# Modelling of Completely Braced Multistoreyed Building Frames Subjected to Gravity and Earthquake Loads

Jiya Jose[1], Dona Sunny[2]
[1]PG Student, [2]Assistant Professor
Department Of Civil Engineering
Mangalam College of Engineering and Technology, Kottayam, Kerala, India

***Abstract*:- The structure in high seismic areas may be susceptible to the severe damage. Along with gravity load structure has to withstand to lateral load which can develop high stresses. Now-a-days, shear wall in R.C.structure and steel bracings in steel structure are most popular system to resist lateral load due to earthquake, wind, blast etc. bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear. Through the addition of the bracing system, load could be transferred out of the frame and into the braces, by passing the weak columns while increasing strength. In this study R.C.C. building is modelled and analysed for 3-bay and 4-bay G+11 structure in two Parts viz., Model without RC bracing (bare frame), (ii) Model completely RC braced .The computer aided analysis is done by using STAAD-PRO to find out the effective lateral load system during earthquake in high seismic areas.**

***Keywords: Bracing, G+11 Structure,Bare Frame,***

## 1. INTRODUCTION

Bracing is a highly efficient and economical method of resisting of lateral forces in a steel structure. The most common types of bracing are those that form a fully triangulated vertical truss. These include the concentric and eccentric braced types. In high-rise buildings, the location and number of bracings is an important limitation to the architectural plan. A similar scheme has been used in larger scale spanning multiple stories and bays in tall buildings which is called large-scale bracing system. Large-scale bracing (LSB) is a particular form of a space truss. Analytical results show that, the large-scale bracing is more adequate system under the lateral loads.

## 2. LITERATURE REVIEW

1. DEEPAK D.MASLEKAR: 17th March 2018: A braced frame is an efficient structural form for resisting lateral loads. It acts as a vertical truss, with the columns as chords and the braces and girders as web members. The most efficient and conventional type of bracing, using full diagonals, is also the most obstructive to architectural plan. Other arrangements are available that are more amenable to allowing openings, but that are less stiff horizontally. The efficiency of bracing in being able to produce a laterally high stiffness for a minimum of additional material makes it an economic structural system for any height of building.

2. FEMA P-749 / December 2010: Today's design professionals know how to design and construct buildings and other structures that can resist even the most intense earthquake effects with little damage. However, designing structures in this manner can significantly increase their construction cost. Even in the areas of highest earthquake risk in the United States, severe earthquakes occur infrequently, often with 100 or more years between events capable of causing widespread damage. Given that many structures have, on average, useful lives of 50 years, constructing every structure so that it is invulnerable to earthquake damage would not be a wise use of society's resources.

3. Dhananjay.S.Pawar et al. Int. Journal of Engineering Research and Applications: Over the past three decades, India has experienced number of earthquakes that caused large damage to residential and industrial structure. Today, over 60% of Indian land areas lies in higher three seismic zone III, IV and V as per Indian seismic code [IS 1893 (Part-1):2002]. However, only about 3% of build environment is properly engineered. India has potential for strong seismic shaking with large stock of vulnerable buildings. Thus, there is urgent need to introduce proper earthquake-resistant design and construction features. Use of steel in construction can be of significant help in building safe built-environment in earthquake prone regions of India. Steel as material is ductile.

4. Amin Mohebkhah* and Marzieh AkefiJune 23, 2016: Braced steel frames are sometimes designed with out-of-plane shifted bracing members on the first story due to architectural or functional considerations. Such frames are classified and designated as frames having the Type-4 horizontal structural irregularity entitled "frames with out-of-plane offset irregularity" as per the Minimum Design Loads for Building and Other Structures (ASCE 7-10). The purpose of this study is to investigate the nonlinear seismic behavior of ordinary steel concentrically braced frames with out-of-plane offset irregularity and evaluate their seismic design parameters.

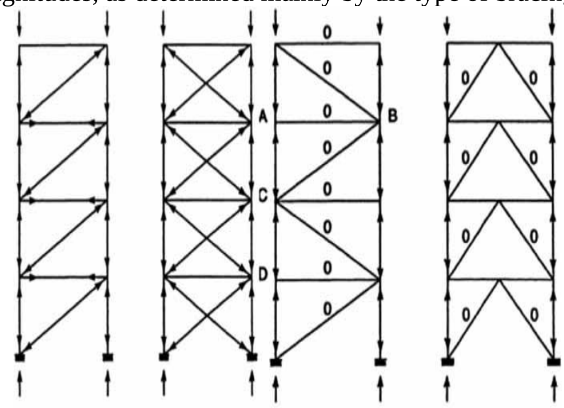
## 3. RELATED WORK

3.1 Analysis of Multi-storeyed Building Subjected To Various Loads

Multi-storeyed buildings are designed for gravity loads as well as lateral loads and their combination. IS code providing these loading combination for which structure need to be analysed and designed. In the analysis the internal forces in the component structures, displacements are found out. A number of structures with different heights and widths- with and without braces have been analysed. The responses of braced frames of different types have been compared with each other and the same also have been compared with unbraced frame.

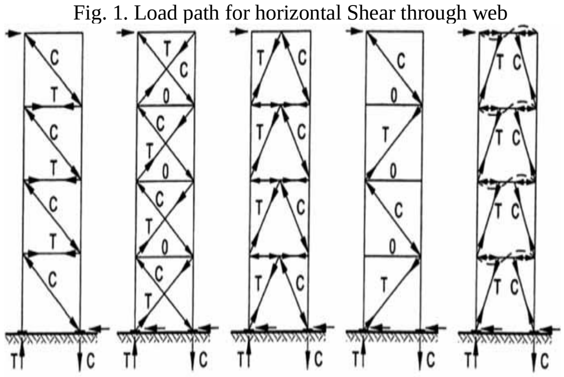
3.2 Behaviour of different bracing systems

In braced frames, the columns act as the chords in resisting the overturning moment, with tension in the windward column and compression in the leeward column. The diagonals work as the web members resisting the horizontal shear in axial compression or tension, depending on the direction of inclination. The beams act axially, when the system is a fully triangulated truss. They undergo bending only when the braces are eccentrically connected to them. The effect of axial deformation of the columns results in a ‘‘flexural’’ configuration of the deflection with concavity downwind and a maximum slope at the top. The axial deformations of the web members, on the other hand, cause a ‘‘shear’’ configuration of deflection with concavity upwind, a maximum slope at the base, and a zero slope at the top. The resulting deflected shape of the frame is a combination of the effects of the flexural and shear curves, with a resultant configuration depending on their relative magnitudes, as determined mainly by the type of bracing.




a – single diagonal; b – X; c – single-diagonal; d – chevron

Fig. 1. Load path for horizontal Shear through web



a – single diagonal; b – X; c – chevron;
d – single-diagonal; e – knee

Fig. 2. Gravity load path in CBF systems

4. METHODOLOGY

4.1 Methods of structural analysis

To perform an accurate analysis structural engineer must determine such information as structural loads, geometry, support conditions and material properties. The results of such an analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure. Advanced structural analysis may examine dynamic response, stability and nonlinear behaviour. The structural analysis is basically done by three approaches.

i. Mechanics of material approach- Applied to very simple structural elements under relatively simple loading condition.

ii. Elasticity theory approach- Applied to general geometry under general loading condition.

iii. Finite element approach- Applied at highly complex geometry and loading conditions.

4.2 Methods of Earthquake Analysis

Earthquake analysis of building is required to know how the building is going to behave at the time of earthquake. There are two methods of earthquake analysis static analysis and dynamic analysis. Static analysis does not give us clear idea of how the structure is going to behave during earthquake but gives approximate forces and displacements. Dynamic analysis gives somewhat accurate results. This method requires large amount of computational work. Moreover, to carry out this analysis ground motion data is required.

4.3 Problem Definition

Plane frame is one in which all the members and applied forces lie in same plane. The joints between members are generally rigid. The stress resultants are axial force, bending moment and corresponding shear force. As plane frames were used for the project so linear elastic plane frame analysis is performed for the different models of the building using STAAD III analysis package. The frame members are modelled with rigid end zones.

If the base of the structure is suddenly moved, as in a seismic event, the upper part of the structure will not respond instantaneously, but will lag because of the inertial resistance and flexibility of the structure. The resulting stresses and distortions in the building are the same as if the base of the structure were to remain stationary while time-varying inertia forces are applied to the upper part of the building. Generally, the inertia forces generated by the horizontal components of ground motion require greater consideration for seismic design since adequate resistance to vertical seismic loads is usually provided by the member capacities required for gravity load design. These forces are called inertia forces that is F = ma. In the equivalent static analysis procedure, the inertia forces are represented by equivalent static forces. Fig.1 shows various configurations used for structural analysis and Table 1 shows Models used for this analysis.

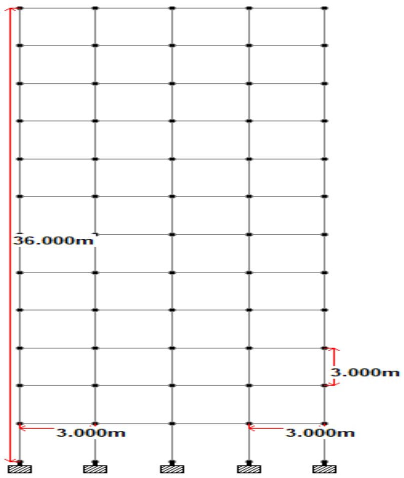



Fig.3 Bare frame

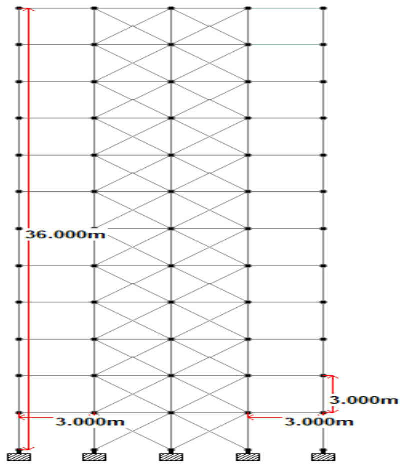



Fig.4 Zip Braced Frame

5. MODELS USED

| Sr. No. | Model | Storey Variation | Bay Variation | Beam depth(mm) |
|---|---|---|---|---|
| I | Bare Frame | G+11 | 3 and 4 | 350 to 600 |
| II | Fully Braced Frame | G+11 | 3 and 4 | 350 to 600 |

6. LOAD COMBINATIONS

In the limit state design of reinforced concrete structures, following load combinations shall be accounted as per I.S. 1893 (Part I) – 2002[1], where the terms D.L., I.L., and EL. stand for the response quantities due to dead load, imposed load and designated Earthquake load respectively.

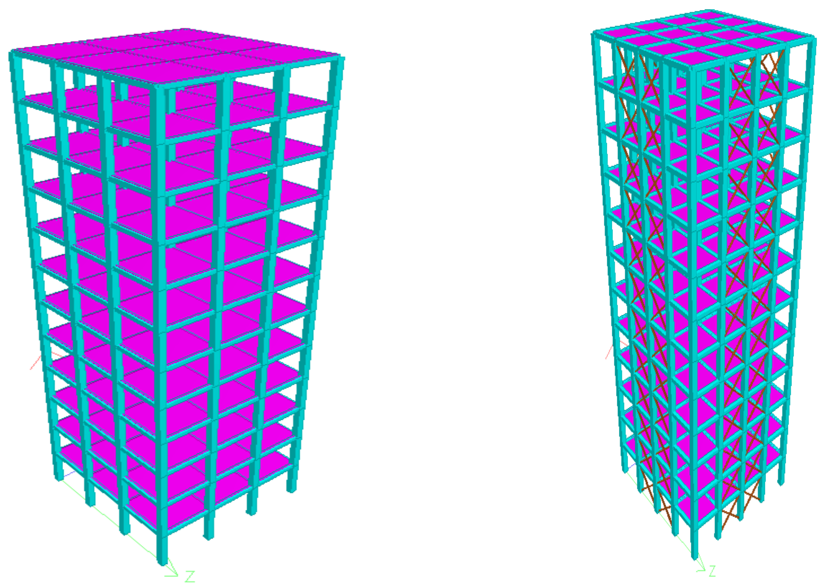


Fig.4 G+11 structures with and without bracings

## 7. RESULTS AND DISCUSSION

Bare Frames and Frames with Zip Type of Bracing

Table 2:

Variation of axial force, Ra, shear force, Rs and bending moment, Rm in bottom node of *bare frame* having specific no. of bays as depth of beam is changed

| **No. of bays** | **Axial force, Ra ( G+11)** | | | | | |
|---|---|---|---|---|---|---|
| | **Beam Depth** | | | | | |
| | **350** | **400** | **450** | **500** | **550** | **600** |
| **3** | 2369.05 | 2316.54 | 2262.93 | 2305.32 | 2345.1 | 2381.85 |
| **4** | 2367.93 | 2315.63 | 2259.11 | 2301.03 | 2340.32 | 2376.96 |

| **No. of bays** | **Shear force, Rs ( G+11)** | | | | | |
|---|---|---|---|---|---|---|
| | **Beam Depth** | | | | | |
| | **350** | **400** | **450** | **500** | **550** | **600** |
| **3** | 36.525 | 36.092 | 35.824 | 36.617 | 36.465 | 36.361 |
| **4** | 38.784 | 38.362 | 38.017 | 37.747 | 37.543 | 37.401 |

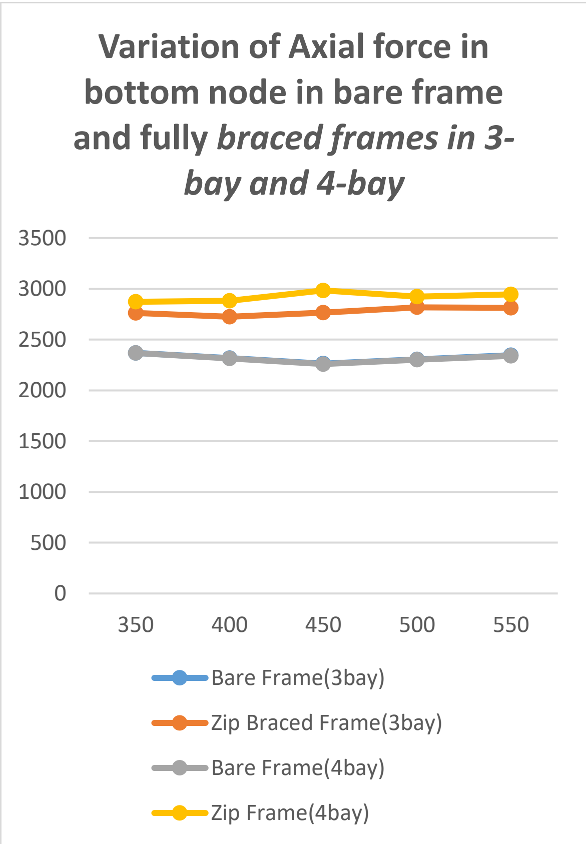
| **No. of bays** | **Bending Moment, Rm ( G+11)** | | | | | |
|---|---|---|---|---|---|---|
| | **Beam Depth** | | | | | |
| | **350** | **400** | **450** | **500** | **550** | **600** |
| **3** | 351.846 | 300.087 | 289.285 | 246.905 | 221.021 | 140.157 |
| **4** | 385.786 | 332.601 | 280.835 | 247.812 | 221.502 | 180.357 |

Table 3: Variation of axial force, Ra, shear force, Rs and bending moment, Rm in bottom node of fully braced frame having specific no. of bays as depth of beam is changed

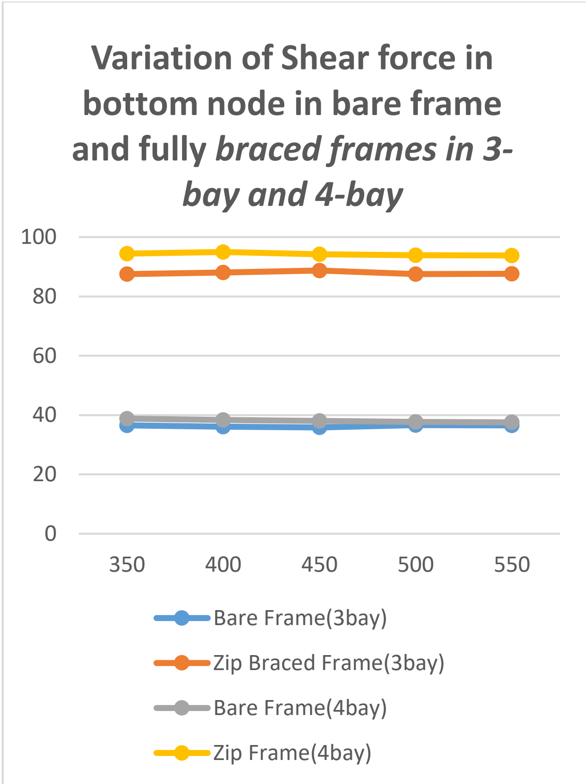
| **No. of bays** | **Axial force, Ra ( G+11)** | | | | | |
|---|---|---|---|---|---|---|
| | **Beam Depth** | | | | | |
| | **350** | **400** | **450** | **500** | **550** | **600** |
| **3** | 2762.23 | 2725.09 | 2766.83 | 2817.58 | 2812.43 | 2941.5 |
| **4** | 2872.05 | 2883.22 | 2984.42 | 2922.30 | 2945.32 | 2938.32 |

| **No. of bays** | **Shear force, Rs ( G+11)** | | | | | |
|---|---|---|---|---|---|---|
| | **Beam Depth** | | | | | |
| | **350** | **400** | **450** | **500** | **550** | **600** |
| **3** | 87.532 | 88.054 | 88.733 | 87.524 | 87.589 | 87.789 |
| **4** | 94.458 | 94.974 | 94.221 | 93.831 | 93.792 | 94.025 |

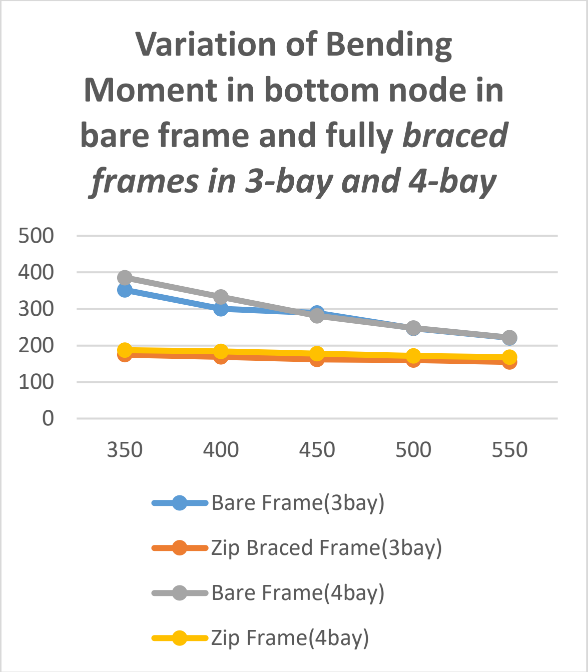
| No. of bays | Bending Moment, Rm ( G+11) | | | | | |
|---|---|---|---|---|---|---|
| | Beam Depth | | | | | |
| | **350** | **400** | **450** | **500** | **550** | **600** |
| **3** | 174.666 | 169.248 | 162.240 | 160.742 | 154.852 | 153.356 |
| **4** | 187.243 | 183.53 | 178.033 | 171.207 | 167.832 | 163.782 |



Graph 1: Variation of Axial Force



Graph 2: Variation of Shear Force




Graph 3: variation of bending moment

## 8. CONCLUSIONS

About Bare Frame

- For a bare frame irrespective of number of bays is found to attract about 6.5 to 8% additional axial force as the beam depth increases from 350 mm to 600 mm.
- Shear force marginally reduces as the beam depth increases. Percent reduction in the shear for 600mm beam depth was found to be 2.24 for 3 bay and 2.83 for 4 bay frame.
- The bending moment is found to reduce about 47.5 to 48% for 3 and 4 bay structures for beam depth 600mm

About Fully Braced Frame

- When compared with bare frames, it is found that axial force attracted by column segment at all levels remains almost same, shear force increases and bending moment reduces substantially.
- All frames exhibit a continuous rise in the axial force as the depth of beam increases.
- Shear force reduces as the depth of beam increases. This reduction was found to be 2.06 to 2.5% for 600mm beam depth for 3 bay and 4 bay structures respectively.
- Braces are subject prominently to axial compression and carry negligibly small shear and bending moment.

Following table reveals the reduction in moment in worst loaded column segment C1 in fully braced frames in comparison with bare frame.

| **No of Bays** | **% Reduction in moment** |
|---|---|
| | **(G+11)** |
| 3 | 51.27 |
| 4 | 48.56 |

## REFERENCES

[1] I.S. 1893 (part I) – 2002, criteria for earthquake resistant design of structure, general provision and building, *Bureau of Indian Standards, New Delhi.*
[2] *DEEPAK D.MASLEKAR: 17th March 2018:*
[3] A. R. Khaloo and M. Mahdi Mohseni, "Nonlinear seismic behavior of RC frames with RC braces", Asian journal of Civil Engineering, Vol. 9, No. 6 (2008).
[4] STAAD-2006 structural analysis and design commercial software.
[5] Saptadip sarkar "Design of earth-quake resistant multi-storied rcc building on a sloping ground" Department of Civil engineering National institute of technology Rourkela, India (2010)
[6] Roberto T. LEON and Chaung – Sheng YANG, " Special Inverted – V – Braced frames with suspende zipper struts", Department of Civil and Environmental engineering, Georgia, (2001).
[7] Methods of analysis for earthquake resistant structures-is – 1893 (part-1) -2002 (G. P. Chandradhara Department of Civil Engineering S. J. College of Engineering, Mysore 2010)
[8] Earthquake-Resistant Design Concepts-An Introduction to the NEHRP Recommended Seismic Provisions for New Buildings and Other Structures(*FEMA P-749 / December 2010)*
[9] K.K. Sangle, K.M. Bajoria, V. Mhalunkar, [2012] "*Seismic analysis of high rise steel frame with and without bracing*" 15 WCEE LISBOA.
[10] S.H. Chao and M.R Bayat [2008], "*Performance based plastic design of steel concentric braced frame for enhanced confidence level*," 14**th** World conference on Earthquake engineering October 12-17.