



Article Title: Analysis of Soft Storey Buildings with Different Types of Steel Bracing Under Seismic Load

Analysis of Soft Storey Buildings with Different Types of Steel Bracing Under Seismic Load

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ABSTRACT

A soft storey is one that has a discontinuity in the stiffness of the building where one storey is significantly more flexible than the other storey. In order to tackle the problem of parking space, open ground storey is more preferred. The soft storey effect is the main criteria to be considered while constructing a building with open ground storey configuration. These buildings possess a higher tendency for collapse during earthquake due to soft storey effect. The discontinuity in stiffness will result in large bending moment and shear force action in open ground storey building. The study aims to find out the effects of soft storey configuration in the building with different types of steel bracings under seismic loads. The types of steel bracing include concentric bracing, eccentric bracing and cross bracing. The effect of bracings systems used in soft storey building under seismic load are studied using ETABS software. The different parameters like lateral displacement, bending moment, storey drift, storey shear, storey stiffness needs to be analysed and compared. Response spectrum analysis and nonlinear dynamic time history analysis is carried out to understand the behaviour of building under earthquake loads. From the results it was concluded that, the inclusion of cross steel bracing proved to be the most effective structural configuration closely followed by the concentric inverted V steel bracing configuration in order to mitigate the soft storey effect in all zones. The stability of a building can be improved by using these lateral load resisting systems.

Keywords: ETABS, Buildings, Soft storey.

1 Introduction

An earthquake is the sudden shaking of earth's surface as a result of the action of seismic waves. Over the past decades, millions of people lost their life and property due to this phenomenon. The destruction caused due to earthquake depends on its intensity which includes collapse of buildings and bridges, damaging gas pipelines, falling of trees etc. The ground motion may in turn results in landslides, volcanic eruptions and tsunamis. The major earthquakes are occurring in the belts which coincide with the margins of the tectonic plates. The shaking of earth is caused due to the sudden release of energy in some limited portion of the rock in the earth. The released energy may be expressed as chemical reactions, motion of massive bodies or elastic strain. Among these, elastic strain is the major destructive cause and the energy released due to elastic strain will lead to tectonic earthquake. This phenomenon is explained by elastic rebound theory.



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Considering about the facts of earthquake, the structures we are constructing now should be resistant to seismic action. Earthquake engineering has come a long way since its birth, and it still seems to grow rapidly as we gain experience. We learn something new during each earthquake and the profession grows widely to accommodate it. Owing to the practice and research, both are concerned mostly with the design of structures which are safe and needs to survive the seismic event with a minimum number of casualties. In India, a significant fraction of population is living in the high seismic hazard region. When we develop a structure, it should not only survive the strongest expected earthquake without collapse but also to survive with little or no damage in the earthquake with large probabilities of occurrence in the structure life. According to present codes, the reinforced concrete (RC) structures are designed as shear walls, moment resisting space frames, coupled shear walls or any combination, hence to withstand strong ground motions are expected to deform well into the inelastic range and it release energy input by the base movement through stable hysteric behavior of components of structure.

2 Recent Works

The buildings are modeled as symmetric and regular in plan. The plan dimension of the building is 25 m × 25 m. All the degree of freedom is restrained by making the base of the structure rigid. The buildings are located in seismic zone III according to IS 1893 (Part-1): 2016 and is founded on soil type II (medium). The models of building include:

- (a) **MR-A** (Bare frame building).
- (b) **MR-B** (Frame with open ground storey and infill walls in the upper storey of the building).
- (c) **MR-C** (Frame with open ground storey and infill walls in the upper storey with provision of shear wall at corners).
- (d) **MR-D** (Frame with open ground storey with provision of steel diagonal bracing at ground storey and infill walls in the upper storey of the building).
- (e) **MR-E** (Frame with open ground storey with provision of steel cross bracing at ground storey and infill walls in the upper storey of the building)

3 Proposed Work Explanation

For validation, the analytical study conducted by Kiranet *al.* (2017) is taken. The bare frame building, frame with soft storey configuration, frame with infill walls in upper storey and diagonal bracing in ground storey and frame with infill walls in upper storey and cross bracings in ground storey were analysed in Etabs software. Response Spectrum analysis is carried out for the mentioned models. The parameters like storey displacement, storey drift, storey shear



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and storey stiffness were studied and compared. They also conducted nonlinear static pushover analysis in the same building models.

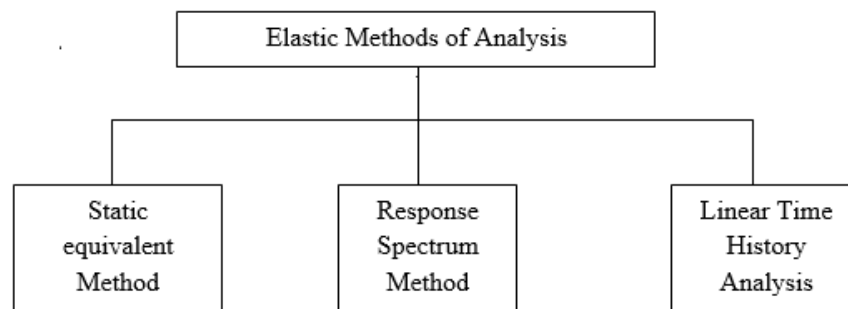


Figure 1: *Elastic methods of analysis*

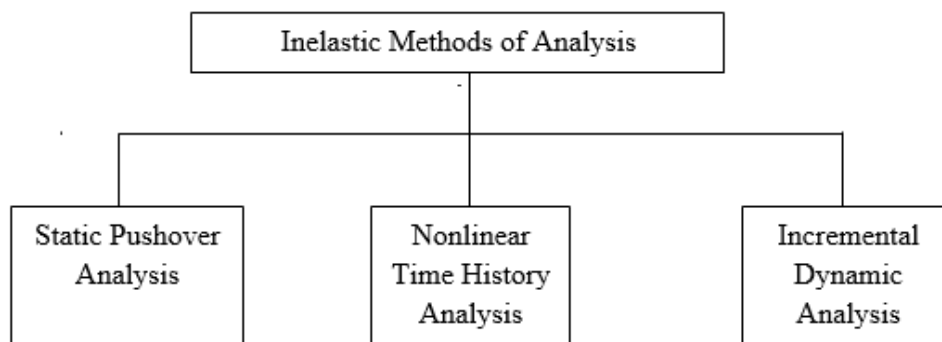


Figure 2: *Inelastic methods of analysis*

3.1 Mathematical Expressions and Symbols

In equivalent static method of analysis, the magnitude of lateral force depends only on the fundamental period of the vibration of building. It is calculated by using the empirical formula provided in the seismic code. But in case of a building which is multistoried, it possesses multiple degrees of freedom, therefore it exhibits many possible patterns of deformations. The base shear is distributed over the height of the structure and is obtained due to the super position of all the modes of vibration of the multi degrees of freedom system. The equivalent static analysis procedure is explained below:

(i) Determination of fundamental natural period (T_a) of the structure

- (a) Moment resisting reinforced concrete building without brick masonry infill wall

$$T_a = 0.075 \times h^{0.75} \dots\dots (1)$$

- (b) Moment resisting steel frame building without brick masonry infill wall

$$T_a = 0.085 \times h^{0.75} \dots\dots (2)$$

- (c) All other buildings including moment resisting reinforced concrete frame with brick masonry infill wall



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$$T_a = 0.09 \times (h/\sqrt{d}) \dots \dots \quad (3)$$

where, h = height of the building (m)

d = base dimension of the building at plinth level (m) along the considered direction of lateral force.

(ii) Determination of base shear of the building (V_B)

$$V_B = A_h \times W \dots \dots \quad (4)$$

Where,

$$A_h = \frac{Z \times I \times S_a}{2 \times R \times g} \dots \dots \quad (5)$$

A_h is called the design horizontal seismic coefficient. A_h is a function of seismic zone factor (Z), Importance factor (I), Response reduction factor (R) and average response acceleration coefficients (S_a/g). S_a/g depends on the nature of soil in foundation (soft soil sites, medium or rock), damping and the natural period of the building.

(iii) Distribution of base shear

The design base shear which is obtained from the analysis is dispensed along the height of the structure as per the following expressions:

$$Q_i = V_B \times \sum_{i=1}^n \frac{W_i h_i^2}{\sum W_i h_i^2} \quad (6)$$

Where, Q_i = Design lateral force

W_i = Seismic Weight

h_i = Height of the i^{th} floor measured from base

n = number of stories of the building

4. Results and Discussion

After the validation, the results from validation and the results from the journal (Kiranet *al.*, 2017) were compared. Both the results shows similar trend. Some variations are there in values because only the equation for calculating the width of infill wall is given in the journal and it didn't mentioned the value of the width of infill wall taken for analysis. Cross steel braced building shows much practicability in resisting the lateral loads in both the results. The storey displacement and storey drift value of the cross steel braced structure is less when compared to other models. The stiffness of the structure is increased with the provision of cross steel braced frame.

4.1 Preparation of Figures and Tables

The buildings are symmetric and regular in plan. The plan dimension of the building is 25 m×25 m. All the degree of freedom is restrained by making the base of the structure rigid. The buildings are located in various seismic zones according to IS 1893 (Part 1): 2016 and is



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founded on soil type II (medium). The modeling of masonry infill wall in the building is done by equivalent diagonal strut method as given in FEMA-273.

Table 1: Data used for the analysis

SL. No.	Description	Specifications
1	Building frame system	G+6 (OMRF)
2	Ground storey height	3.5 m
3	Typical storey height	3.5 m
4	Type of soil	Medium (II)
5	Support Condition	Fixed
6	Grade of concrete	M30
7	Grade of steel	Fe415
8	Live load	3.5 kN/m ²
9	Floor finish	1 kN/m ²
10	Steel Section	ISMB 600
11	Infill panel	Brick Masonry
12	Importance Factor	1
13	Response Reduction Factor	3
14	Column size	650 mm × 650 mm
15	Beam size	400 mm × 400 mm
16	Slab Thickness	125 mm
17	Thickness of brick wall	230 mm

The generated models of buildings in ETABS, with different suggested structural arrangements are shown below in Figure 5.2 (a) - (f). The models of building in various seismic zones are also provided with the same structural configurations but they are not shown here for brevity. The buildings are designed according to IS1893 (Part 1): 2016 and the steel sections are designed according to IS 800: 2007. The frame considered is Special Moment Resisting Frame (SMRF). The plan dimension of the building is 25 m×25 m.



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Table 2: Dimensions of the frame members

	Zone II	Zone III	Zone IV	Zone V
Beam size	230 mm× 300 mm	230 mm×300 mm	230 mm×350 mm	230 mm×350 mm
Column Size	300 mm×300 mm	300 mm×300 mm	350 mm×350 mm	400 mm ×400 mm
Steel section	ISMB 250	ISMB 250	ISMB 300	ISMB 300
Infill wall size	230 mm×500 mm	230 mm×500 mm	230 mm×600 mm	230 mm×600 mm

Table 3: Data used for the analysis

SL. No.	Description	Specifications
1	Building frame system	G+6 (SMRF)
2	Ground storey height	3 m
3	Typical storey height	3 m
4	Type of soil	Medium (II)
5	Support Condition	Fixed
6	Grade of concrete	M30
7	Grade of steel	Fe415
8	Live load	3 kN/m ²
9	Floor finish	1 kN/m ²
10	Infill panel	Brick Masonry
11	Response Reduction Factor	5
12	Importance Factor	1
13	Slab Thickness	125 mm
14	Thickness of brick wall	230



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5 Conclusions

In this project, studies have been carried out to mitigate the effect of soft storey in buildings with different types of steel bracings. Two studies are conducted to analyze the building in various zone. Formerly, buildings are designed with same dimensions and same properties in all the 4 zones of India. Latterly, the buildings are designed separately in each of the zone. This was done because while design specifically in each zone the dimensions of the frame members can be designed economically. The dimension of frame members is reduced in buildings which are designed separately while comparing the former design. The response of the two studies does not show much variation in all zones.

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