# Study on Effect of High Rise Steel Building with Different Masses

**Thi Thi Hein Lwin, Kyaw Lin Htat**

***Abstract*****—** This paper presents twelve-storeyed steel building with different masses which is situated in seismic zone IV. In this study, computer–aided analysis and design of superstructure for this building is carried out by using ETABS software. One regular building and three irregular buildings are compared. They have same plan size. The overall height is 129 ft and it is L-shaped. In these cases, mass irregularity is considered at bottom floor, middle floor and top floor of the proposed building. It is composed of special moment resisting frame (SMRF). Dead loads, superimposed dead loads, live loads, wind loads and earthquake loads are considered based on UBC-97. All structural members are designed according to AISC-LRFD 1999. Wide flange W-sections are used for frame members. Structural steel used in building is A572 Grade 50 steel. Structural stability checking (overturning moment, sliding, storey drift, torsional irregularity and P-Δ effect) are carried out for the stability of the superstructure. After checking the stability, the proposed building is analysed with time history analysis case. Suitable bracing types such as X-bracings are used in this case. The response of steel building with different masses is investigated. The drifts, shear, moment, displacement of stories of building with different masses are compared. Comparison of mode shape and time and internal forces of interior column are investigated. In this paper, storey drift, storey shear, storey moment and story displacement from static analysis are smaller than that of dynamic analysis. From the analysis results, it is found that the buildings with vertical structural irregularity have lower performance than the regular buildings. R=regular building, B-3= mass increased 3 floors in bottom, M-3= mass increased 3 floors in middle, T-3= mass increased 3 floors in top.

***Index Terms*****— Different masses, Same plan size, Seismic zone 4, Time history case, X- bracing**

## I. Introduction

Nowadays, like other countries, the growth of population of Myanmar is getting more and more. The requirements of increased population and natural geology of country highly demands the high-rise building. Myanmar is situated in a secondary seismic belt which is in the junction of two major belts. It is likely to meet highly destructive damage of earthquake to the buildings in some areas. Therefore, high-rise building should be designed to resist the earthquake effects. To save the construction time and other several factors, steel structures are commonly designed. Steel structures are more preferable than other structural materials. Steel members are widely used all over the world because of high strength, long life, ease of construction and fire resisting. So, most people like steel structured buildings because of faster construction period and many others. And they can resist seismic force more than reinforced concrete buildings.

In this paper, steel frame are constructed with X-bracing for lateral stiffness. The design of steel structure is done with the aid of computer software program named "ETABS".

## II. Data Preparation For Design Of Structure

### *A. Structural Framing System*

The proposed structure is a twelve-storey steel building. Details of the superstructure are described below,

| | |
|---|---|
| Location | : Seismic zone IV |
| Type of Structure | : 12-storeyed steel frame building |
| Type of Occupancy | : Hotel |
| Height of Structure | : 129 ft |
| Typical story height | : 10 ft |
| Bottom story height | : 12 ft |

The plan view and 3D view of the building are shown in figure 1, figure 2 and mass increase floor is shown in figure 3.

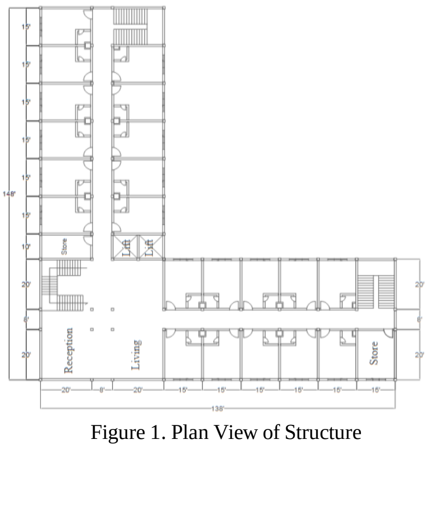


Figure 1. Plan View of Structure

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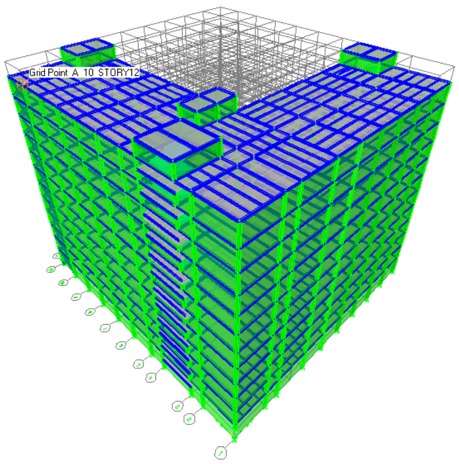
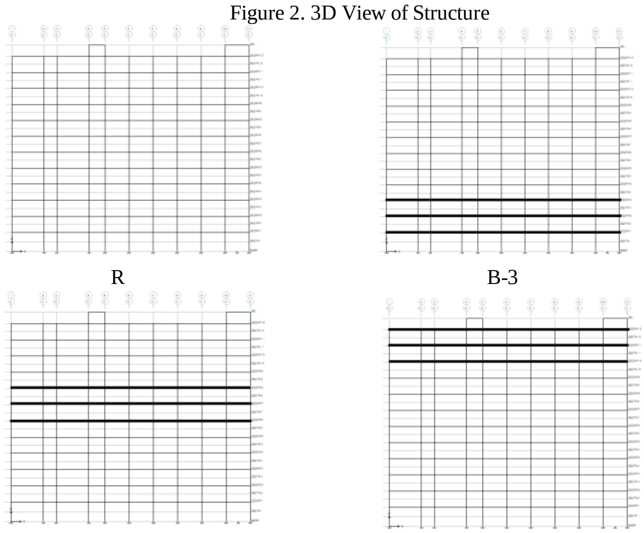



Figure 2. 3D View of Structure




M-3 T-3

Figure 3. Location of Mass Irregularity

## B. *Material Properties*

The strength of a structure depends on the strength of the materials from which it is made.

Analysis property data

- Weight per unit volume = 490 pcf
- Modulus of elasticity for steel = $29\times10^6$ psi
- Poisson's ratio = 0.3
- Coefficient of thermal expansion = $6.5\times10^{-6}$

Design property data

- Concrete strength, $f_c'$ = 3.5 ksi
- Yield stress , $F_y$ = 50 ksi
- Tensile stress , $F_u$ = 65 ksi

## C. *Loading Consideration*

There are two kinds of load considered in this study which is gravity load, that includes dead and live load, lateral load that includes wind and earthquake load. AISC-LRFD-99 design load combinations are also used.

*Gravity Load*

All masses are attracted toward the centre of the earth by the gravitational force. Loads are defined as these attracting forces acting upon their corresponding masses. There are two different gravity loads: (1) Dead loads and (2) Live loads.

*1) Dead Load*

Dead loads consist of the weight of all material and fixed equipments incorporated into the building.

- 4.5" thick wall weight = 55 lb/ft$^2$
- 9" thick wall weight = 100 lb/ft$^2$
- superimposed dead load = 30 lb/ft$^2$
- unit weight of concrete = 150 lb/ft$^3$

*2) Live Load*

Live loads are gravity load produced by the used and occupancy of the building and do not include dead loads, construction load, or environmental loads such as wind and earthquake loadings are based on to UBC-97.

- live load on residential = 40 lb/ft$^2$
- live load on stair case = 100 lb/ft$^2$
- live load on roof = 20 lb/ft$^2$
- unit weight of water = 62.4 pcf

Lateral Load

*1) Wind Load*

The wind pressure on a structure depends on the wind response of the structure. Required Data in designing for wind load:

- Exposure type = Type B
- Basic wind velocity = 80 mph
- Total height of building = 134 ft
- Method used = Normal Force Method
- Windward coefficient = 0.8
- Leeward coefficient = 0.5
- Importance Factor = 1.0

*2) Earthquake Load*

Required data for earthquake load are:

(i) Seismic Importance Factor, I
(ii) Seismic Zone Factor, Z
(iii) Soil Profile Types, $S_D$
(iv) Seismic Source Type
(v) Near - Source Factors, $N_a$ and $N_v$
(vi) Seismic Response Coefficients, $C_a$ and $C_v$
(vii) Response Modification Factor, R

- Seismic zone = IV
- Seismic Source Type = A
- Soil Type = $S_D$
- Structural frame structure = Special Moment Resisting Frame
- Zone Factor = 0.4
- Importance Factor, I = 1.0
- Response Modification Factor, R = 8.5
- Time period factor, $C_t$ = 0.035

## D. *Loading Combination*

Design codes applied are AISC-LRFD-99 and UBC-97. There are 18 number of load combinations.

(1) 1.4DL
(2) 1.2DL+1.6LL
(3) 1.2DL+LL+1.6WX
(4) 1.2DL+LL -1.6WX
(5) 1.2DL+LL+1.6WY
(6) 1.2DL+LL -1.6WY



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| Column Section | Story Level | | | | |
|---|---|---|---|---|---|
| | Story 1-3 | Story 4-6 | Story 7-9 | Story 10-12 | Stair Roof |
| C1 | W 14×159 | W 14×132 | W 14×90 | W 14×82 | W 14×82 |
| C2 | W 14×176 | W 14×145 | W 14×109 | W 14×99 | - |
| C3 | W 14×233 | W 14×193 | W 14×109 | W 14×99 | W 14×99 |
| C4 | W 14×283 | W 14×257 | W 14×120 | W 14×82 | W 14×82 |
| C5 | W 14×283 | W 14×211 | W 14×109 | W 14×82 | W 14×82 |

(7) 1.2DL+0.8WX
(8) 1.2DL -0.8WX
(9) 1.2DL+0.8WY
(10) 1.2DL -0.8WY
(11) 1.05 DL+1.275 LL+1.4025 EQX History
(12) 1.05 DL+1.275 LL -1.4025 EQX History
(13) 1.05 DL+1.275 LL+1.4025 EQY History
(14) 1.05 DL+1.275 LL -1.4025 EQY History
(15) 0.9 DL+1.43 EQX History
(16) 0.9 DL -1.43 EQX History
(17) 0.9 DL+1.43 EQY History
(18) 0.9 DL -1.43 EQY History

### E. *Time History Analysis*

This is included live load, super imposed dead load and self weight. For lateral load, ground motion (1940 Elecentro ground motion PGA=0.32g) is used.

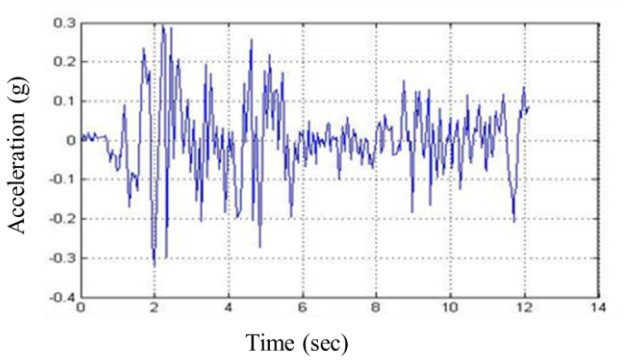


Figure 4. Time-Acceleration Curve

## III. Design Results Of Proposed Building

In this paper, the design sections of proposed structure with static analysis are shown in figure 5, table I and II.

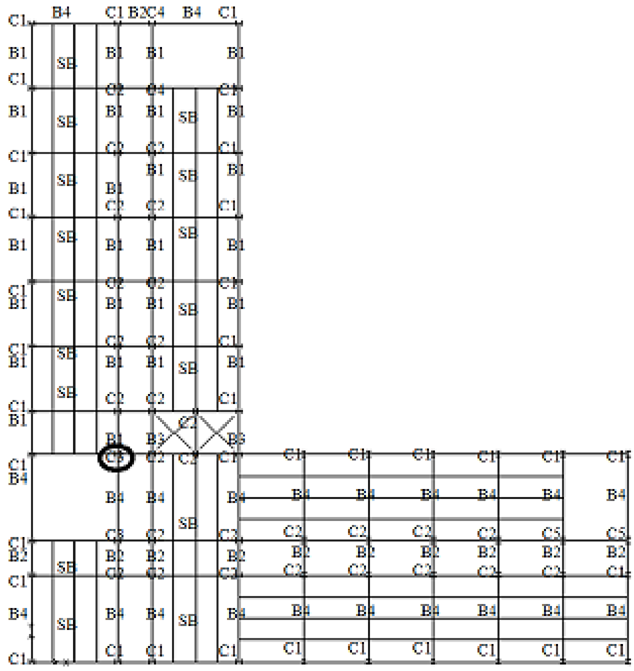

Figure 5. Beam and Column Layout Plan

TABLE I
Column Sections of Proposed Structure
TABLE II
Beam Sections of Proposed Structure

| Beam Name | Section |
|---|---|
| B1 | W10×22 |
| B2 | W10×19 |
| B3 | W10×22 |
| B4 | W10×39 |
| SB | W10×12 |
| BR | W14×48 |

## IV. Comparison Results For Dynamic Analysis

After static analysis, the proposed building is analyzed with dynamic (Time History Analysis). The structural performance results are compared as follows;

### *A.Comparison of Story Drift*

The comparison of story drift for regular and irregular buildings are graphically shown in figure 6 and figure 7.

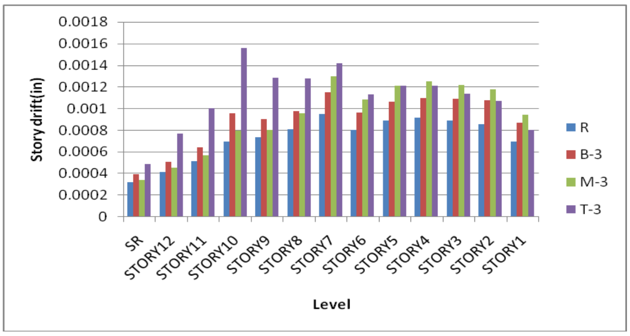


Figure 6. Comparison of Story Drift in X-dir; for EQX History


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In the comparison of story drift in X-dir; maximum story drift is occurred at T-3. Its value is 0.001558 at story 10 which is 1.65 times greater than that of regular building.

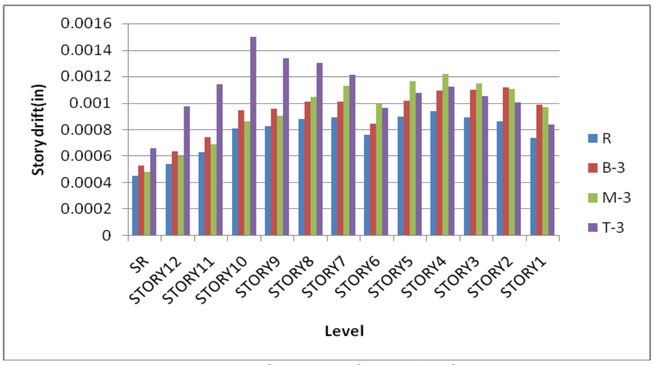


Figure 7. Comparison of Story Drift in Y-dir; for EQY History

In the comparison of story drift in Y-dir; maximum story drift is occurred at T-3. Its value is 0.001498 at story 10 which is 1.59 times greater than that of regular building.

*B. Comparison of Story Shear*

The comparison of story shear for regular and irregular buildings is graphically shown in figure 8 and figure 9.

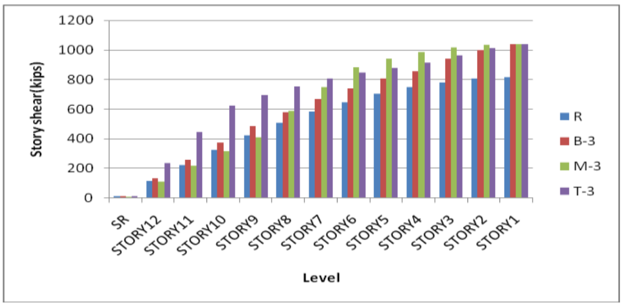


Figure 8. Comparison of Story Shear in X-dir; for EQX History

In comparison of storey shear in X-dir; the maximum shear is found at T-3 which is 1.27 times greater than that of regular building.

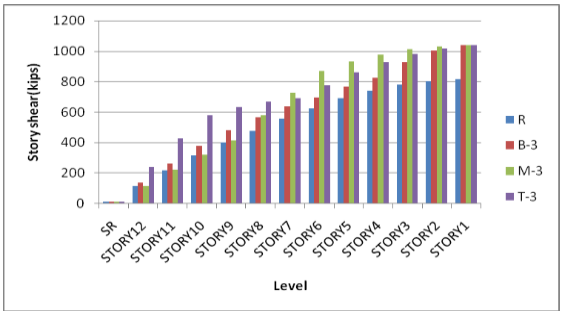


Figure 9. Comparison of Story Shear in Y-dir; for EQY History

In comparison of story shear in Y-dir; the maximum shear is found at T-3 which is 1.27 times greater than that of regular building.

*C. Comparison of Story Moment*

The comparison of story moment for regular and irregular buildings is graphically shown in figure 10 and figure 11.

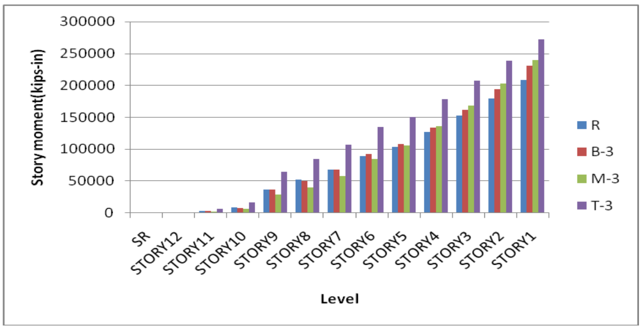


Figure 10. Comparison of Story Moments in X-dir; for EQX History

In comparison of story moment in X-dir, the maximum moment is occurred at T-3 which is 1.3 times greater than that of regular building.

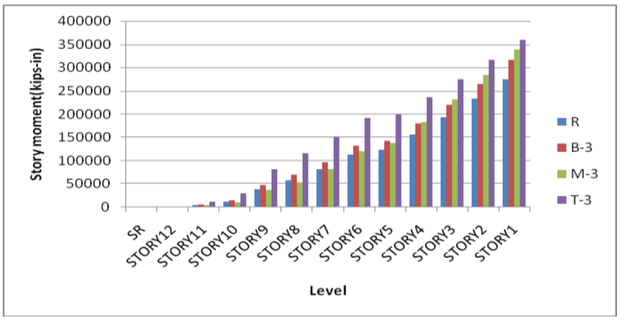


Figure 11. Comparison of Story Moments in Y-dir; for EQY History

In comparison of story moments in Y-dir; the maximum moment is occurred at T-3 which is 1.3 times greater than that of regular building.

*D. Comparison of Story Displacement*

The comparison of story displacement for regular and irregular buildings is graphically shown in figure 12 and figure 13.

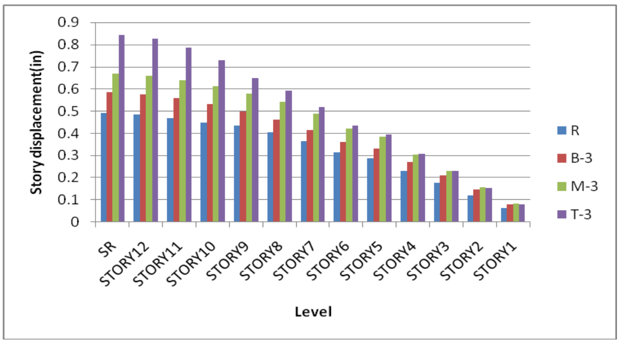


Figure 12. Comparison of Story Displacement in X-dir; for EQX History

In the comparison of story displacement in X-dir; maximum story displacement is occurred at T-3 which is 1.72 times greater than that of regular building.

*E. Comparison of Story Displacement*

The comparison of story displacement for regular and irregular buildings is graphically shown in figure 12 and figure 13.



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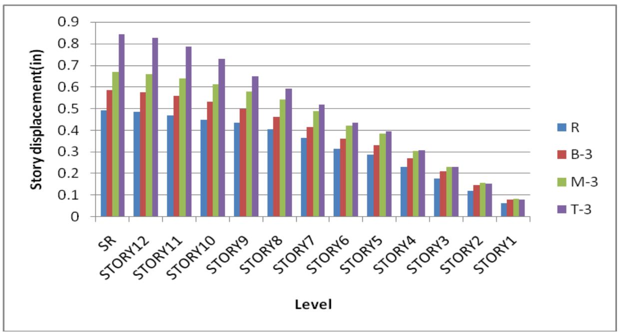


Figure 13. Comparison of Story Displacement in Y-dir; for EQY History

In the comparison of story displacement in Y-dir; maximum story displacement is occurred at T-3 which is 1.27 times greater than that of regular building.

*F. Comparison of mode shape and time*

The comparison of mode shape and time for regular and irregular buildings is graphically shown in figure 14.

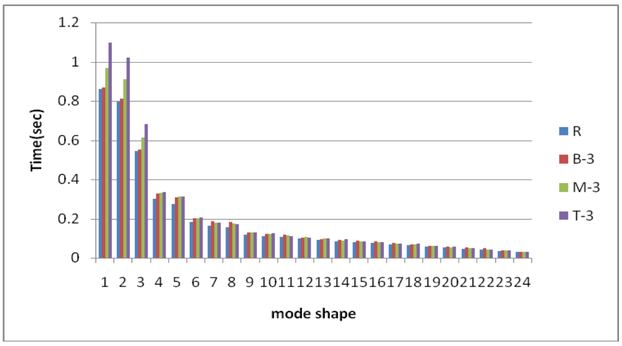


Figure 14. Comparison of mode shape and time

In the comparison of mode shape and time, the first mode shape has the longest time which is found at T-3 building. It takes 1.09 sec while the regular building does 0.862 sec.

## V. Comparison Of Member Forces of Proposed Structure

In comparing member forces, interior column C3 is selected because it is the maximum loaded column for regular and irregular buildings. Axial force, shear force, bending moment and torsion force of the selected column, C3are compared as follow;

*A. Comparison of Axial Force For Interior Column*

The comparison of axial force for interior columns of regular and irregular buildings is graphically shown in figure 15.

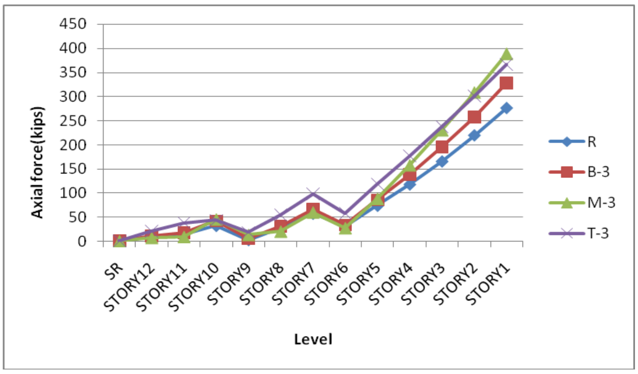


Figure 15. Comparison of Axial Forces for Interior Column C3

In the comparison of axial force, the maximum axial force is occurred at T-3 which is 1.32 times greater than that of regular buildings.

*B. Comparison of Shear Force for Interior Column*

The comparison of shear force for interior columns for regular and irregular buildings are graphically shown in figure 16.

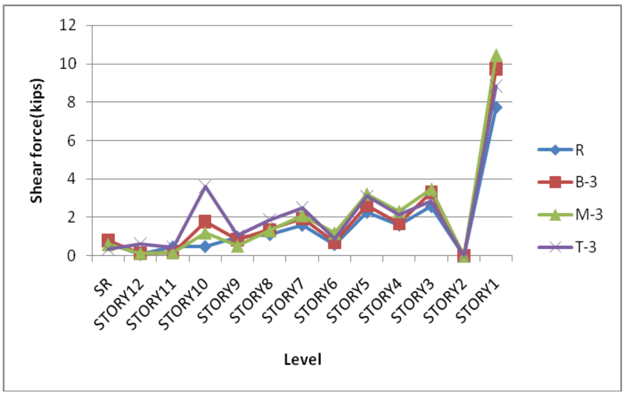


Figure 16. Comparison of Shear Forces for Interior Column C3

In comparison of shear force, the maximum shear force of M-3 is 1.35 times greater than that of regular building.

*C. Comparison of Bending Moment for Interior Column*

The comparison of bending moment for interior columns for regular and irregular buildings are graphically shown in figure 17.

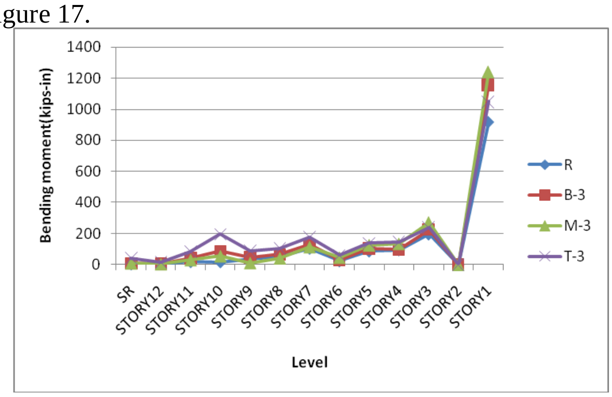


Figure 17. Comparison of Bending Moment for Interior Column C3

In the comparison of bending moment, the maximum moment of M-3 is 1.35 times greater than that of regular building.



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*D.Comparison of Torsion Force for Interior Column*

The comparison of torsion force for interior columns for regular and irregular buildings are graphically shown in figure 18.

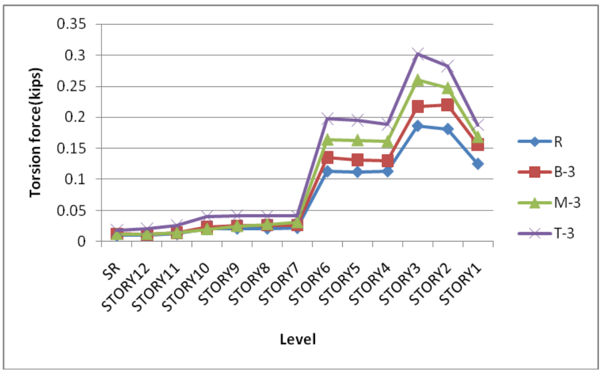


Figure 18. Comparison of Torsion Force for Interior Column C3

In comparison of torsion force, the maximum torsion force of T-3 is 1.5 times greater than that of regular building.

## VII. Conclusions

In this study, twelve-storey steel frame buildings with different masses are considered in zone IV. The structure is analyzed according to ETABS software and AISC- LRFD 1999 specifications. Static approach procedure was analyzed according to UBC-97.The stability checking of the buildings is within the design limitation. Therefore, the structures are stable. In dynamic analysis, the bracing size of W14x48 is needed at the corner of the proposed building. From the analysis results, it is found that the dynamic results are greater than the static results. In comparison of story drift in X-direction and Y-direction, the maximum drift of T-3 is 1.65 times greater than that of regular building. In the comparison of story shear in X-direction and Y-direction, the maximum shear of T-3 is 1.27 times greater than that of regular building. In the comparison of story moment in X-direction and Y-direction, the maximum moment of T-3 is 1.3 times greater than that of regular building. In the comparison of story displacement in X-direction and Y-direction, the maximum displacement of T-3 is 1.72 times and 1.27 times greater than that of regular building. Also, the first mode shape of T-3 takes 1.09 sec while the regular building does 0.862 sec. In the comparison of member forces results, interior column C3 is selected because it is the maximum loaded column for regular and irregular buildings. In the comparison of axial force and shear force, the maximum axial force of T-3 is 1.32 times and the maximum shear force of M-3 is 1.35 times greater than that of regular building. In the comparison of bending moment and torsion force, M-3 moment is 1.35 times and T-3 torsion force is 1.5 times greater than that of regular building. For most cases, it can be found that the building with vertical structural irregularity have lower performance than the regular building.

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