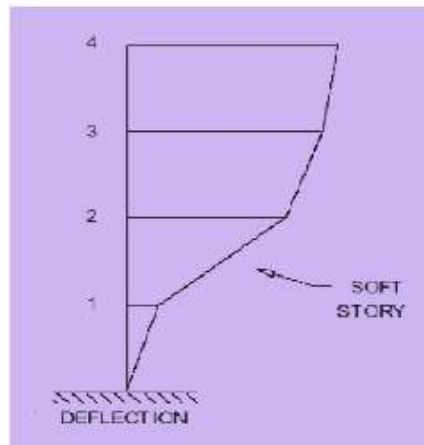


Fig 1.3 Soft storey behavior of a building structure under lateral loading

### 1.3 Objectives

Many research papers are available to understand the behavior of soft storey when provided at ground level but very few papers are available when soft storey is provided at upper level. However there is little work carried out by researcher related to finding vulnerability of existing RCC building with soft storey at different levels in multistorey building using pushover analysis. Hence it is proposed to study vulnerability of existing RCC building with soft storey at GL along with at intermediate floor using nonlinear static analysis.

The main objective of performance based earthquake engineering is to avoid total catastrophic damage and to restrict the structural damage caused to the performance limit of the structure and to check its performance level. Conventional seismic design procedures involve the determination of the building's seismic base shear demand using a structural response factor to account for inelastic action and over strength. Such methods are approximate and do not provide guidance on likely seismic performance under an extreme event. Pushover analysis provides useful information that cannot be obtained by linear static or dynamic analysis procedure. The pushover analysis of multistoried building with soft stories at different levels, to check their performance against lateral forces.

The objectives of proposed work are as follows,

1. To study seismic capacity of reinforced concrete framed multistorey buildings with soft storey at different levels.
2. To find out performance points of a building.
3. To study the plastic hinges formation pattern for multistorey building with soft storey at different levels.
4. To analyze the seismic performance of above buildings by retrofitting with shear wall.

## II. Pushover Methodology

Pushover analysis is a static, nonlinear procedure in which the magnitude of the lateral force is incrementally increased, maintaining the predefined distribution pattern along the height of the building. With the increase in the magnitude of the loads, weak links and failure modes of the building are found. Pushover analysis can determine the behavior of a building, including the ultimate load and the maximum inelastic deflection. Local Nonlinear effects are modeled and the structure is pushed until a collapse mechanism gets developed. At each step, the base shear and the roof displacement can be plotted to generate the pushover curve. It gives an idea of the maximum base shear that the structure was capable of resisting at the time of the

earthquake. For regular buildings, it can also give a rough idea about the global stiffness of the building.

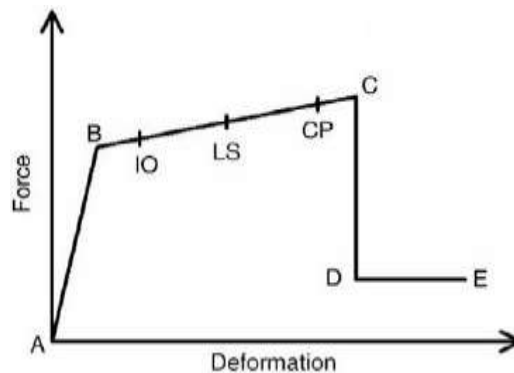
### 2.1. Nonlinear Plastic Hinges Properties

The building has to be modeled to carry out nonlinear static pushover analysis. This requires the development of the force - deformation curve for the critical sections of beams, columns. The force deformation curves in flexure were obtained from the reinforcement details and were assigned for all the beams and columns. The Nonlinear properties of beams and columns have been evaluated using the section designer and have been assigned to the computer model in SAP2000. The flexural default hinges (M3) and shear hinges (V2) were assigned to the beams at two ends. The interacting (P-M2-M3) frame hinges type a coupled hinge property was also assigned for all the columns at upper and lower ends .

### 2.2 Performance Levels

The structural and non- structural components of the buildings together comprise the building performance. The performance levels are the discrete damage states identified from a continuous spectrum of possible damage states. The structural performance levels based on the roof drifts are as follows:

Five points labeled A, B, C, D and E are used to define the force deflection behavior of the hinge and these points labeled as



### 2.1 Pushover Curve

The performance levels (IO, LS, and CP) of a structural element are represented in the load versus deformation curve as shown below,

1. A to B – Elastic state,
  - i) Point ‘A’ corresponds to the unloaded condition.
  - ii) Point ‘B’ corresponds to the onset of yielding.
2. B to IO- below immediate occupancy,
3. IO to LS – between immediate occupancy and life safety,
4. LS to CP- between life safety to collapse prevention,
5. CP to C – between collapse prevention and ultimate capacity,
  - i) Point ‘C’ corresponds to the ultimate strength
6. C to D- between C and residual strength,
  - i) Point ‘D’ corresponds to the residual strength
7. D to E- between D and collapse
  - i) Point ‘E’ corresponds to the collapse.

## III. Structural Modeling And Analysis

The modeling is done with software SAP 2000 for the analysis. The RCC symmetrical building having G+10 storey consider for study. The performance of the building is studied considering second floor, fifth floor and eighth floor along with ground floor as a soft storey. To find out performance points of building with soft storey at these levels with push over analysis is carried out and also analyze the seismic performance of the building by using strengthening measures.

All the building Frames considered are 16m x 16m in plan area and 11 storey (G+10).

### 3.1 Soft Storey Cases

The following 8 cases have been framed for analysis purpose -

- 1) Soft storey at ground floor. (G)
- 2) Soft storey at second floor along with ground floor. (G+2)
- 3) Soft storey at fifth floor along with ground floor. (G+5)
- 4) Soft storey at eight floor along with ground floor. (G+8)
- 5) Soft storey at ground floor retrofitted with shear wall. (G SW)
- 6) Soft storey at second floor along with ground floor retrofitted with shear wall. (G+2 SW)
- 7) Soft storey at fifth floor along with ground floor retrofitted with shear wall. (G+5 SW)
- 8) Soft storey at fifth floor along with ground floor retrofitted with shear wall. (G+8 SW)

### 3.2 Material And Geometrical Properties

Following material properties have been considered in modeling :-

Density of RCC:  $25 \text{ kN/m}^3$

Density of Masonry:  $20 \text{ kN/m}^3$

Poisson ratio : 0.2

The column size is 500mm x 500mm and the beam size is 550mm x 300mm.

Thickness of wall : 230mm.

### 3.3 Loading Conditions

Following loading are conducted for analysis

#### 1) Dead Loads:

Self wt. of slab considering 150mm thick. Slab =  $0.15 \times 25 = 3.75 \text{ kN/m}^2$

Floor Finish load =  $1 \text{ kN/m}^2$

Water Proofing Load on Roof =  $1 \text{ kN/m}^2$

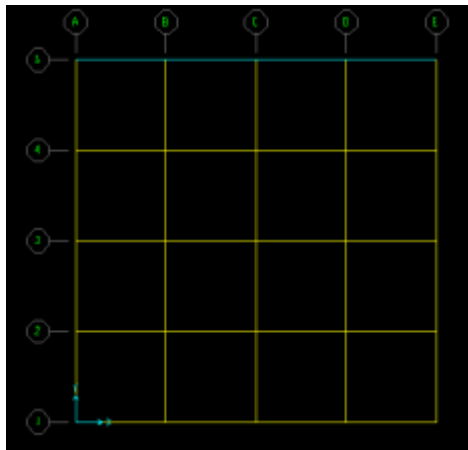
Masonry Wall Load =  $0.23 \times 2.45 \times 20 = 12 \text{ kN/m}$

#### 2) Live Loads:

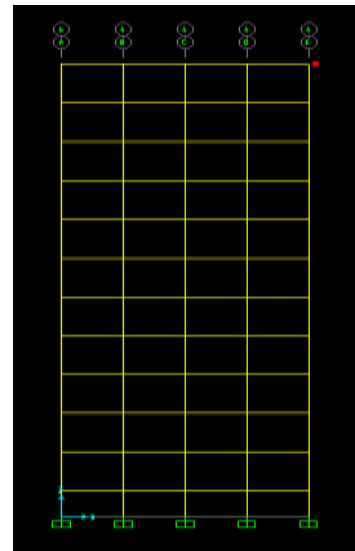
Live Load on typical floors =  $3 \text{ kN/m}^2$

Live Load on Roof =  $2 \text{ kN/m}^2$

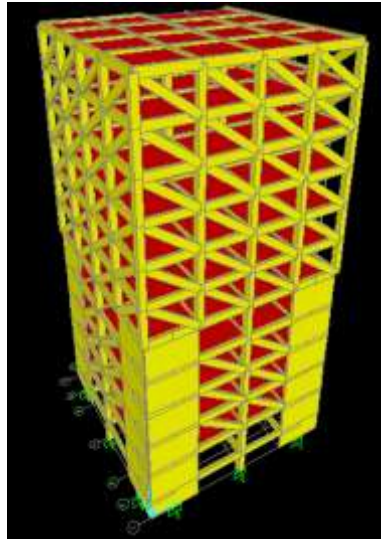
Seismic zone = V



3.1 Plan of building.



3.2 Elevation Of Building



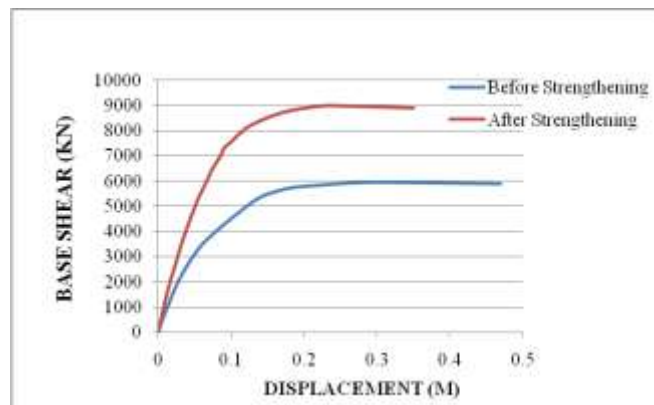
3.3 3D View After Strengthening.

#### IV. Results and Discussion

Create the basic computer model of four storey building frame structure. Define properties and acceptance criteria for the pushover hinges. The program includes several built-in default hinge properties that are based on average values from ATC-40 for concrete members and average values from FEMA-356 for steel members. These built in properties can be useful for preliminary analyses, but user defined properties are recommended for final analyses. Locate the pushover hinges on the model by selecting one or more frame members and assigning them one or more hinge properties. Define the pushover load cases. Pushover load case is used to apply gravity load and then lateral pushover load cases are specified to start from the final conditions of the gravity pushover. Pushover load cases can be force controlled, that is, pushed to a certain defined force level, or they can be displacement controlled, that is, pushed to a specified displacement.

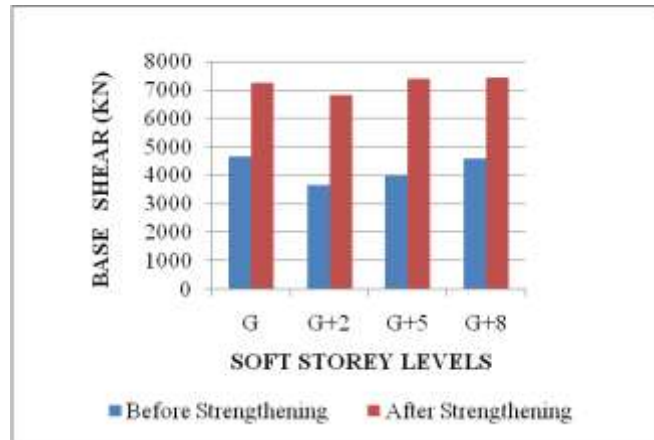
In the present study, non-linear response of RC frame high rise building with soft storey at different levels in addition to one at ground floor using SAP2000 under the loading has been carried out. The objective of this study is to see the variation of load- displacement graph and check the maximum base shear and displacement of the frame with soft stories at different levels. After running the analysis, the pushover curve is obtained as shown in figures.

##### 4.1 Pushover Curve



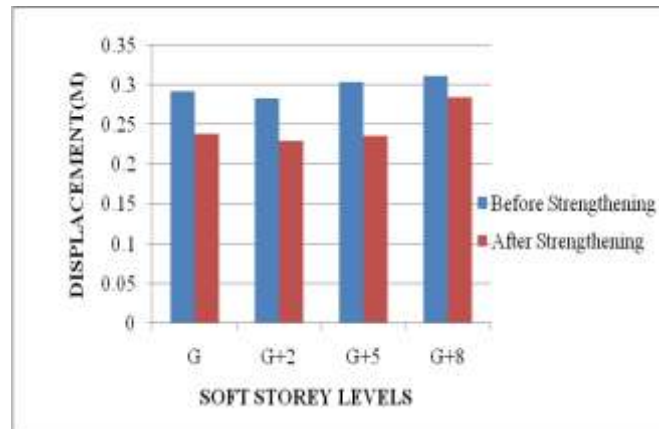
4.1 Push Over Curve For Ground Soft Storey

4.2 Base Shear



4.2 Base shear for different soft storey levels.

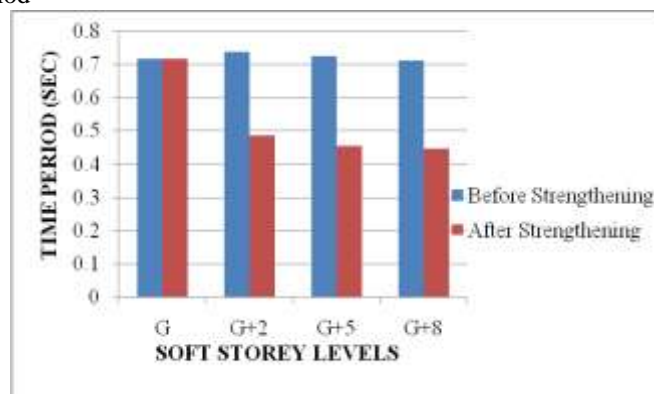
4.3 Target Displacement



4.3 Target displacement for different soft storey levels.

It has been observed from above graphs of base force for different level soft stories, if we use soft storey at ground floor base shear is more, but as we shift the soft storey to higher level with ground floor soft storey combination, base shear goes on increasing and displacement also.

4.4 Fundamental Natural Period

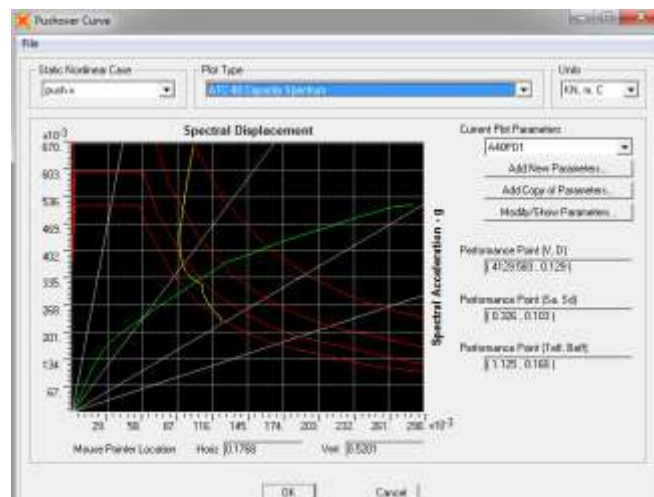


4.4 Natural time period for different soft storey cases.

From pushover analysis and capacity spectrum curve we are getting natural period 0.716 Sec to 0.440 Sec. after strengthening for different cases of soft stories which is within specified limit.

#### 4.5 Performance Point

TABLE : Performance Points As per Base Shear And Displacement				
Storey	Before Strengthening		After Strengthening	
	Base Shear (KN)	Displacement (M)	Base Shear (KN)	Displacement (M)
G	4635.65	0.128	4684.65	0.129
G+2	4129.58	0.129	6491.093	0.074
G+5	4229.79	0.128	7428.71	0.084
G+8	4500.80	0.131	8993.62	0.084



4.5 Capacity spectrum for G+2 Model

A 11 storied reinforced concrete frame structure of building was taken to analysis. The analysis was done as per ATC 40 approach. The frame was subjected to design earthquake forces as specified in the IS code for zone V along longer directions. Pushover curves for the building in X directions as shown in Figure 4.1. These curves show the behavior of the frame in terms of its stiffness and ductility. For maximum base shear from pushover analysis for ground storey is 5143.419 KN and maximum displacement of 0.157m in X direction. After strengthening base shear is 9852.582 and displacement 0.140. Capacity spectrum is the capacity curve spectral acceleration Vs spectral displacement (Sa Vs Sd) co-ordinates. The performance point is obtained by superimposing demand spectrum on capacity curve transformed into spectral coordinates. The frame shows the performance of the on the spectral acceleration corresponding to the performance point. The performance point is obtained at a base shear level of 4635.65KN and displacement of 128mm in the X direction

### V. Conclusion

From present analysis model in SAP2000 it can be concluded that, Maximum yielding occurs at the soft storey, because of soft stories maximum plastic hinges are forming though the base force is increasing. As we shifted soft storey to higher level, yielding is less than lower level soft storey and lower intensity hinges are forming after maximum number of pushover steps. As we shift soft storey to higher level it can be seen from pushover and capacity spectrum curve that time period goes on reducing from 0.716 Sec. for 2nd floor soft storey to 0.446 Sec. at 8th floor soft storey. Which means soft storey is safer at higher level in high rise building. Most of the hinges developed in the beams and few in the columns. It is observed that plastic hinges are



developed in columns of ground level soft storey which is not acceptable criteria for safe design. After retrofitting of all the models with shear walls hinges are not developed in any of the columns. In medium high rise buildings (i.e. greater than 10 storeys) provision of shear walls is found to be effective in enhancing the overall seismic capacity characteristics of the structure.

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