"Seismic Analysis of Reinforced Concrete Frame With Soft Story and using Various Retrofitting Methods" 'Modelling using Sap2000 Software'

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Abstract- *Many urban multistorey building in India today have ground storey open and it is being utilized for parking space as there is population explosion and huge amount of increase in the number of the vehicles on the road. So it became necessity to keep ground storey open. Now a day it is necessary to provide soft storey at different level to resist earthquake load. Buildings are susceptible to the abrupt non-ductile strength deterioration after reaching ultimate strength, which reduces energy dissipation capacity of building causing brittle failure. Thus enhancing seismic performance is essential. This paper aims to analyse the seismic behavior and performance of the reinforced concrete frame subjected to the earthquake load, lateral forces and non-linear static push-over analysis. The non-linear properties of the elements of the structure are determined by using push-over analysis for modeling and analysis of structure using SAP 2000 software. Performance based seismic evaluation is the new trend to earthquake resistant design.*

Keywords- soft storey, push-over analysis, retrofitting and rehabilitation methods, performance of building

I. INTRODUCTION

Investigations of past and recent earthquake damage have illustrated that building structures are vulnerable to severe damage or collapse during moderate to strong ground motion. An earthquake of higher magnitude can cause severe damage to the structures such as buildings, fly-overs, bridges, industries and ports. During last decade we have seen several high magnitude earthquakes which have caused high damage to the structures due to their poor performance. Generally structures are designed to carry their own load. A soft storey is defined as a storey in a building that has less stiffness and inadequate ductility to resist the earthquake causing motion in building. According to IS 1893(part 1):2002 'a soft storey is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storey above'. The vertical irregularities in the building are common causes of failure of the building such as uneven distribution of mass, plan and elevation both presenting strength and stiffness, discontinuous members of the frame and masonry infill walls. The force and deformation is being concentrated at the junction point in the discontinuous member leads to failure and collapse of structure. The natural period of the building determines the total seismic base shear experienced by the structure during an earthquake.

Masonry infill walls are extensively used throughout the world as a partition inside the building. Single compressive equivalent diagonal strut technique is widely used to design infill panel. According to FEMA-356 masonry infill walls are supposed to act as non-structural members or elements so that they are not considered while designing the building. Masonry infill walls act as stiff and brittle if taken separately but it acts as flexible and ductile when taken with the frame. The composite action of beam-column and masonry infill walls gives additional required strength and stiffness to the structure. The addition of stiffness from column, shear wall and bracing from each storey is the lateral strength of the building. The buildings without any lateral resisting element tend to fail or collapse during an earthquake. Evidences of the failure and collapse of intermediate soft storey during an earthquake are due to stiffness which is not properly distributed as there are no walls present in the intermediate soft storey. The bare frame is less stiff than that of masonry infilled frame as it can bear large amount of lateral forces. Seismic performance of the building can be increased by introducing shear wall, brick infill and steel X bracing. Retrofitting of the building alters its behavior from predominant force action to the predominant truss action and transfers its seismic load through diagonals.

II. NON-LINEAR STATIC ANALYSIS

Seismic analysis is a part of Structural analysis and is the response of the building during an earthquake. It is carried out while designing the structures, structural assessment and retrofitting in the areas where possibility of earthquake is prevalent. In non-linear analysis, a pattern of forces is applied to structure and total force verses displacement is being plotted on a graph and is known as capacity curve. To reduce the problem of single degree of freedom system, capacity curve is combined with demand curve. This approach is also called as "pushover" analysis.

Performance level of the building:

It describes the limiting damage state of the structural systems and nonstructural systems.

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:

Immediate occupancy(IO), Life Safety(LS), Collapse prevention(CP) are the three levels arranged in order according decreasing performance of the lateral load resisting systems.

Point 'A' corresponds to the unloaded condition.
Point 'B' corresponds to the onset of yielding.
Point 'C' corresponds to the ultimate strength.
Point 'D' corresponds to the residual strength.
Point 'E' corresponds to the maximum deformation capacity with the residual strength.

The three performance levels (IO, LS, CP) of the building are shown on the graph of load verses deformation curve. These levels represent the amount of damage, economic loss and disruption may occur.

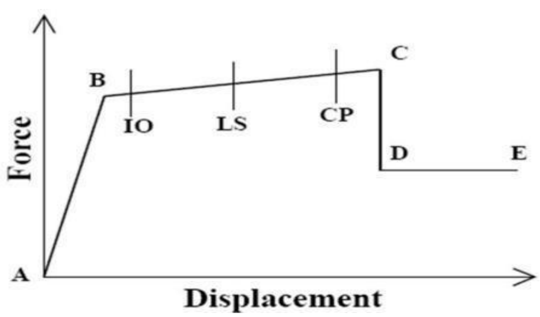

Fig.1 Performance level of pushover analysis

Lateral load for pushover analysis

In pushover analysis the building is pushed with a specific load distribution pattern along the height of the building. The magnitude of the total force is increased but the pattern of the loading remains same till the end of the process. Pushover analysis results are very sensitive to load pattern. The lateral load patterns should approximate the inertial forces expected in the building during an earthquake.

Pushover analysis is an approximate method in which the structure is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached. Pushover analysis consists of a series of sequential elastic analysis, superimposed to approximate a force-displacement curve of the overall structure. A two or three dimensional model which includes bilinear or trilinear load deformation diagrams of all lateral force resisting elements is created and gravity loads are applied initially.
Steps for pushover analysis

In pushover analysis the lateral force or displacement is being applied to a nonlinear model of building. The nonlinear load-deformation pattern of each segment of building is modeled individually. The force is applied monotonically increasing such that either the selected node exceeds the target value or the segment reaches its collapse point. Latter is being considered convenient. The maximum displacement of the building is considered to be the targeted displacement which the building will experience during an earthquake.

Initially, the gravity load is applied on the building until total load reaches target value in a force controlled system. In linear analysis the target value can be same as of the design gravity load. The load is distributed as in inverted parabolic pattern along the height of the building which can be termed as lateral load pattern of the gravity pushover.

The direction of monitoring of behavior is same as the push direction. As the displacement is increased, building elements such as beams, columns and 'equivalent struts or walls' may undergo in-elastic deformation. The non-linear inelastic behavior in flexure, shear or axial compression is modeled through assigning appropriate load-deformation properties at potential plastic hinge locations.

III. OBJECTIVES OF PROJECT

To study the G+12 storey building located in the zone V and to determine seismic performance and behavior of the reinforced concrete building with soft storey at different height using SAP 2000 software.

To study hinge formation pattern of the G+12 storey building.

To calculate the natural time period of the building with soft storey and retrofitting methods.

To study performance of the building by using various retrofitting methods in SAP 2000 software.

To suggest the most efficient method to strengthen the structure out of infill walls, shear wall and steel bracing system.

IV. MODELLING AND ANALYSIS OF THE BUILDING

Description of the structure:

Size of the building: 20metres x20metres. Floor to floor height is 3.20. The building is Special Moment Resisting Frame (SMRF) situated in zone V. Soil condition is medium. Plinth height above foundation: 2m, parapet height: 1.5m, slab thickness: 150mm, wall thickness: 230mm.
Size of columns: 600mm x600mm
Size of beam: 300mm x300mm
Material properties are considered as follows:
Grade of concrete: M25
Grade of steel: Fe415
Poisson's ratio 0.20
Density of concrete: 25 KN per cubic meter
Density of masonry wall: 20 KN per cubic meter

Load intensities are considered as follows:

Live load on floor: 4 KN per meter square
Floor finish: 1.5 KN per meter square
Live load on roof: 1.5 KN per meter square

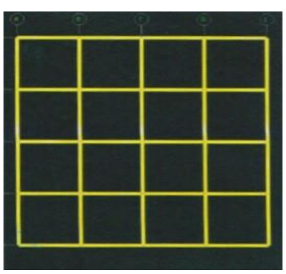

Fig 2: Plan of building

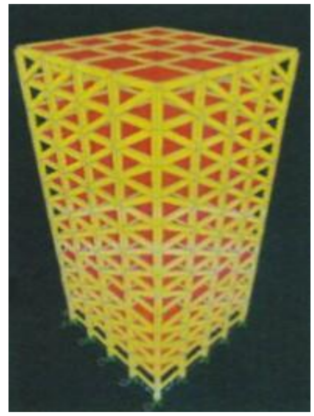

Fig 3: Elevation of building

The modeling of the building is done in the various segments as:

Case 1: Analyze the displacement pattern and force controlled push mechanism of the building with soft storey at different heights.
Case1.1 G+12 storey building with soft storey at ground level and fourth floor
Case 1.2 G+12 storey building with soft storey at ground level and eighth floor
Case1.3 G+12 storey building with soft storey at ground level and twelfth floor
Case2: Analyze the displacement pattern and force controlled push mechanism of the building with soft storey at different height and retrofit the floor with brick infill
Case 2.1 G+12 storey building with soft storey at ground level and fourth floor retrofitted with brick infill
Case 2.2 G+12 storey building with soft storey at ground level and eighth floor retrofitted with brick infill
Case 2.3 G+12 storey building with soft storey at ground level and twelfth floor retrofitted with brick infill
Case3: Analyze the displacement pattern and force controlled push mechanism of the building with soft storey at different height and retrofit the floor with Shear wall
Case 3.1 G+12 storey building with soft storey at ground level and fourth floor retrofitted with shear wall
Case 3.2 G+12 storey building with soft storey at ground level and eighth floor retrofitted with shear wall
Case 3.3 G+12 storey building with soft storey at ground level and twelfth floor retrofitted with shear wall
Case 4: Analyze the displacement pattern and force controlled push mechanism of the building with soft storey at different height and retrofit the floor with steel X bracing
Case 4.1 G+12 storey building with soft storey at ground level and fourth floor retrofitted with steel X bracing
Case 4.2 G+12 storey building with soft storey at ground level and eighth floor retrofitted with steel X bracing
Case 4.3 G+12 storey building with soft storey at ground level and twelfth floor retrofitted with steel X bracing

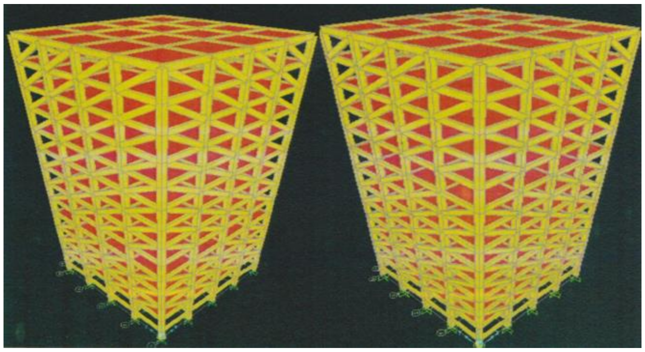

Fig 4: Ground level, fourth floor and eighth floor soft storey Hinge formation pattern

The following figures show the hinge formation pattern at performance point for the G+12 storied building with soft storey at different level along with the soft storey retrofitted with infill wall, steel bracing and shear wall.

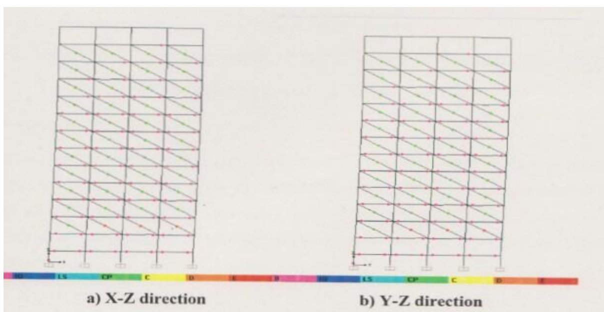

Fig5: Hinge formation for Ground level and twelfth storey at performance point

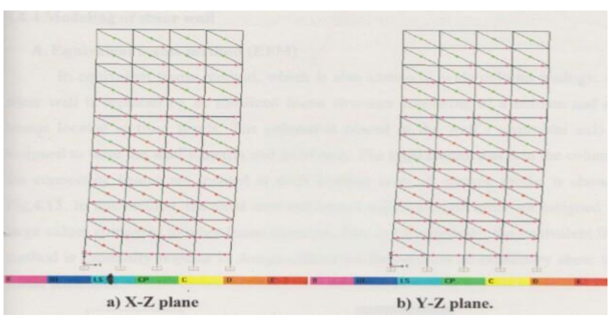

Fig6: Hinge formation of Ground level and eighth floor retrofitted with infill wall

V. RESULTS AND DISCUSSION

Soft storey level	Gravity load		Infill wall		Steel X bracing		Shear wall	
	X direction(KN, mm)	Y direction(KN, mm)	X direction(KN, mm)	Y direction(KN, mm)	X direction(KN, mm)	Y direction(KN, mm)	X direction(KN, mm)	Y direction (KN, mm)
Ground level& fourth floor	5350.91,123	5350.91,123	5771.32,122	5771.32,122	6000, 118	6000, 118	7273.72,93	7273.72, 93
Ground level& eighth floor	5606.61,125	5606.61,125	5908.3, 123	5908.3, 123	6047.53,119	6047.53,119	8335, 92	8335, 92
Ground level& twelfth floor	5782.51,127	5782.51,127	6024.24,123	6024.24,123	6077.64,120	6077.64,120	9248.39,91	9248.39, 91

Table1: Comparison of performance point for various retrofitting strategy

From table 1 it is clear that as the soft storey is shifted to upper level the base shear increases. The building when retrofitted with shear wall results in higher performance compared to other retrofitting methods. The shear wall reduces the displacement of the building to much greater extent than other retrofitting methods. The performance of the steel X bracing is better in compared to infill walls and without retrofitting model.

Soft storey level	Gravity load		Infill wall		Steel X bracing		Shear wall	
	X direction (sec)	Y direction (sec)	X direction (sec)	Y direction (sec)	X direction (sec)	Y direction (sec)	X direction (sec)	Y direction (sec)
Ground level& fourth floor	2.280	2.280	2.161	2.161	2.055	2.055	1.456	1.456
Ground level& eighth floor	2.191	2.191	2.116	2.116	2.038	2.038	1.25	1.25
Ground level& twelfth floor	2.171	2.171	2.103	2.103	2.034	2.034	1.1	1.1

Table2: Comparison of natural time period at different levels with soft storey and of various retrofitting methods

From table 2 it is clear that as the soft storey is shifted to upper level the natural time period decreases. The building retrofitted with shear wall performs better compared to other retrofitting models and non-retrofitted model. The time period of the retrofitted model with shear wall is in permissible limit.

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VI. CONCLUSION

This study highlights the poor performance of the reinforced concrete building with soft storey at different level along with soft storey at ground level. The three models with soft storey at as such a) Ground level and fourth floor, b) Ground level and eighth floor, c) Ground level and twelfth floor are studied in SAP 2000 and Nonlinear static analysis is carried out. Buildings were found to be weak due to formation of hinges in columns at ground soft storey as well columns in upper soft storey. Hence buildings are failed due to plastic hinge formation and collapse mechanism of the storey and hence retrofitting is carried out. As a result different strengthening methods are applied and the best suitable one is found out.

From the study it is concluded that the building model with shear wall strengthening measure is most suitable compared to the infill wall, steel bracing and non-retrofitted model. The base has increased in order of soft story without retrofitting, soft storey with infill wall, steel bracing and shear wall. There is no formation of hinge mechanism in shear wall as it is present in the rest three models. The time period of the shear wall was lowest among steel bracing, infill wall and non -retrofitted soft storey respectively.

VII. SCOPE FOR FUTURE WORK

In this work nonlinear behavior of building has studied by static pushover analysis method for soft storey with different level along with retrofitting measures to strengthen the building. In this study the soil surface interaction has not been considered. Hence by considering soil surface interaction, further study can be carried out.

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