Analysis and Design of High-Rise RC Structure in Different Seismic Zones

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Abstract – *One of the major problems that the country facing is the rapidly growing population, which necessities more facilities in the restricted availability of land, which can be solved to a certain extent with the construction of multi-storied buildings, which can serve many people in available limited area. Hence it is the necessary requirement of multi-storied building with all facilities. Hence an attempt is made in the project for analyzing and Designing of the multi-storied RC building of G+15 in various seismic zones.*

In this paper we are comparing the H shaped structure in the present seismic zones of India as per IS 1893:2002. We are considering within this H-shaped structure, two models one with connecting beams and the other without connecting beams.

Complicated and high-rise structures need very time taking and cumbersome calculations using conventional manual methods. STAAD-Pro provides us a fast, efficient, easy to use and accurate platform for analyzing and designing the structures. The design method used in STAAD-Pro analysis is Equivalent Static Method, conforming to Indian Standard Code of Practice. STAAD-Pro is a very powerful software tool which can save much time and is very accurate in designs. For the analysis various loads like Dead load, Live load and Seismic load are applied and results are studied for both the models i.e. with and without connecting beams.

***Key Words*: STAAD-Pro, Lateral force, Base Shear, Steel percentage, Maximum Shear force, Maximum Bending Moment, Maximum Deflection, Seismic zones.**

1. INTRODUCTION

The method of analysis is based on Linear Equivalent Static Method, which gives scope to take values from IS 1893:2002 and performs the analysis. Using this method we can analyze the building up to the height of 75 m in Zone II and Zone III and up to the height of 40 m in Zone IV and Zone V. In this paper we have taken two types of column orientations i.e. the column layout varies at stair and lift zone in our paper. Building exceeding the above mentioned heights must be performed for Dynamic analysis, which is more complex when compared with the Static Analysis method. Base shears have also been calculated manually.

1.1 Stages in structural design:

The process of structural design involves the following stages: Collection of data, Preparation of plan in AutoCAD, Modeling in STAAD.Pro software, computation of loads, Performing analysis, Deriving results and conclusions

2. LITERATURE REVIEW

- **Akash Panchal, Ravi Dwivedi:** Seismic analysis of the structures is carried out on the basis of lateral force assumed to act along with the gravity loads. In this project seismic evaluation for the existing residential building is carried out for different seismic zones by an equivalent static analysis method using STAAD.Pro softwareA G+6 existing RCC framed structure has been analyzed and designed using STAAD-Pro V8i.

- **Narla Mohan, A.Mounika Vardhan:** The objectives were how the seismic evaluation of a building should be carried out. To study the behaviour of a building under the action of seismic loads and wind loads. To compare various analysis results of building under zone II, III, IV and zone V using ETABS Software. The building model in the study has twenty storey's with constant storey height of 3m. Five models are used to analyze with constant bay lengths and the number of Bays and the bay width along two horizontal directions are kept constant in each model for convenience.

- **Tiriveedhi Sai Krishna, V.Srinivasa Rao:** The analysis of multistoried buildings is explained in two ways in this project i.e. with earth quake and without earthquake. In this Report they have Analyze base shears for structure in manually in all seismic zones by calculating the gravity loads using IS 1893-2002.This study addresses the performance and the variation of steel quantity for the whole structure in seismic zones by using STAAD.Pro software.They calculated B.M. and S.F. in the beams, axial loads in columns and compared the axial loads in different seismic zones

3. METHODOLOGY

- DRAWING UP THE PLAN
  - The plan of both the models have to be drawn using AutoCAD software.

- MODELING IN STAAD.PRO SOFTWARE
  - Both the models have to be modeled.
- CONSIDERING LOADS
  - The loads have been considered based on manual calculations as per IS codes.
- ANALYSIS
  - Analysis of RCC framed structure after assigning the loads and Shear Force, Bending Moment and Deflections calculations.
- DESIGN
  - Design of beam,column and slab
- GEOMETRIC PARAMETERS
  - Beam = 350 x 350 mm
  - Column Type 1 = 450 x 600 mm
  - Column Type 2 = 600 x 450 mm
  - Depth of Slab = 150 mm

4. OBJECTIVES

- To study the behavior of structure in various seismic zones.
- To study the variations in parameters such as Shear Force, Bending moment and Displacement in all seismic zones as per IS: 1893-2002.
- To compare the structure in two models of H shaped Structure without connecting beams and with the connecting beam.

5. MODELING, ANALYSIS AND DESIGN

5.1 Development of Plan

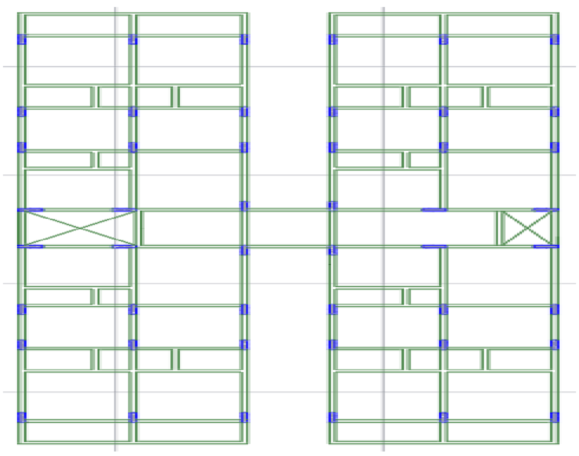


Fig.1 Model-I without Connecting Beams

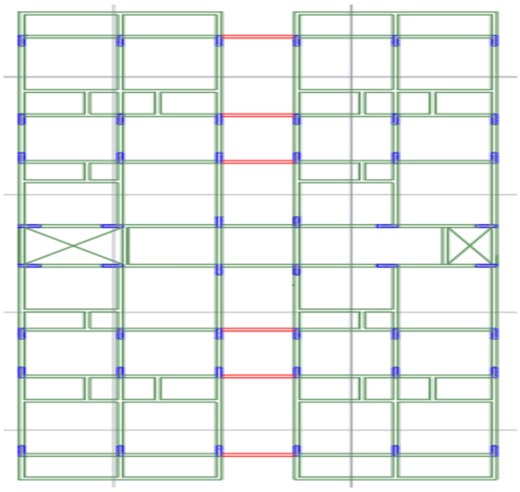


Fig.2 Model-II with connecting beams

5.2 Creation of Structure

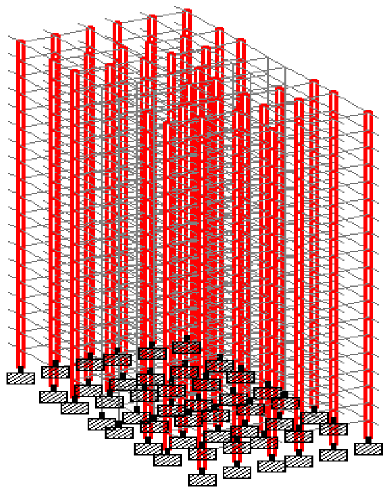


Fig.3 Column layout excluding stairs and lift zone

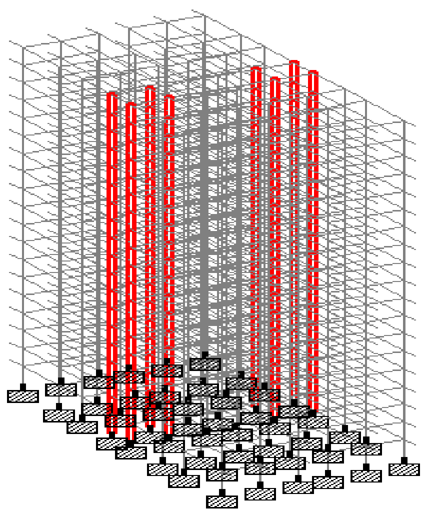


Fig.4 Column layout at stairs and lift zone

5.3 Load Considerations

5.3.1.Dead Loads

- The Dead loads have been considered as per IS 875:1987-Part I.
- Load 3.75 kN/m^2 is defined in Global Y direction calculated as per dimensions.
- Load intensity 11.73 kN/m has applied for floors up to 14th floor and intensity 5.86 kN/m has applied for top floor with 3.45kN/m as parapet wall. All the forces have been taken in Global Y direction.

5.3.2. Live Loads

- The Live loads have been considered as per IS 875:1987-Part II.
- Live Load intensity 4 kN/m^2 has been assigned from base to 14th floor and 2 kN/m^2 has been assigned on 15thfloor.All the forces have been taken in Global Y direction only.

5.3.3. Seismic Load Combinations

The load combination cases have been derived from IS 1893:2002, Clause 6.3.1.2

- 1.5 (Dead Load + Live Load)
- 1.2 (Dead Load + Live Load + Earthquake Load)
- 1.2 (Dead Load + Live Load - Earthquake Load)
- 1.5 (Dead Load + Earthquake Load)
- 1.5 (Dead Load - Earthquake Load)
- 0.9 (Dead Load) + 1.5 (Earthquake Load)
- 0.9 (Dead Load) - 1.5 (Earthquake Load)

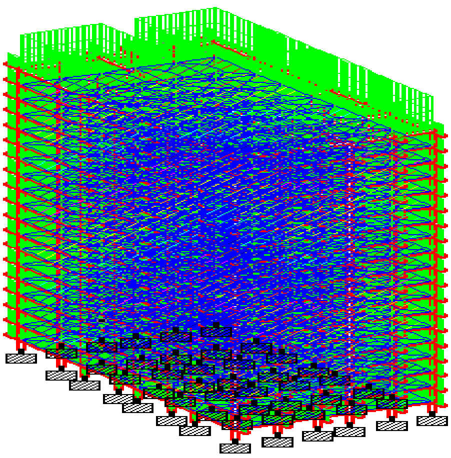


Fig.5 Structure after applying all the loads

5.4 Generation of Analysis Results

The analysis has been done by using STAAD.Pro software and the following figures show the derived Shear Force, Bending moment and Deflection variations.

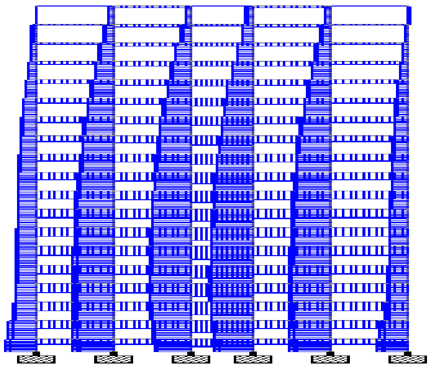


Fig.6 Shear Force Diagram in Zone V from +Z view

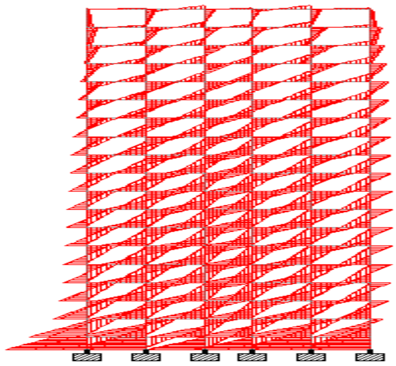


Fig.7 Bending Moment Diagram in Zone V from +Z view

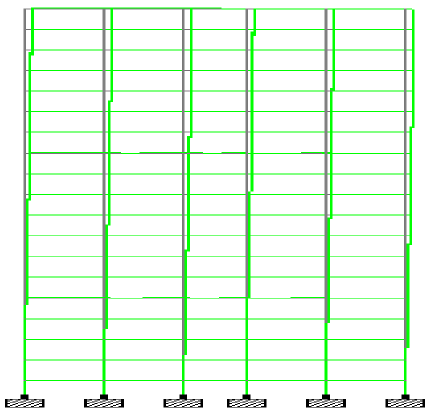


Fig.8 Deflection Diagram in Zone V from +Z view

5.5 Design

5.5.1. Design of Beam

Manual calculation for beam

Cross section of beam: b x d = 350mm x 350 mm

A_{st} = 2520 mm^2

$(100xA_{st}) / (bxd) = 1.17$

Vertical shear force = V_u =232.591kN

τ_c = 0.29 N/mm^2 (from table 19 of IS 456 200)

τ_v = [(V_u) / (bxd)] = 1.89

$\tau_v \geq \tau_c$

Design reinforcement **V_{us} = [(V_u) – (τ_cx b x d)] = 149290 kN**

For vertical stirrups **V_{us} = (0.87 $f_y A_{sv}$ d) / S_v**

Therefore S_v = 129.69 mm i.e 130 mm

S_v shall not be more than

- 0.75d = 0.75 x 350 = 262.5 mm
- 300 mm
- Minimum shear reinforcement

Minimum shear reinforcement = [(A_{sv}) / (b_{sv})] ≥ [(0.4) / (0.87 f_y)]

Therefore provide 2 legged 10 mm diameter bars @ 130 mm center-to-center spacing

Hence the design is matched with output of STAAD.Pro

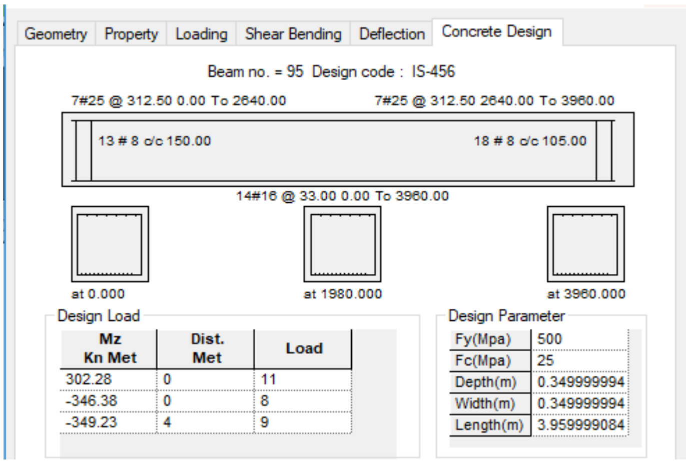


Fig.9 Beam design output

5.5.2. Design of Column

Manual Design

f_{ck}= 25N/mm² and f_y = 500 N/mm² and P_{uz} = 5551.74

b = 450 mmand d = 600 mm

P_{uz}= [(0.45$f_{ck}A_c$)+ (0.75$f_y A_{sc}$)]

By substituting values and solving we get A_{sc} = 6912 mm²

Hence provide main reinforcement of 24 bars of 20 mm diameter as shown in above figure.

5.5.3. Design of Slab

Size of slab taken = 3.92 x 3.96 m and thickness of slab = 150 mm

Live load = 4kN/m² and Dead Load = 3.75 + 1 = 4.75 kN/m²

Total load = 8.75 kN/m² and Factored load = 1.5 x 8.75 = 13.125 kN/m²

Positive bending moment at mid span = [(Wl²) / 12] = 16.81 kN-m and negative bending moment at support = 19.75 kN-m

M_u limit = [$\frac{0.36X_{umax}}{d}$ (1-0.42$\frac{X_{umax}}{d}$) x f_{ck} bd²] = 3.45 bd²

Assuming b = 1000 mm

d = $\sqrt{15.8X10^6/3.45X1000}$ = 67.67 mm

Therefore adopt 28 mm diameter bars as reinforcement

Effective cover = 20 mm and Overall depth = 87.67 mm

Effective depth = 150 – 20 = 130 mm

M_u = 0.87$f_y A_{st}$ d (1-$\frac{f_y X A_{st}}{b d f_{ck}}$)

Substituting values and solving we get A_{st} = 446.188 mm²

Providing minimum steel of 12% bD = $\frac{12}{100} X\ 1000\ X150$ = 186 mm²

Spacing of 10 mm diameter bars = 176.02 mm center-to-center spacing

Distribution reinforcement

Providing 0.12% of gross area as distribution reinforcement

Area of steel = (0.12 X 150 X 1000) = 180 mm

Hence provide 6 mm diameter bars @ 150 mm center-to-center spacing

Check for development length

L_d=[$\frac{\emptyset X \sigma_{st}}{4 X b d}$] = 402.95 mm and $L_{davailable}$ = [(M_1)/V] + L_o

M_u = 087$f_y A_{st}$ d (1-$\frac{f_y X A_{st}}{b d f_{ck}}$) = 20.5 X 10⁶ N mm

V = $\frac{WL}{2}$ = 25.72 kN

[(M_1)/V] + L_o = 727 mm

$L_{davailable}$ > L_{dreq}

Hence design is safe.

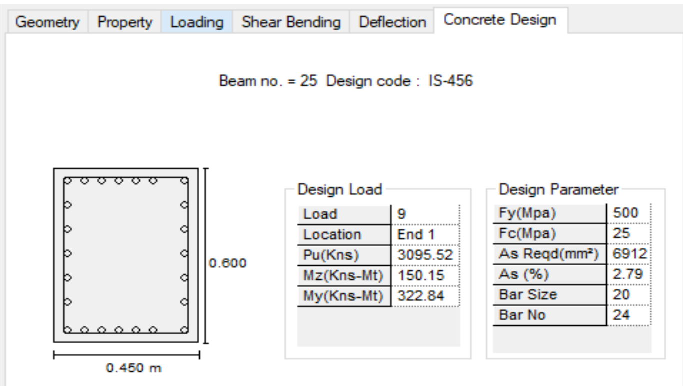
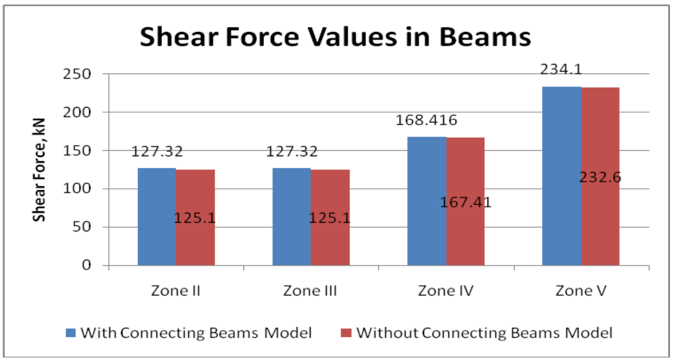


Fig.10 Column Design output

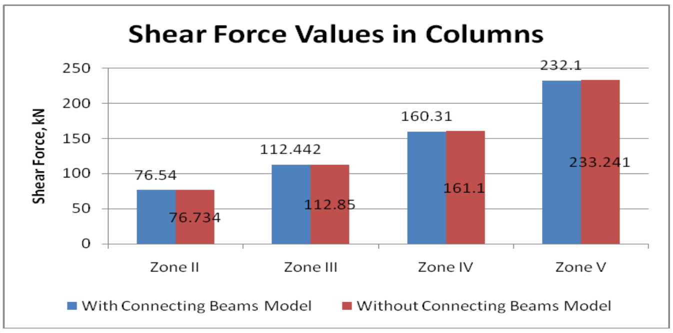
6. Results

6.1 Shear force Variations

In beams

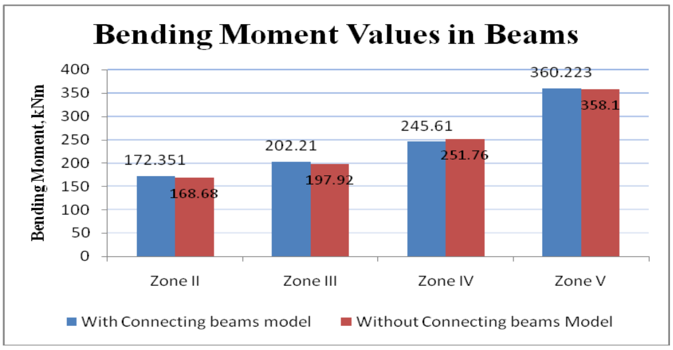


In columns



6.2 Bending moment Variations

In beams



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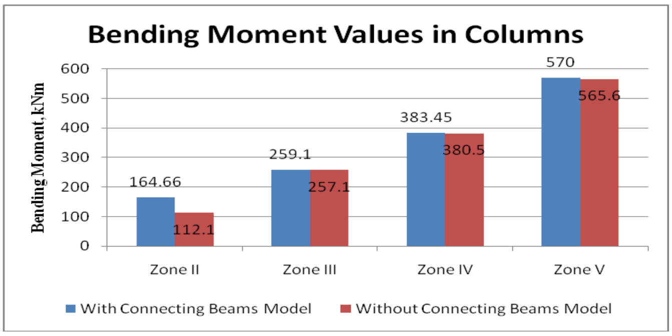
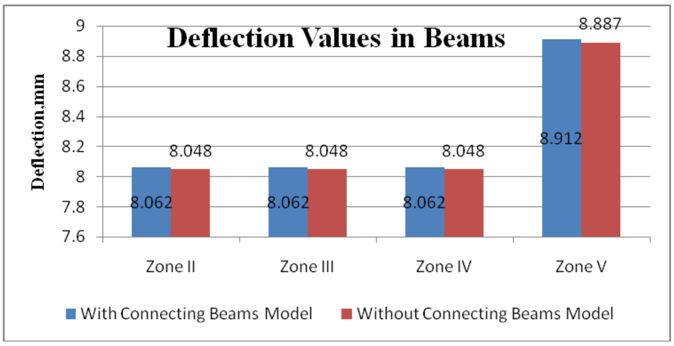


6.3 Deflection Variations

In beams



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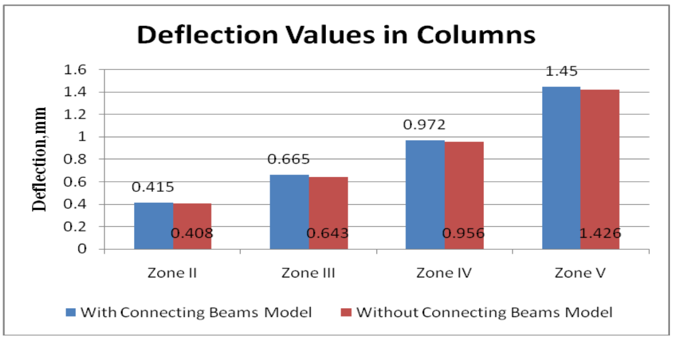
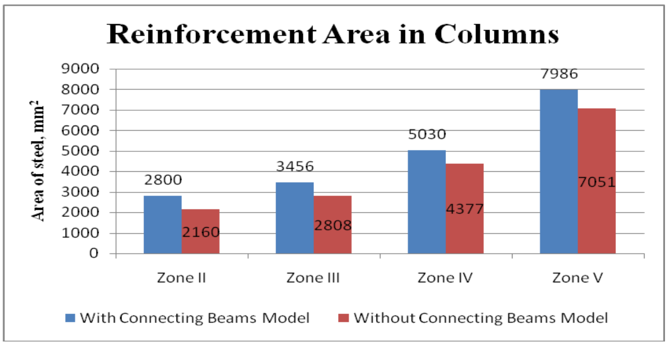


6.4 Percentage of Reinforcement Variations

In columns



7. CONCLUSIONS

Shear Force variations:

Table.1 Shear Force values in Beams and Columns

Zones	SF in Beams		Variation in %	SF in Columns		Variation in %
	Model-I	Model-II		Model-I	Model-II	
II	127.32	125.1	1.74	76.54	76.734	0.25
III	127.32	125.1	1.74	112.442	112.85	0.36
IV	168.42	167.4	0.6	160.31	161.1	0.5
V	234.1	232.6	0.64	232.1	233.241	0.5

The above table.1 shows the comparative results of Shear Forces in beams are likely varying as 1.74, 1.74, 0.6and 0.64 in % and in columns are 0.25, 0.36, 0.5 and 0.5 in % for Zones II, III, IV and V respectively subjected loadings as per IS 1893-2002. Where Model-I is H-shaped Structure with Connecting Beams and Model-II is without Connecting beams.

Bending Moment variations:

Table.2 Bending Moment values in Beams and Columns

Zones	BM in Beams		Variation in %	BM in Columns		Variation in %
	Model-I	Model-II		Model-I	Model-II	
II	172.35	168.68	2.13	164.7	112.1	31.9
III	202.2	197.92	2.12	259.1	257.1	0.78
IV	245.6	251.76	2.51	383.5	380.5	0.77
V	360.22	358.1	0.6	570	565.6	0.77

The above table.2 shows the comparative results of bending moment in beams are likely varying as 2.13, 2.12, 2.51 and 0.6 in % and in columns are 31.9, 0.78, 0.77 and 0.77 in % for Zones II, III, IV and V respectively subjected loadings as per IS: 1893-2002 for two models.

Deflection variations:

Table.3 Deflection in Beams and Columns

Zones	Beams		Variation in %	Columns		Variation in %
	Model-I	Model-II		Model-I	Model-II	
II	8.062	8.048	0.17	0.415	0.41	1.68
III	8.062	8.048	0.17	0.665	0.643	3.31
IV	8.062	8.048	0.17	0.972	0.956	1.65
V	8.912	8.887	0.28	1.45	1.43	1.655

Form the table 3 it is found that variations in deflections in beams are 0.17, 0.17, 0.17 and 0.28 in % and in columns are 1.68, 3.31, 1.65 and 1.655 in % for Zones II, III, IV and V respectively when subjected loadings as per IS: 1893-2002.

Percentage of Reinforcement*:*

From table.4 it is found that area of steel in varying as 22.85%, 18.75%, 12.98% and 11.7% for two models when subjected to loadings as per IS: 1893-2002, for zones II, III, IV and V respectively.

Table.4 Comparison of Reinforcement in two models

Zones	Area of Steel, mm^2		Variation in %
	Model-I	Model-II	
II	2800	2160	22.85
III	3456	2808	18.75
IV	5030	4377	12.98
V	7986	7051	11.7

8. REFERENCES

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