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Research Article

Seismic Performance of Multistorey Building with Soft Storey at Different Level with RC Shear Wall

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Abstract

Due to increasing population since the past few years car parking space for residential apartments in populated cities is a matter of major concern. Hence the trend has been to utilize the ground storey of the building itself for parking. Also for offices or for any other purpose such as communication hall etc. soft storeys at different levels of structure are constructed. Experience in the past earthquake has shown that a building with discontinuity in the stiffness and mass 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. Hence in this paper attempt has been made to study performance of a building with soft storey at different level along with at GL. The nonlinear static pushover analysis is carried out. The hinges formed in the basic models are seen at performance point and to increase the performance, it is retrofitted with shear walls. Then the result obtained for basic models and retrofitted models are compared in the form of performance point and hinge formation pattern at performance point.

Keywords: *Nonlinear static pushover analysis, performance point, performance level, plastic hinges, shear wall, soft storey.*

1. Introduction

Many urban multistory buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first stories. Also for offices or for any other purpose such as communication hall etc. soft storeys at different levels of structure are constructed. IS 1893 (Part1): 2002 classifies a soft storey as 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 storeys above. Hence in multistory building with no infill walls in the first storey or any intermediate storey is known as soft storey.

Infill panels are generally not considered in the design process and treated as architectural (non-structural) components. The presence of masonry walls has a significant impact on the seismic response of an RC frame building, increasing structural strength and stiffness (relative to a bare RC frame), but, at the same time, introducing brittle failure mechanisms associated with the wall failure and wall-frame interaction. The seismic force distribution is dependent on the distribution of stiffness and mass along the height. The essential characteristics of soft storey consist of discontinuity of strength or stiffness which occurs at the second floor column connection (Rahiman G. Khan *et al*, 2013).This discontinuity is caused because of lesser strength or increased flexibility in the first floor vertical structure results in extreme deflection in the first floor. Fig. 1 and 2 shows the behavior of soft storey due to discontinuity in mass and stiffness.

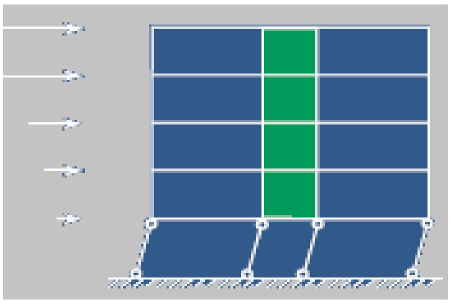

Fig.1 Behavior of soft storey at GL.(Hugo Bachmann, 2003)

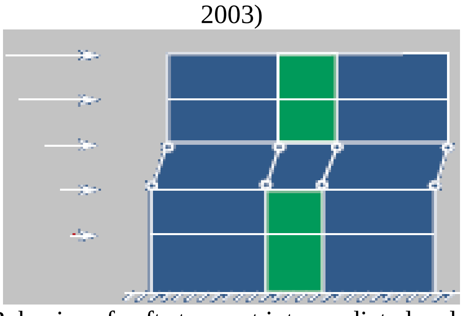

Fig.2 Behavior of soft storey at intermediate level. (Hugo Bachmann, 2003)

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1.1 Pushover analysis

The structural engineering community has developed a new generation of design and seismic procedures that incorporate performance based structures and are moving away from simplified linear elastic methods and towards a more non-linear technique. Recent interests in the development of performance based codes for the design or rehabilitation of buildings in seismic active areas show that an inelastic procedure commonly referred to as the pushover analysis is a viable method to assess damage vulnerability of buildings. Basically, a pushover analysis is a series of incremental static analysis carried out to develop a capacity curve for the building. Based on the capacity curve, a target displacement which is an estimate of the displacement that the design earthquake will produce on the building is determined. The extent of damage experienced by the structure at this target displacement is considered representative of the damage experienced by the building when subjected to design level ground shaking. Many methods were presented to apply the nonlinear static pushover (NSP) to structures. These methods can be listed as:
(1) Capacity Spectrum Method (CSM)
(2) Displacement Coefficient Method (DCM)
(3) Modal Pushover Analysis (MPA). The approach has been developed by many researchers with minor variation in computation procedure methods. Since the behavior of reinforced concrete structures may be highly inelastic under seismic loads, the global inelastic performance of RC structures will be dominated by plastic yielding effects and consequently the accuracy of the pushover analysis will be influenced by the ability of the analytical models to capture these effects. (S. I. Khan *et al*, 2013).

2. Modeling and Analysis of Building

In this paper, for analytical study multistory building is considered with soft storey at different level along with ground level. The building is modeled with shear wall at core as shown in fig. 3 using finite element software SAP2000 version 14.4.2 and non-linear static pushover analysis is performed on all building models. To improve the seismic performance of such buildings lateral load resisting element i.e. shear walls are used. Shear walls are provided at corner of building in L shaped to improve seismic performance of building.

2.1 Building description

The study is carried out on reinforced concrete moment resisting G+20 storey buildings with soft storey at different levels. The plan of building is same for all models. Height of each storey is 3.2 m. The building has plan dimensions 28 m x 20 m as shown in fig.3. In the analysis special RC moment-resisting frames (SMRF) is considered. Other relevant data is given as below.

1. Size of Building: 28 m X 20 m
2. Grade of concrete: M 30
3. Grade of steel: Fe 415
4. Floor to floor height: 3.2 m
5. Plinth height above foundation: 2 m
6. Parapet height: 1 m
7. Slab thickness: 150 mm
8. Wall thickness: 230 mm
9. Size of columns

External: 300 mm x 600 mm,
Internal: 300 mm x 1200 mm (below 5th floor) and
Internal: 300 mm x 900 mm (above 5th floor)

10. Size of beam: 300 mm x 500 mm
11. Live load on floor: 5 kN/m ^{2}
12. Floor finishes: 2 kN/m ^{2}
13. Roof treatment: 1.5 kN/m ^{2}
14. Seismic zone: V
15. Soil condition: Medium
16. Importance factor: 1
17. Density of concrete: 25 kN/m ^{3}
18. Density of masonry: 20 kN/m ^{3}

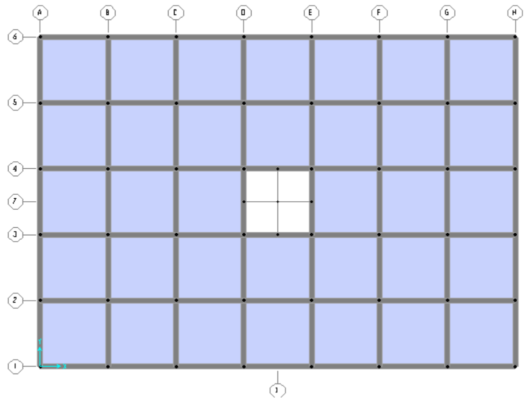

Fig. 3 Plan of building

2.2 Seismic response of soft storey building

Four models with soft storey at different levels are considered along with soft storey at ground level and these models with incorporation of shear walls are considered. Various models under consideration are:
Model I: **G+20/G & 5 building**- G+20 storeys building with soft storey at GL and 5th floor without retrofitted with shear walls as shown in fig.4
Model II: **G+20/G & 10 building**- G+20 storeys building with soft storey at GL and 10th floor without retrofitted with shear walls as shown in fig.5
Model III: **G+20/G & 15 building**- G+20 storeys building with soft storey at GL and 15th floor without retrofitted with shear walls as shown in fig.6
Model IV: **G+20/G & 20 building**- G+20 storeys building with soft storey at GL and 20th floor without retrofitted with shear walls as shown in fig.7
Model V: **G+20/G & 5/SW building**- G+20 storeys building with soft storey at GL and 5th floor retrofitted with shear walls as shown in fig.8
Model VI: **G+20/G & 10/SW building-** G+20 storeys building with soft storey at GL and 10th floor retrofitted with shear walls as shown in fig.9
Model VII: **G+20/G & 15/SW building-** G+20 storeys building with soft storey at GL and 15th floor retrofitted with shear walls as shown in fig.10

Model VIII: **G+20/G & 20/SW building-** G+20 storeys building with soft storey at GL and 20th floor retrofitted with shear walls as shown in fig.11

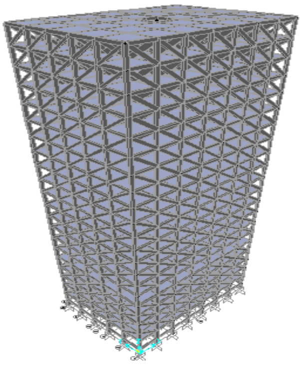

Fig.4 G+20/G & 5 building

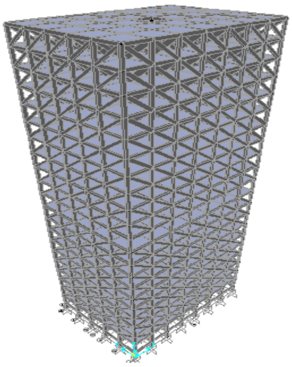

Fig.5 G+20/G & 10 building

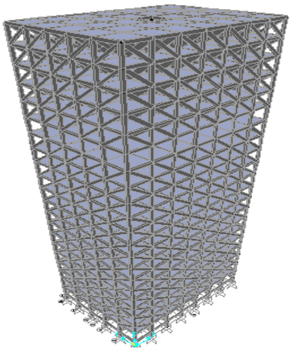

Fig.6 G+20/G & 15 building

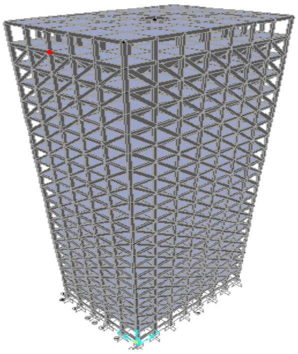

Fig.7 G+20/G & 20 building

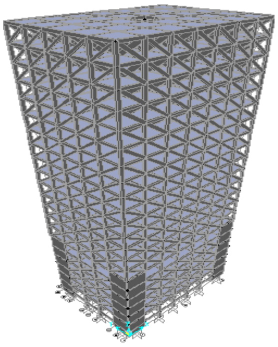

Fig.8 G+20/G & 5/SW building

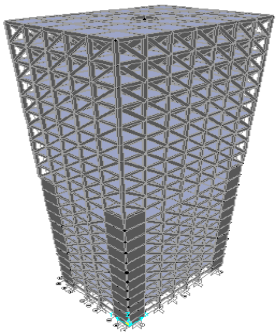

Fig.9 G+20/G & 10/SW building

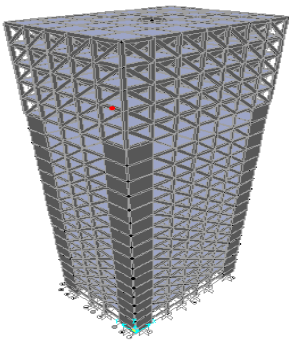

Fig.10 G+20/G & 15/SW building

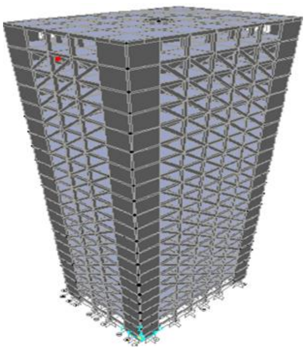

Fig.11 G+20/G & 20/SW building

3. Result and Discussion

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 and the result are presented in terms of performance point and roof displacement.

3.1 Comparison of performance of various frames

Pushover analyses of models with and without shear walls are carried out. Comparison between the performance point in terms of base shear and roof displacement obtained from the nonlinear static analysis and hinge formation pattern of the models without shear walls and with shear walls are done. Table 1 shows the performance point and roof displacement of models with and without shear walls.

Table 1: Performance point and performance level for model without shear walls and model with shear walls.

Description	Model without shear walls	Model with shear walls
Soft storey at GL & 5th floor		
Performance point in X direction	15154.171,198	16797.89;177
Performance point in Y direction	16111.231,216	17598.99;189
Performance level	B-IO	B
Soft storey at GL & 10th floor		
Performance point in X direction	15062.498,197	17112.3;170.3
Performance point in Y direction	16006.147,215	18057.5;183.4
Performance level	B-IO	B
Soft storey at GL & 15th floor		
Performance point in X direction	15296.713,198	17413.4;168.2
Performance point in Y direction	16228.164,215	18573.7;181.04
Performance level	B-IO	B
Soft storey at GL & 20th floor		
Performance point in X direction	15377.813,199	17686.3;169.2
Performance point in Y direction	16390.202,215	18897.3;181
Performance level	B-IO	B

From table 1 it is clear that the performance level for the models without shear walls is within B-IO range. Though the performance level is within B-IO range, it is observed that hinges are formed in columns of ground level soft storey. Hence retrofitting is carried out with shear walls. It is observed that the performance level for the models with shear walls is linear (B) and the roof displacement of retrofitted models is less as compared to models without shear walls. Also it is observed that hinges are not formed in columns for buildings with shear walls. Hence shear walls improves the seismic performance of the building.

3.2 Hinge formation pattern

Fig. 12 to fig. 15 show the hinge formation pattern in models without shear walls. From this it is clear that, due to the high shear forces at ground level soft storey; the hinges are formed in columns of ground soft storey. However it is observed that no hinges are formed in columns of ground soft storey, when retrofitted with shear walls.

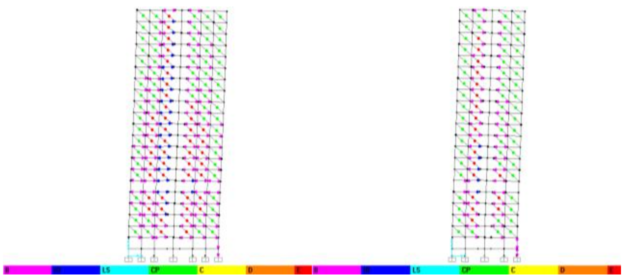

Fig.12 Hinge formations at performance point for G+20/G & 5 building in X and Y direction

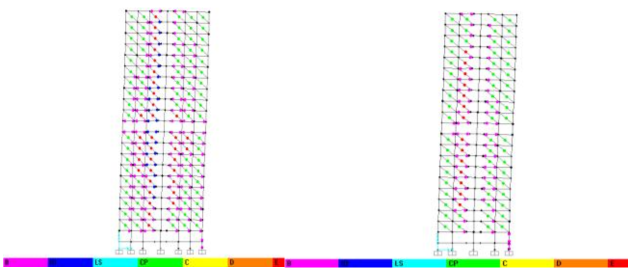

Fig.13 Hinge formations at performance point for G+20/G & 10 building in X and Y direction

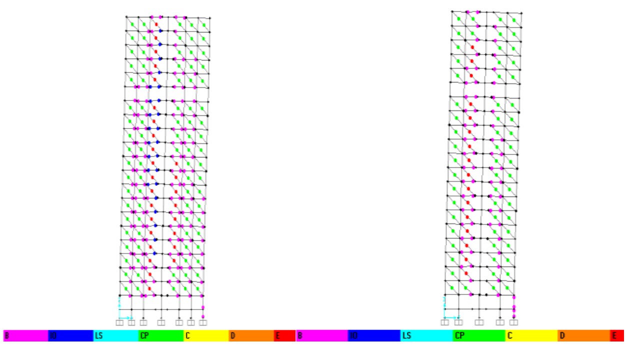

Fig.14 Hinge formations at performance point for G+20/G & 15 building in X and Y direction

Fig. 16 to fig. 19 show the hinge formation pattern in retrofitted models. From this hinges formation pattern, it is clear that no hinges are formed in bottom storey columns and the performance of the soft storey is improved.

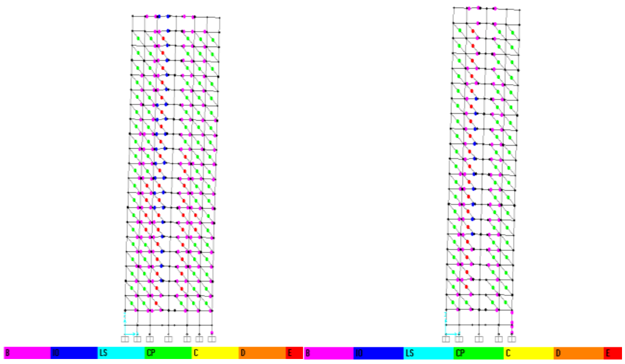

Fig.15 Hinge formations at performance point for G+20/G & 20 building in X and Y direction

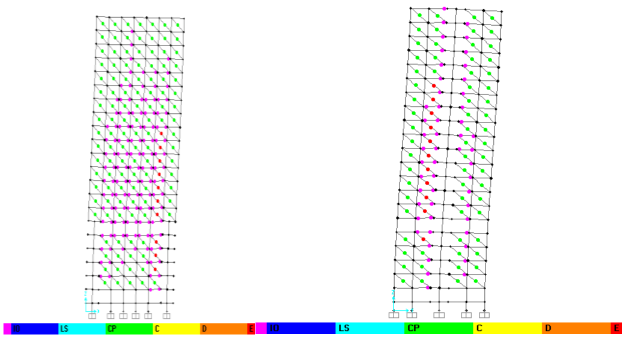

Fig.16 Hinge formation at performance point for G+20/G & 5/SW building in X and Y direction

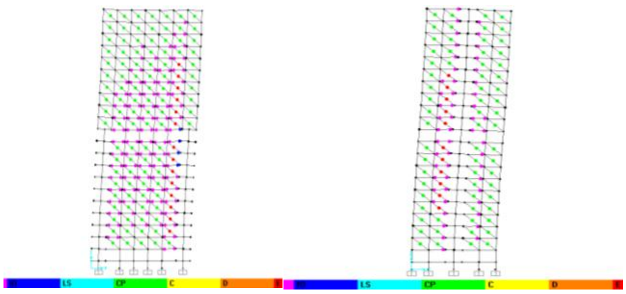

Fig.17 Hinge formation at performance point for G+20/G & 10/SW building in X and Y direction

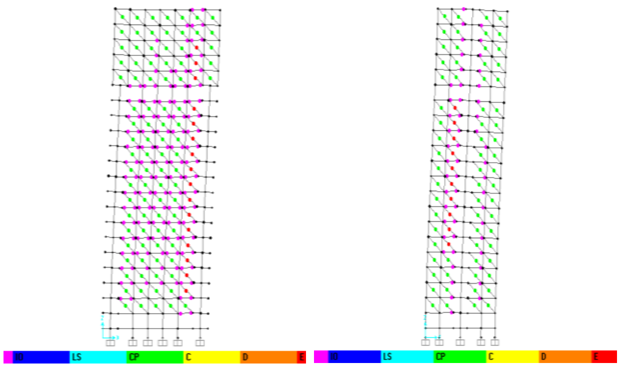

Fig.18 Hinge formation at performance point for G+20/G & 15/SW building in X and Y direction

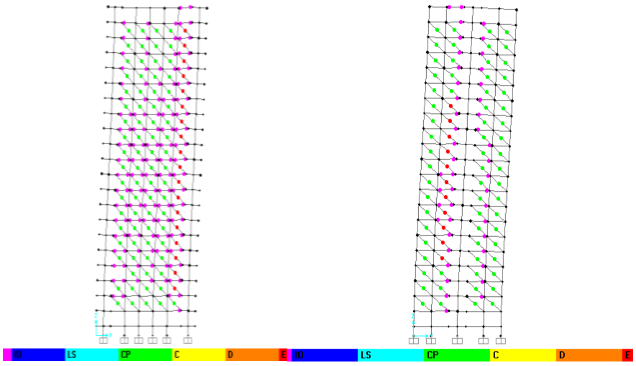

Fig.19 Hinge formation at performance point for G+20/G & 20/SW building in X and Y direction

Conclusions

1**.** This study highlights the poor seismic performance of G+20 RCC building with soft storey at different level along with soft storey at ground level.
2. It is observed that plastic hinges are developed in columns of ground level soft storey which is not acceptable criteria for safe design.
3. After retrofitting of all the models with shear walls hinges are not developed in any of the columns.
4. Provision of shear walls results in reduction in lateral displacement.
5. Displacement reduces when the soft storey is provided at higher level.
6. After retrofitting the base shear carrying capacity is increased by 8.45% to 13.26%.

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