Seismic performance of a multi storey building with steel bracings: A comparative study

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Abstract:

Steel bracing is a most efficient and economical method which improves the seismic performance by increasing lateral stiffness and capacity to resist the lateral forces of a multi storey building. According to this investigation the main focus is to study the different types of bracing system such as cross bracing and V bracing at different orientations of a G+5 storied building. The building considered in analysis has a plan dimension of 16m x 20m is subjected to Bhuj earthquake ground motion. Time history method one of the advanced methods of non-linear dynamic analysis is used to study the seismic performance of the structure. Commercial software STAAD Pro. V8i is used for this analysis. The behavior of the structure is evaluated by parameters such as storey drift, storey displacement, base shear, nodal displacement and time-acceleration response etc. The results of the seismic performance of each model are tabulated and represented graphically for comparing the variation in performances of each model (bare frame and braced frame) and determining the effective bracing systems and its location.

Key words: Cross Bracing, V bracing, Time History Analysis, Base shear, Storey drift, Storey displacement, Time-acceleration.

INTRODUCTION

In case of multistoried building Steel bracings can be provided with different orientations of the building and designed properly to increase the building strength and stiffness capacity. For construction steel bracings are more suitable than concrete bracing because steel bracings are more economic and easy to erect from their position. Therefore for the construction it is a vital factor to decide the effective location for providing steel bracings for a lateral load resisting frame. In this study the results are to be compared for different bracing types with different orientations according to bare frame which can be a deciding factor for an economic construction.

RELATED WORKS

I. Adithya,M., Swathi rani,K.S, Shruthi,H.K, and Ramesh, B.R.(2015) studied the seismic behavior of a Multi storied R.C.C building with steel bracing. This project is studied about the efficiency of using different types of bracings and with different steel profiles for bracing members for multi-storey steel frames.

II. Mehta, V., and Rana K. (2017) studied on Multi-storey regular buildings with (G+25) stories have been modelled using software STAAD Pro. for seismic zone V in India and by using Time history method for multi-storey building the storey displacement and storey drift calculated.

III. Kulkarni, Y.U., Chandak, P.G., Devtale, M.K., Sayyed, S.S. (2016) studied on the behaviour of the bracing system in analysis for parameters like displacement, weight etc by using different types of bracing systems e.g. X bracing, V bracing, Inverted V bracings, Knee bracings.

DESCRIPTION OF MODELS

In this study a G+5 building with plan dimension 16m x 20m has been considered for seismic analysis. The height of the each storey of this building is 3m. The seismic analysis has been carried out in STAAD pro. V8i software using Time history analysis. For this analysis the collection of Bhuj Earthquake time-acceleration data is taken as the external input which is processed by IIT, Roorkee.
Table-1: Dimensional properties of structure

<table>
<thead>
<tr>
<th>S.no</th>
<th>Properties</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Columns</td>
<td>0.5 x 0.5 m</td>
</tr>
<tr>
<td>2</td>
<td>Beams</td>
<td>0.3 x 0.5 m</td>
</tr>
<tr>
<td>3</td>
<td>Member weight on floor beams</td>
<td>12.5 kN/m</td>
</tr>
<tr>
<td>4</td>
<td>Member weight on roof beams</td>
<td>4.2 kN/m</td>
</tr>
<tr>
<td>5</td>
<td>Slab thickness</td>
<td>0.125 m</td>
</tr>
<tr>
<td>6</td>
<td>Bracing</td>
<td>ISA150 x150 x12</td>
</tr>
<tr>
<td>7</td>
<td>Imposed load on floors</td>
<td>3.0 kN/m²</td>
</tr>
<tr>
<td>8</td>
<td>Imposed load on roof</td>
<td>1.5 kN/m²</td>
</tr>
<tr>
<td>9</td>
<td>Damping</td>
<td>5%</td>
</tr>
</tbody>
</table>

Bracings are provided at four different locations in the frame and the models are represented as follows.

Table-2: Representation of Models

<table>
<thead>
<tr>
<th>TYPE OF MODEL</th>
<th>REPRESENTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare frame</td>
<td>Type 1</td>
</tr>
<tr>
<td>Braced frame of X bracing</td>
<td>Type 2A</td>
</tr>
<tr>
<td>Braced frame of V bracing</td>
<td>Type 2B</td>
</tr>
<tr>
<td>Bracing applied at corner of X bracing</td>
<td>Type-3A</td>
</tr>
<tr>
<td>Bracing applied at corner of V bracing</td>
<td>Type-3B</td>
</tr>
<tr>
<td>Bracing applied at middle of X bracing</td>
<td>Type-4A</td>
</tr>
<tr>
<td>Bracing applied at middle of V bracing</td>
<td>Type-4B</td>
</tr>
<tr>
<td>Bracing applied at periphery diagonally of X bracing</td>
<td>Type-5A</td>
</tr>
<tr>
<td>Bracing applied at periphery diagonally of V bracing</td>
<td>Type-5B</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

The seismic analysis has been done by using STAAD Pro. V8i software and the results are tabulated and then represented graphically. To ascertain the behavior of the structure parameters considered are maximum base shear, inter storey drift, storey displacements and maximum nodal displacements and time-acceleration.

Base Shear:

The base shear is interpreted as the maximum expected lateral force that will occur due to the seismic ground motion at the base of a structure.

<table>
<thead>
<tr>
<th>Type of Model</th>
<th>Base shear (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type-1</td>
<td>1323.877</td>
</tr>
<tr>
<td>Type-2A</td>
<td>1384.311</td>
</tr>
<tr>
<td>Type-2B</td>
<td>1373.557</td>
</tr>
<tr>
<td>Type-3A</td>
<td>1309.801</td>
</tr>
<tr>
<td>Type-3B</td>
<td>1298.725</td>
</tr>
<tr>
<td>Type-4A</td>
<td>1337.495</td>
</tr>
<tr>
<td>Type-4B</td>
<td>1310.681</td>
</tr>
<tr>
<td>Type-5A</td>
<td>1304.492</td>
</tr>
<tr>
<td>Type-5B</td>
<td>1319.469</td>
</tr>
</tbody>
</table>

Table-3: Base shear in X direction

Among the bracing frames maximum base shear in X direction is observed in Type-2A and minimum for Type-3B. When the bracing system is provided at other positions of the building like corner, middle and periphery diagonally and as compared to the bare frame maximum base shear is observed in Type-4A and minimum base shear is observed in Type-3B.

Inter Storey Drift:

Storey drift should be taken within 0.4% of the storey height as per IS 1893-2002 (Part-1). The building considered in this study, the safe limit for storey drift is 12mm. Inter storey drifts in the bare frame was found to exceed this limit of 12mm.
Table 4: Inter Storey Drift in X direction

<table>
<thead>
<tr>
<th>Storey</th>
<th>Type 1</th>
<th>Type 2A</th>
<th>Type 2B</th>
<th>Type 3A</th>
<th>Type 3B</th>
<th>Type 4A</th>
<th>Type 4B</th>
<th>Type 5A</th>
<th>Type 5B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>10.132</td>
<td>3.419</td>
<td>3.552</td>
<td>4.428</td>
<td>4.856</td>
<td>5.800</td>
<td>4.794</td>
<td>5.8</td>
<td>6.468</td>
</tr>
<tr>
<td>6</td>
<td>5.297</td>
<td>1.253</td>
<td>1.472</td>
<td>2.616</td>
<td>2.918</td>
<td>3.517</td>
<td>2.509</td>
<td>3.517</td>
<td>3.785</td>
</tr>
<tr>
<td>7</td>
<td>3.037</td>
<td>0.646</td>
<td>1.432</td>
<td>1.722</td>
<td>2.483</td>
<td>2.375</td>
<td>1.559</td>
<td>2.375</td>
<td>2.720</td>
</tr>
</tbody>
</table>

Figure 7: Inter storey drift in X direction

Minimum inter storey drift was observed in Type-2A and maximum in Type-1. When the bracing system is provided at other positions of the building like corner, middle and periphery diagonally and as compared to the bare frame maximum inter storey drift is observed in Type-1 and minimum inter storey drift is observed in Type-4B.

Storey displacement:

Storey displacement may be interpreted as lateral displacement of a given storey with respect to the basement of the structure. Storey displacements for the models with different steel bracing orientations are tabulated below.

Table 5: Storey Displacement in X direction

<table>
<thead>
<tr>
<th>Storey</th>
<th>Type 1</th>
<th>Type 2A</th>
<th>Type 2B</th>
<th>Type 3A</th>
<th>Type 3B</th>
<th>Type 4A</th>
<th>Type 4B</th>
<th>Type 5A</th>
<th>Type 5B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Minimum storey displacement was observed in Type-2A and maximum in Type-1. When the bracings are provided at some positions of the building like corner, middle and periphery diagonally and as compared to the bare frame maximum storey displacement is observed in Type-1 and minimum storey displacement is observed in Type-4A.

**Maximum Nodal Displacement:**

The maximum nodal displacement in lateral directions of the bare frame was found to be higher than the braced frames. For the safety purpose nodal displacement should be minimum.

**Table 6: Maximum Nodal Displacement in direction**

<table>
<thead>
<tr>
<th>Model Type</th>
<th>Maximum Nodal displacement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type-1</td>
<td>42.683</td>
</tr>
<tr>
<td>Type-2A</td>
<td>19.474</td>
</tr>
<tr>
<td>Type-2B</td>
<td>20.969</td>
</tr>
<tr>
<td>Type-3A</td>
<td>24.606</td>
</tr>
<tr>
<td>Type-3B</td>
<td>26.717</td>
</tr>
<tr>
<td>Type-4A</td>
<td>23.129</td>
</tr>
<tr>
<td>Type-4B</td>
<td>25.204</td>
</tr>
<tr>
<td>Type-5A</td>
<td>29.252</td>
</tr>
<tr>
<td>Type-5B</td>
<td>31.443</td>
</tr>
</tbody>
</table>
Among the models, with steel bracings, minimum nodal displacement was observed in case of type-2A i.e. in braced frame and maximum nodal displacement was observed in case of type-1 i.e. bare frame. When the bracing provided at some position of the building like corner, middle and periphery diagonally and as compared to the bare frame maximum nodal displacement is observed in Type-1 and minimum nodal displacement is observed in Type-4A.

**Acceleration according to time period:**

According to time period the acceleration graph are to be plotted for various models.

Among the models, with steel bracing, minimum acceleration was observed in case of type-2A i.e. in braced frame and maximum acceleration was observed in case of type-1 i.e. bare frame. When the bracing provided at some position of the building like corner, middle and periphery diagonally and as compared to the bare frame maximum acceleration is observed in Type-1 and minimum acceleration is observed in Type-4A.

**CONCLUSION**

Form the results obtained it can be concluded that when the bracings are applied the inter storey drift, storey displacement and nodal displacement, acceleration reduced significantly. Hence Type-2A may be considered as the stiffer orientation in comparison to other type of models. When the bracing provided at some position like corner, middle and periphery diagonally of the building and the bare frame Type-4A may be considered as the stiffer orientation in comparison to other models and cross bracing is more suitable than V bracing.

**REFERENCES**

2. [https://strongmotioncenter.org/](https://strongmotioncenter.org/) the previous data of earthquake ground motion data collected from “Center For Engineering Strong Motion Data.”
