Seismic Behavior of Flat Slab for Optimum Location of Bracings

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Abstract. As increasing population necessity of the land required to build a structures is keep on decreasing so that high rise structures are everywhere. Use of flat slab in high rise structure has many advantages compared to RC conventional slab system. To increase the lateral resistivity of the flat slab building, diagonal type buckling restrained braces are provided at the corners. The main objective is to know about the Seismic behavior of flat slab with BRB for different re-entrant corner irregularities (Plus, T, L), using nonlinear time history analysis with help of ETABS software. 20storey flat slab drop panel building with BRB is modelled and analyzed in zone III. Comparing the different re-entrant irregularity buildings with and without bracings. Plus shape flat slab with bracing building shows better performance compared to all other models with respects to various parameters such as lateral displacement. Storey drift, storey stiffness, base shear and time period.

Key words- Flat slab; Drop panel; Buckling restrained braces; Re-entrant corner irregularity.

1. Introduction

Due to increasing population every day availability of land required to build a house is keep on decreasing so, it is necessary to increase the verticality of a building instead of width of a building hence engineers are decided to build a high rise structure. In today’s world high rise structures are seeing everywhere. Building a high rise structure is not an easy, increasing the height of structure make the structure vulnerable to lateral loads it cause damage or collapse of the structure. It makes the structure uneconomical. Use of flat slab in high rise structure has may advantages compare to RC conventional slab. In flat slab system it doesn’t contain any beam slab is directly resting over the column. Flat slab system is economical and require less form work, faster construction rate, architectural feasibility, gives better illumination to structure and easy to install mechanical and electrical services [1-2]. But flat slab is not much efficient has RC conventional slab to resist the lateral load so that additional resisting technique’s that is bracings are provided. Bracings has many different type such X, V, K, diagonal, zigzag, etc and different steel section bracings are pipe, Box, double...
angle, BRB, tube, etc. Bracings make the structure stable stiffer. BRB is ability of bracings to resist the buckling in structure and reduce deflection. More the span in the structure more the buckling to reduce that it better to choose the BRB it is easy to install and economical [3-6].

In our project we are taking plan irregular, the shape of the building irregularities is +, T and L shape all these shapes are coming under re-entrant coroner type irregularities. The main objective of this project is to study the seismic behavior of flat slab with irregular plan provided with BRB bracings at the coroner portion analysis carried by non-linear time history method using ETAB software 2016.

2. Buckling restrained braces

- The ability of bracings to resist the buckling under compression are called buckling restrained bracings.
- BRB can be used for new and seismic retrofit projects.
- Simple design and erection.
- Use of BRB is a clear cost saving.
- BRB is a low weight so it is doesn’t require a foundation strengthening.
- BRB controls the stiffness of the building hence it leads to the better performance of the building.
- Investigation and replacement after earthquake is very easy due to damages concentrated only on small areas.

![Components of BRB](image)

Figure 1. Components of BRB

3. Objective

Objective of the present work is to determine the performance of G+19 storey flat slab building having different irregular plan with and without bracings is analysed in ETAB software using non-linear time history method.

- Determine the Story displacement, Story drift, Base shear, Storey stiffness for all the models.
- Compare the seismic response of different irregular plan with and without bracings subjected to lateral load.
- Finally identify the suitable irregular building model in all the models to resist the seismic loads.
4. Structural information about the Building

In this project we are considered 20 storey irregular plan having L,T, + shape flat slab building with bracings at the corners.

Following are the structural information about the building.

- Type of the frame: SMRF
- Spacing in X and Y direction: 8M
- Number of grid lines in both the direction: 7
- Column dimension: 1100X1100MM
- Width and thickness of the drop: 3000MM ad 300MM
- Number of stories: 20
- Soil type: II (medium)
- Zone: 3
- Importance factor: 1
- Response reduction factor: 5
- Slab thickness: 200mm
- Live load: 2.0 KN/m²
- Height of the floor: 3.2m.
- M30 grade concrete is used for both columns and slab Fe 415 steel is used.
- BRB 1.0 weld is used for steel bracing.

5. Modelling of building

Modelling is done for the 20 storey irregular building plan flat slab building with bracings and without bracing. Here buckling restrained zig-zag type bracing are used. Flat slab Building is designed according to IS: 456-2000 and earthquake details were considered as per the recommendation of IS: 1893-2002. All building models considered here is assumed to be located in seismic zone 3 of India and rest on soil type II condition. Seismic parameters considered are, Zone factor for seismic zone 3 = 0.16, Soil site factor for medium soil condition = 2, important building Importance factor = 1. Response reduction factor = 5 Damping ratio = 0.05. Analyses is carried out by nonlinear time history method considering the ELECENTRO earthquake and checked for other two earthquakes such as YERMO-1 and SYLMARFF-1 using ETAB 2016 software. The live load is taken as 2kN/m². Load combinations are applied as per the IS 875 part 5 Indian standard codes.

Total 18 models are analysed in this project. L,T,PLUS shape bare frame models and bracings at the corners for 3 different earthquake magnitude.

For this steel bracing BRB.1.0 weld is used. Fe 415 steel is for reinforcement.

The following are the irregular plan, and arrangements of bracing systems.
5.1. Etab software models

Figure 2. L shape flat slab building

Figure 3. L shape flat slab building with bracings

Figure 4. Plus shape flat slab building

Figure 5. Plus shape flat slab building with bracings

Figure 6. T shape flat slab building

Figure 7. T shape flat slab building with bracings

6. Results

6.1. Lateral displacement

- Displacement of the one storey with respect the base of the structure is called maximum displacement.
- Maximum permissible limit of the displacement for the models is 
  \[ \frac{H}{500} = 128 \text{mm} (H=64000\text{mm}) \].
- Lateral displacement of T shape building is more as compared to other types of building.
- For unbraced models lateral displacement of Plus shape building is 19.53% and L shape building is 9.54% less than the T shape building.
- For braced models lateral displacement of Plus shape building is 9.08% and L shape building is 1.46% less than the T shape building.
Providing the bracings at the corners reduces the lateral displacement of the building. Providing bracings reduces lateral displacement up to 22.56% in T shape, 15.64% in L shape and 12.51% in Plus shape.

Following graph shows the lateral displacement of all the model.

![Displacement Graph](image)

**Figure 8.** Lateral displacement values of all the model

6.2. Maximum drift

- Drift is defined as the displacement of the storey with respect to the adjacent storey.
- Permissible limit of the drift as per the IS 1893:2002 code book is \(=0.004h\), where \(h=\) storey height in m = 0.0128 mm. Storey drift is more in T shape building compared to all other building.
- Storey drift is 25.11% less in plus shape and 15.96% less in L shape building compared to T shape building for unbraced models.
- Storey drift is 12.66% less in plus shape and 5.57% less in L shape building compared to T shape building for braced models.
- Providing the bracings at the corners reduces the storey drift of the building. Providing bracings reduces storey drift up to 24.66% in T shape, 15.35% in L shape and 12.14% in Plus shape.

![Drift Graph](image)

**Figure 9.** Drift values of all the models

6.3. Storey stiffness

- Stiffness is defined as the rigidity of the building to resist the deformation to a certain extent in response to applied force.
Higher the stiffness, lower will be the building deflection.

Storey stiffness is 84.10% less in T shape and 3.22% less in L shape building compared to Plus shape building for unbraced models.

Storey stiffness is 83.64% less in T shape and 7.5% less in L shape building compared to Plus shape building for braced models.

Providing the bracings at the corners reduces the storey stiffness of the building. Providing bracings increases storey stiffness up to 12.29% in Plus shape, 8.24% in L shape and 14.75% in T shape.

Following graph shows the storey stiffness of all the models.

![Storey Stiffness](image)

**Figure 10.** Storey stiffness values of all the models

### 6.4. Base shear

- Base shear is defined as the horizontal forces acting at the base of the structure to resist the seismic loads or wind loads.
- More the base shear, higher capacity will be the structure to resist the lateral loads.
- T shape flat slab building as the lesser value of the base shear compare to the all other models.
- Base shear of T shape and L shape building is 2.29% less than the Plus shape building for unbraced models.
- For braced models base shear of T shape building is 13.25% and L shape is 7.68% less than Plus shape building.
- Providing the bracings at the corners increases the base shear in all the models, base shear is increased to 0.0035% in T shape, 10.75% in Plus shape and 5.2% L shape buildings.
- Following graph shows the base shear of all the models.
6.5. Time period

- Time period is defined as the time taken to complete one cycle.
- In this project we considered elcentro earthquake for non linear time history analysis, according to that following values are the time period values of the each models.
- Time period value is almost same all the models except T shape flat slab building with bracings and without bracings. Other than that all the models have same value of the time period.
- Following graph shows that comparison time period value of the all the models.

![Time Period Graph](image)

**Figure 12.** Time period value of all the models
7. Conclusions

- Bracings provided at the corner shows better performance to resist the lateral load in all the models.
- Plus shape flat slab with bracings at all the corner of the building shows greater performance in reducing displacement and drift value compared to all the other models.
- Drift and displacement value is lesser in plus shape building than L shape building and lastly T shape building.
- Plus shape building with bracings has greater value of base shear and storey stiffness compared to L and T shape building.
- Time period value is almost same in all the models.
- By comparing all the values plus shape flat slab building with bracings shows greater value than other models hence plus shape flat slab building with bracings at the corner is recommended.

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