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Design and Analysis of Multistorey Building (G+9) Regular and Irregular Structure At Same Earthquake Zone (Zone IV)

Anvesh Camarshi & Shashank Gupta
B.tech + M.tech (dual degree) Civil Engineering Department Dr.K.N.Modi University
Newai, Tonk, Rajasthan, India-304021
Anvesh.camarshi@gmail.com
Assistant Professor Civil Engineering Department Dr.K.N.Modi University Newai, Tonk, Rajasthan, India-304021
gupta.shashank.kay@gmail.com

Abstract—Structural Analysis is a branch which involves in the determination of behaviour of structures in order to predict the responses of real structures such as buildings, bridges, trusses etc. The structures with different dimensions and different shapes under same earthquake zone produce different results under load. The behaviour of the different structure changes according to earthquake zone. In this paper we have taken two structures with different shape and dimensional property but the material specifications remains the same and are analysed under same seismic zone of India. The analysis brings out different shear force and bending moment values for two different structures. The different bending moment, shear force, deflections, axial forces are being plotted for different loads and load combinations.
STAAD stands for Structural Analysis and Design. The main purpose of this software is to design multi-storeyed building in a systematic process.

Keywords-Structural analysis and design,Regular structure VS Irregular structure, STAAD.PRO, zone IV.

I. INTRODUCTION

A tall building is termed as multistory building when the height of the building goes above 100meters. India is a vast country with diversification of soil strata, the tectonic plates causing earthquakes of various magnitudes and the different wind speed in different locations. Here, in this paper we have designed a 10 storey multistory building with fixed support at the ground. The multistory building possesses various sub structural part i.e. beams, columns and slabs. The floor to Floor height of the building is 3m. The base height from ground floor to the first floor is 3m. The building is having a total height of 30m. All the design codes of steel and concrete are taken from Indian standards1893-part2:2002, IS 456:2000. The model is designed on STAAD.PRO software-2008. This software particularly deals with the design and analysis of a particular building or structures when exposed to loading. Various data is being extracted in the form of maximum bending moment, maximum shear force, and the reactions at various points and graphically presents the values of storey drift and many other physical data under various loading cases and load combination as well.
STAAD stands for Structural Analysis and Design. The main purpose of this software is to design multi-storied building in a systematic process.

Since for a project to bring into essence there must be pros and corns to that. The advantages of these types of projects are they provide space for people to work and lives; it saves land and provides more accommodation in less cross sectional area. Moreover it facilitates human life with ease and leisure. As these are the advantages, there are many disadvantages for having such types of projects as well. The disadvantages being high cost of project, contribute more to noise and air pollution, makes life congested and misbalances the criteria of natural healthy environment.

II. LITERATURE REVIEW

Papa Rao and Kiran Kumar (2013): The author's researches on the changes in the percentage of steel and volume of concrete for the RCC framed structure for various seismic zones of India. They have designed the structure for gravity load and seismic forces, which might be effect on building.

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Perla Karunakar (2014): The author put his efforts to find out the performance and variation in steel percentage and concrete quantities in various seismic zones and impact on overall cost of construction. According to his research, the concrete quantities are increased in exterior and edge columns due to increase in support reactions however; variation is very small in interior column footings. Reinforcement variation for whole structure between gravity and seismic loads are 12.96, 18.35, 41.39, 89.05%.the cost variation for ductile vs. non-ductile detailing are 4.06%.

Salahuddin Shakeeb S M, Prof Brij Bhushan S, and Prof Maneeth P D, Prof Shaik Abdulla (2015): In the work, attempt is made to find the percentages required for various seismic zones by considering the effects of infill and without infill. For the study a symmetrical building plan is used with 13 storey's and analyzed and designed by using structure analysis software tool STAAD-2013. The study also includes the determination of base shear, displacement, moment and shear and the results are compared between gravity loads and various seismic zones. These parameters have also considers the effect of masonry infill's. In the research he concluded that the total variation in percentage steel in columns for infill case with maximum loading from seismic zone-2 to zone-5 are 1.935% to 51.612% compared to gravity loads. and the total variation in percentage steel in columns for without infill case with maximum loading from seismic zone-2 to zone-5 are 1.24% to 9.12% compared to gravity loads. The amount of variation of percentage steel in beams for infill case with maximum loading from zone-2 to zone-5 are 2.7% to 16.21% compared to gravity load and the variation in percentage steel in beams for non-infill case with maximum loading from seismic zone-2 to zone-5 are 16.66% to 68.75% compared to gravity loads.

III. PROBLEM DEFINATION

A. CASE

A 24mx24m multistory regular structure and a 24mx24m irregular structure is taken to design and analyze under same seismic zone i.e. zone 4 on STAAD software and various results are plotted and compared.

B. PRELIMINARY DATA

Length x Width	24m x 24m
Number of stories	10(G+9)
Height of the structure	30m
Floor to floor height	3m
Standard code (steel)	IS 800:2007
Standard code (concrete)	IS 456:2000
Support condition	Fixed
Type and grade of beam	Concrete rectangular; M25
Type and grade of column	Concrete rectangular; M25
Grade of steel	HYSD415
Specification of beam	600mm x 300mm(1-5 story) 200mm x 200mm(6-10story)
Specification of column	600mm x 300mm(1-5 story) 200mm x 200mm(6-10 story)

C. LOAD CONSIDERATION

Loads acting on the structure are dead load (DL), the live load (LL), the Earthquake load for seismic zone 4,the roof live load and the wind loading.

Now the loading is being subjected to the structure in accordance with different seismic loading at different zones. In India the revision of zone 1 and zone 2 are combined and are determined as zone 2. The location selected for the first model is Jaipur, where the soil type is of medium 2 and the soil is alluvial soil. For the second model for zone 5 considerations we take Bhuj, where the soil type is hard soil and the strata are of sedimentary rocks.

- Live load=3kn/m²
- Dead load=4kn/m²
- Weight of partition=2kn/m2
- Earthquake load (IS:1893 PART1-2002)

Properties	Model
Location	DELHI
Zone	4
Zone factor	0.24
Soil type	1; Rocky and hard soil
Response reduction factor	3
Importance factor	1
Damping	5%
Time period	0.96 sec

- Wind load (IS:875PART3-1987)

Properties	Model
Basic wind speed	47m/sec
Risk coefficient, k1	0.90
Terrain category	2
Class	B
K2	1.13
K3	1
Cpe	1.1

D. ACTUAL ANALYSIS

A grid system of 24m x24m is taken and the properties of beams and columns are assigned.

The material of beam and column is taken as rectangular concrete structure. The grade of beam and that of column is M25. The theoretical explanation says that the beams and columns of the structure towards the foundation should be heavy as compared to that in the top. So the beams from 1-4storey are of size 600mm x300mm and from5-10 storey is 200mm x200mm.In similar way the columns from1-4 storey are of size 600mm x 300mm and that from 5-10 storey are 200mm x 200mm.

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IV. LOAD CALCULATION FOR REGULAR STRUCTURE

A. SELF WEIGHT

1) COLUMN

a) COLUMN FROM 1-5 STOREY

B xDxDensity=0.6 x 0.21 x 25=3.15kn

b) COLUMN FROM 6-10 STOREY

BxDxDensity=0.3 x 0.15 x 25=1.1125kn

2) BEAM

a) BEAM FROM 1-5 STOREY

BxDxDensity=0.5 x 0.3 x 25=3.75kn

b) BEAM FROM 6-10 STOREY

BxDxDensity=0.2 x 0.2 x 25=1kn

B. DEAD LOAD

1) COLUMN

a) COLUMN FROM 1-5 STOREY

0.6 x 0.3 x 2.4 x 25 x 25=270kn

b) COLUMN FROM 6-10 STOREY

0.2 x 0.2 x 2.4 x 25x 25=60kn

c) DEAD LOAD OF COLUMN AT ROOF

=½(dead load of column of storey 1-5 + dead load of column of storey 5-10)
=½(330) =165kn

2) BEAM

a) BEAM FROM 1-5 STOREY

B x D x Length of beam x No. of beam on each floor x Density
=0.5 x 0.3 x 10 x 24 x 25=1080kn

b) BEAM FROM 6-10 STOREY

B x D x Length of beam x No. of beam on each floor x Density
=0.2 x 0.2 x 10 x 24 x 25=240kn

C. LIVE LOAD

Live load is considered 3kn/m² on each floor. Each floor has dimension of 24m x24m. Thus live load on each floor can be calculated as

=24 x 24 x 3=1728kn

As per IS 1893:2002 Clause no. 7.3.1, Table no.8, only 25% live load is considered in seismic weight calculations.

25% of live load = 0.25x 1728 = 432 KN

In similar manner the loads are defined for various buildings and the load combination is selected.

For zone 4, the Z value is taken to be 0.24 and the importance factor for both the model is taken to be 1 and the response reduction factor R is taken to be 3 in both cases as the building is of OMRF frames. The value of time period is being calculated as per IS 1893:2002

$$T_a = 0.075h^{0.75}$$

The SI unit for Ta is in seconds. The value of Ta is inserted for calculating Seismic load and wind load.

The wind load is also designed for both x and y direction where the value of Cpe for both leeward and external coefficient is determined and the value of K1 (Risk factor coefficient) and K3 (Topography coefficient) are determined.

D. LUMP MASS

Total plan area=24 x 24= 576m²

Equivalent load at roof level= dead load x plan area+weight of beam at each floor + weight of column at each floor
=4 x 576+1320+165=3789kn

Equivalent load at each floor=equivalent weight at each floor except the roof x plan area+weight of beam at each floor + weight of column at each floor

Equivalent weight at each floor except the roof=6.75 x576+1320+330 =5538kn

Therefore,
Equivalent weight at each floor except the roof=6.75 x 576 + 1320+330 = 5538 KN

E. SEISMIC WEIGHT OF BUILDING

=Equivalent load at roof level + Equivalent load at each floor x number of story
= 3789+ 5538x 10
=93270 KN

F. DESIGN BASE SHEAR

1) BASE SHEAR FOR ZONE 4(Location DELHI)

As per IS 1893:2002, The total design lateral force or design seismic base Shear (VB) along any principal direction shall be determined by the following expression:

$$v_b = A_h \times W$$

Where,
A_h = Design horizontal acceleration spectrum Value
w = Seismic weight of the building

As per IS 1893:2002,

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

Where,
Z =0.24, As per IS 1893:2002, Table No.2 and ANNEX E, Zone Factor for zone 2.
I= 1, As per IS 1893:2002, Importance factor, It is depends on the functional use of the structure.
R= 3, As per IS 1893:2002, Response reduction factor
Sa/g = Average response acceleration coefficient.

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{cases}$$

Fig 4.1. Determination of Sa/g for hard soil

For determination of average response acceleration coefficient, it is required to calculate time period. As per IS 1893:2002, time period T is given by

$$T_a = 0.075h^{0.75}$$

Where,
d=Base dimension of the building in meter = 24 m
Ta = 0.96 sec
Sa/g = 1.04

Now, Design horizontal acceleration spectrum Value can be calculated:

$$A_h = \frac{0.24}{2} \times \frac{1}{3} \times 1.04 = 0.0416$$

Now base shear,

$$v_b = A_h \times W$$

$$v_b = 0.0416 \times 50661 = 2231\text{KN}$$

V. LOAD CALCULATION FOR IRREGULAR STRUCTURE

A. SELF WEIGHT

1) COLUMN

a) COLUMN FROM 1-5 STOREY

B xDxDensity=0.6 x 0.3 x 25=4.5kn

b) COLUMN FROM 6-10 STOREY

BxDxDensity=0.2 x 0.2 x 25=1 kn

2) BEAM

a) BEAM FROM 1-5 STOREY

BxDxDensity=0.6 x 0.3 x 25=3.75kn

b) BEAM FROM 6-10 STOREY

BxDxDensity=0.2 x 0.2 x 25=1kn

B. DEAD LOAD

1) COLUMN

a) COLUMN FROM 1-2 STOREY

B x D x Height of storey x No. of column on each floor x Density
=0.6 x 0.3 x 2.4 x 15 x 25=162kn

b) COLUMN FROM 3-4 STOREY

B x D x Height of storey x No. of column on each floor x Density
=0.3 x 0.15 x 2.4 x 8 x 25=86.4kn

c)COLUMN FROM 5-6 STOREY

B x D x Height of storey x No. of column on each floor x Density
=0.2 x 0.2x 2.4x 6x 25=14.4kn

d)COLUMN FROM 7-9 STOREY

B x D x Height of storey x No. of column on each floor x Density
=0.2x0.2x2.4x6x25 = 14.4kn

e)DEAD LOAD OF COLUMN AT ROOF

=½(dead load of column of all storey)
=½(277.2) =138.6kn

2) BEAM

a) BEAM FROM 1-2 STOREY

B x D x Length of beam x No. of beam on each floor x Density
=0.6 x 0.3 x 2 x 24 x 25=216kn

b) BEAM FROM 3-4 STOREY

B x D x Length of beam x No. of beam on each floor x Density
=0.6 x 0.3 x 2 x 18 x 25=162kn

c)BEAM FROM 5-6 STOREY

B x D x Length of beam x No. of beam on each floor x Density
=0.2 x 0.2 x 2 x 12 x 25 = 24kn

d)BEAM FROM 7-9 STOREY

B x D x Length of beam x No. of beam on each floor x Density
=0.2 x 0.2 x 3 x 6 x 25 = 18kn

C. LIVE LOAD

Live load is considered 3kn/m² on each floor. Thus live load on each floor can be calculated as

Floor area of 1-2 = 24 x 6 = 144m²

Floor area of 3-4 = 18 x 6 = 108m²

Floor area of 5-6 = 12 x 6 = 72m²

Floor area of 7-9 = 6 x 9 = 54m²

Total floor area 144 + 108 + 72 + 54 =378m²

As per IS 1893:2002 Clause no. 7.3.1, Table no.8, only 25% live load is considered in seismic weight calculations.

25% of live load = 0.25x 1134 = 283.5 KN

For zone 4, the Z value is taken to be 0.24 and the importance factor for both the model is taken to be 1 and the response reduction factor R is taken to be 3 in both cases as the building is of OMRF frames. The value of time period is being calculated as per IS 1893:2002

$$T_a = 0.075h^{0.75}$$

The SI unit for Ta is in seconds. The value of Ta is inserted for calculating Seismic load and wind load.

The wind load is also designed for both x and y direction where the value of Cpe for both leeward and external coefficient is determined and the value of K1 (Risk factor coefficient) and K3 (Topography coefficient) are determined.

D. LUMP MASS

Total plan area=378m²

Equivalent load at roof level= dead load x plan area+weight of beam at each floor + weight of column at each floor
=4x378+420+277.2=2209.2kn
Equivalent load at each floor=equivalent weight at each floor except the roof x plan area+weight of beam at each floor + weight of column at each floor

Equivalent weight at each floor except the roof=DL+25%LL=6 + 0.25 x 3=6.75kn

Therefore,
Equivalent weight at each floor except the roof=6.75 x 378+420+277.2=3248.7Kn

E. SEISMIC WEIGHT OF BUILDING

=Equivalent load at roof level + Equivalent load at each floor x number of story
= 2209.2 + 3248.7 x 10
=34696.2KN

F. DESIGN BASE SHEAR

1) BASE SHEAR FOR ZONE 4(Location DELHI)

As per IS 1893:2002, The total design lateral force or design seismic base Shear (VB) along any principal direction shall be determined by the following expression:

$$v_b = A_h \times W$$

Where,
A_h = Design horizontal acceleration spectrum Value
w = Seismic weight of the building

As per IS 1893:2002,

$$A_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

Where,
Z =0.24, As per IS 1893:2002, Table No.2 and ANNEX E, Zone Factor for zone 2.
I= 1, As per IS 1893:2002, Importance factor, It is depends on the functional use of the structure.
R= 3, As per IS 1893:2002, Response reduction factor
Sa/g = Average response acceleration coefficient.

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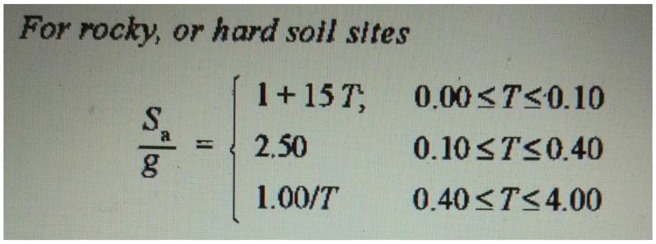
For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \le T \le 0.10 \\ 2.50 & 0.10 \le T \le 0.40 \\ 1.00/T & 0.40 \le T \le 4.00 \end{cases}$$

Fig 5.1. Determination of Sa/g for hard soil

For determination of average response acceleration coefficient, it is required to calculate time period. As per IS 1893:2002, time period T is given by

$$T_a = 0.075h^{0.75}$$

Where,
d=Base dimension of the building in meter = 24 m
Ta = 0.96 sec
Sa/g = 1.04

Now, Design horizontal acceleration spectrum Value can be calculated.

$$A_h = \frac{0.24}{2} \times \frac{1}{3} \times 1.04 = 0.0416$$

Now base shear,

$$v_b = A_h \times W$$

$$v_b = 0.0416 \times 34696.2 = 1443.36KN$$

VI. ANALYSIS AND COMPARISION

After all the loads are assigned the models are being checked for various Errors and Warnings. For repetitive analysis of the structure the model with the irregular and regular shape and size generated the warning.

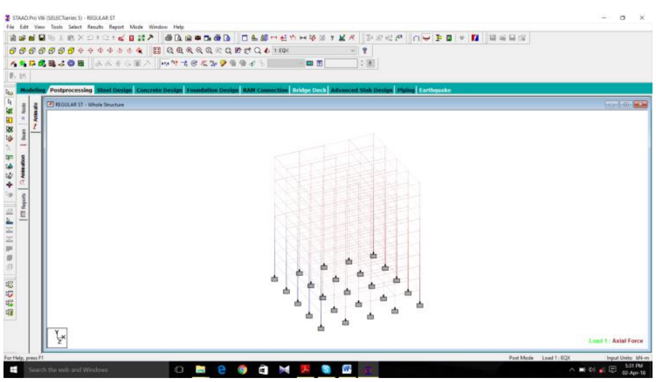

Fig 6.1(a).Axial force along X axis-REGULAR STRUCTURE

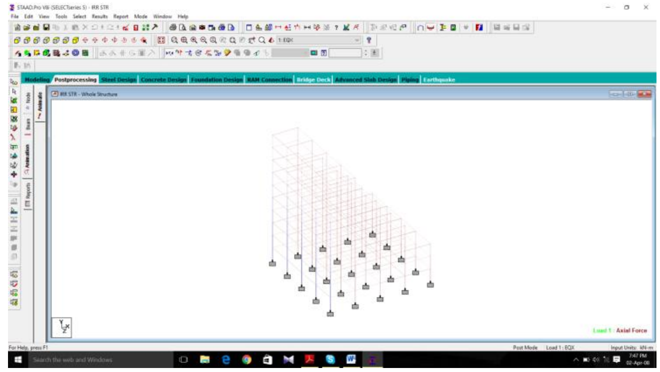

Fig 6.1(b).Axial force along X axis-IRREGULAR STRUCTURE

After the model is checked and all the members under load are passed the model is being analyzed for different loads and the type of members are checked. After the members clearly pass the design check the various criteria are being compared for two different models in same zone.

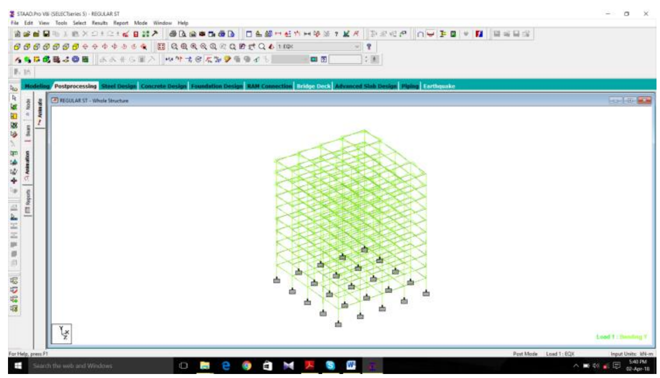

Fig 6.2(a). Bending moment along x axis-REGULAR STRUCTURE

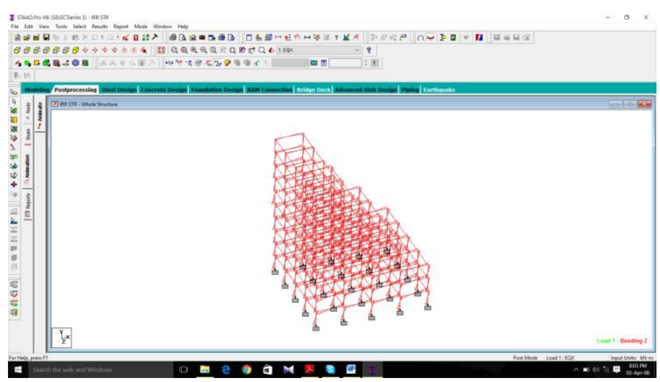

Fig 6.2(b). Bending moment along x axis-IRREGULAR STRUCTURE

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After all the members pass the design check after load application, there are following few comparisons shown diagrammatically and a summary report is also shown for the model having different structural composition but the lateral load i.e. the wind load and the seismic load remains the same.

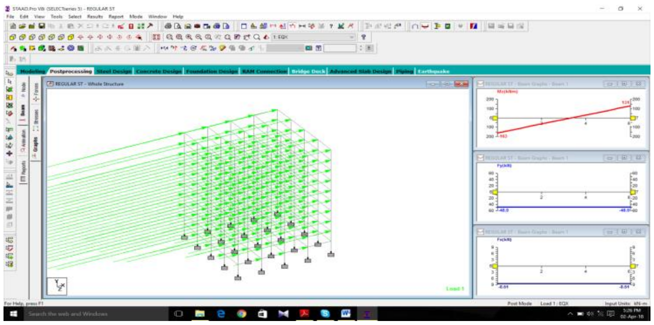

Fig 6.3(a).Bending moment and shear force along Y axis-REGULAR STRUCTURE

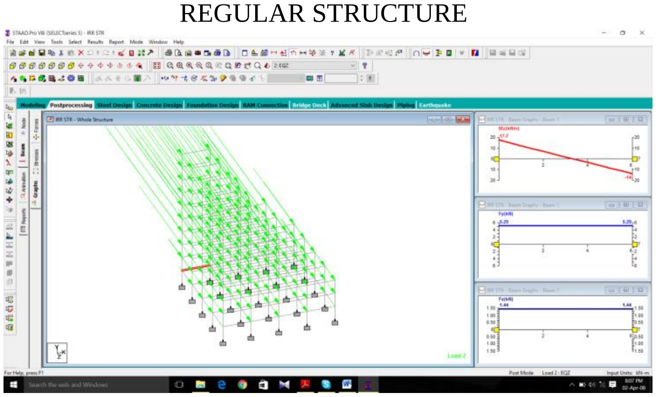

Fig 6.3(b).Bending moment and shear force along Y axis-IRREGULAR STRUCTURE

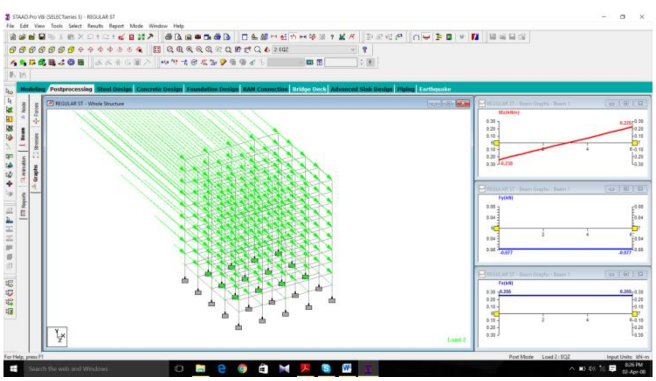

Fig 6.3(c).Bending moment and shear force along Z axis-REGULAR STRUCTURE

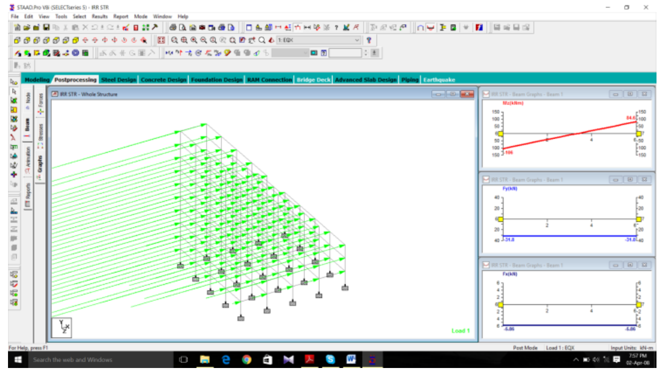

Fig 6.3(d).Bending moment and shear force along Z axis-IRREGULAR STRUCTURE

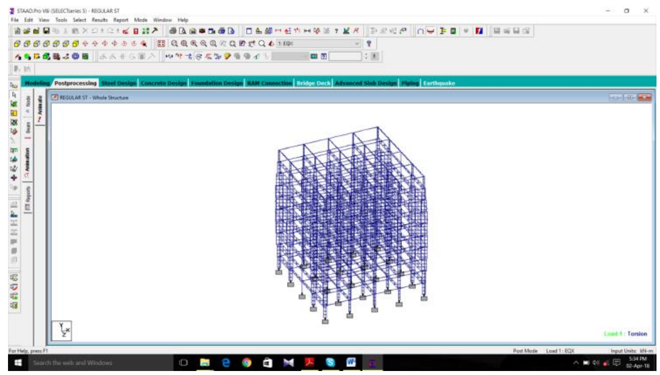

Fig 6.4(a).Torsion force -REGULAR STRUCTURE

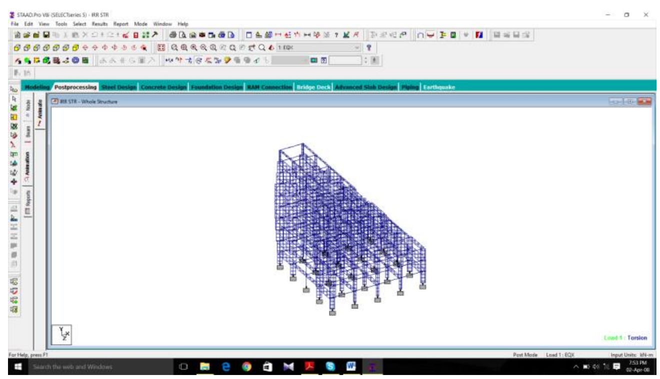

Fig 6.4(b).Torsion force -IRREGULAR STRUCTURE

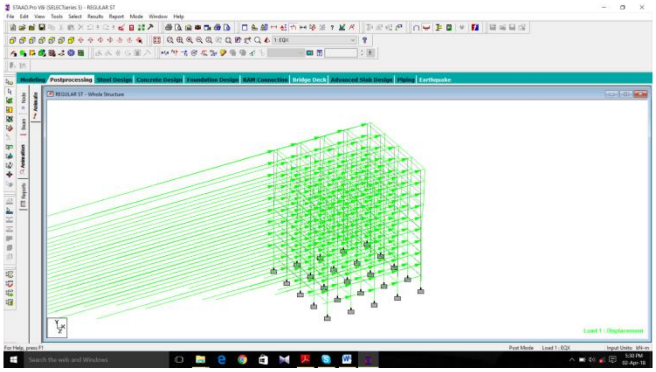

Fig 6.5(a).Deflection -REGULAR STRUCTURE

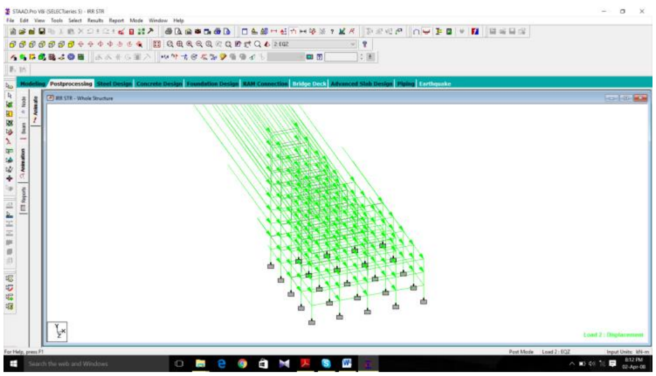

Fig 6.5(b).Deflection -IRREGULAR STRUCTURE

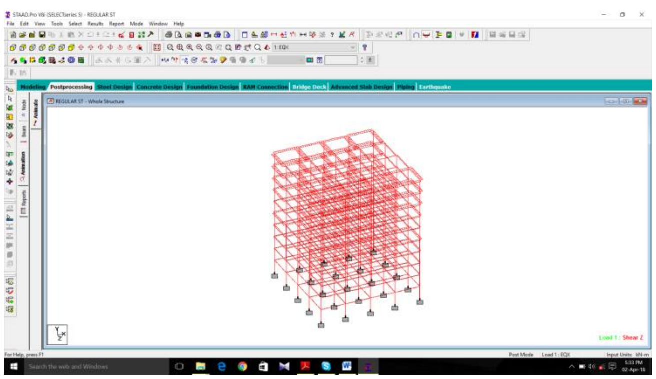

Fig 6.6(a).Shear force -REGULAR STRUCTURE

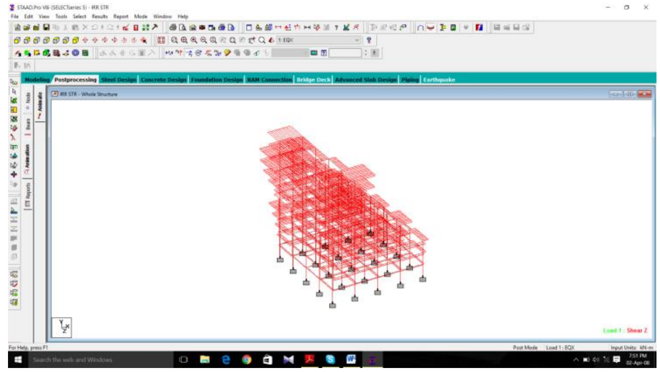

Fig 6.6(b).Shear force -IRREGULAR STRUCTURE

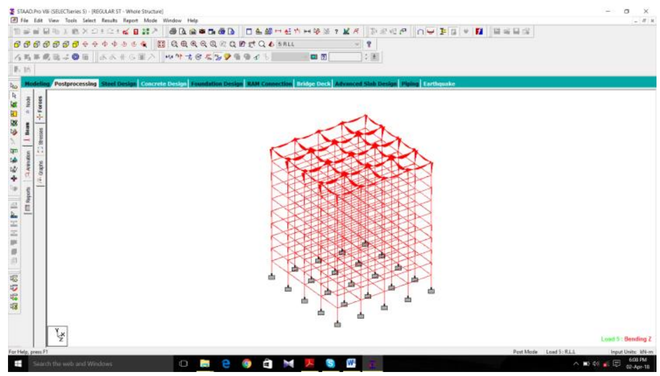

Fig 6.7(a).Deflection of roof live load -REGULAR STRUCTURE

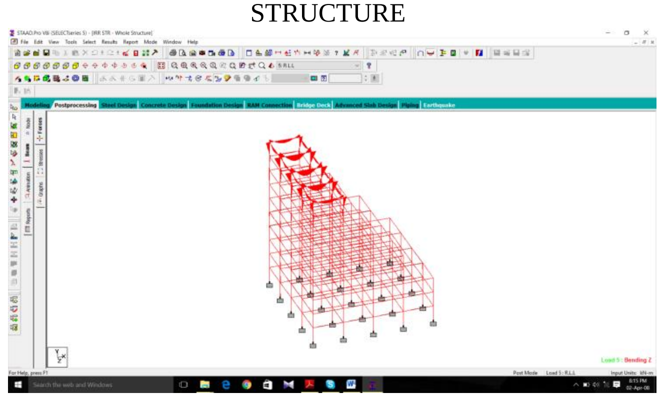

Fig 6.7(a).Deflection of roof live load -IRREGULAR STRUCTURE

VII. CONCLUSION

From the analysis we reached the certain conclusion which is listed as below:

1. The deflection in regular structure is low as compared to the deflection of irregular structure.
2. The shear force of the irregular structure is way more compared to the shear force of regular structure.

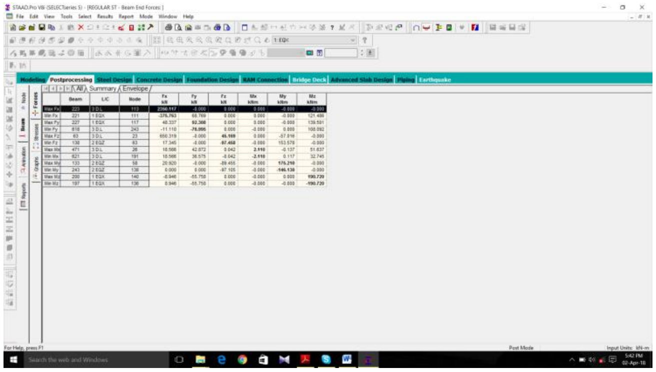

Fig 6.8(a).Summary details of REGULAR STRUCTURE

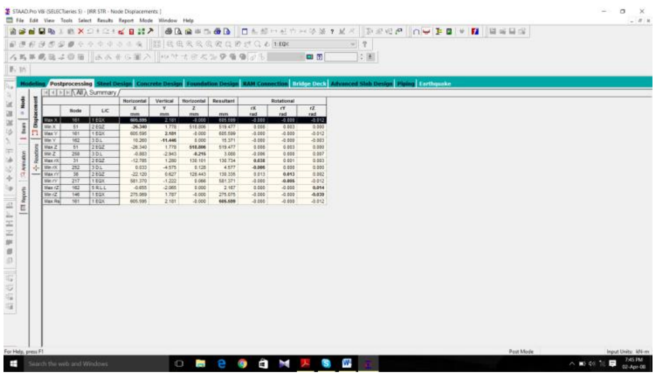

Fig 6.8(b).Summary details of IRREGULAR STRUCTURE

3. The shear force along X axis of Irregular structure is more (-5.86KN) while that of regular structure is less (-8.51KN) forEQ_x.
4. The torsion for irregular structure is more than that of regular structure.
5. The shear force along Y axis of regular structure is -48.9 KN and that of irregular is -31.8KN forEQ_x.
6. The distribution of roof live load for deflection in regular structure is less and for the irregular structure it is more.
7. The bending moment for Earthquake load along Z axis is more for irregular shaped structure (17.7KNm) and is far less than the bending moment of regular structure (0.225KNm).
8. The shear force along Y axis of regular structure is -0.077 KN and that of irregular is -31.8KN for EQ_z
9. The shear force along X axis of Irregular structure is more (1.44KN) while that of regular structure is less (0.255KN) for EQ_z
10. The bending moment for Earthquake load along X axis for regular structure is more (131KNm) than the bending moment for earthquake load along X axis for irregular structure is less (84.6KNm).

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