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OPTIMUM RATIO OF WIDTH TO HEIGHT FOR SEISMIC RESISTANT G+10 RC BUILDING

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ABSTRACT

This paper presents the design and analysis of a multistory building to resist earthquakes taking all seismic zones for various b/d ratios. A 10 storied building is designed as per National Building Code and Building Bye laws and then the earthquake analysis is performed based on the Response Spectrum Method. First the design and analysis is done manually and then it is verified by STAAD-Pro. The manual calculations and STAAD.Pro analysis vary with a maximum variation of 5%. There is no significant variation in the volume of concrete required for the buildings with the variation in seismic zone as the beam and column cross-sections were not varied. As the b/d ratio is decreases, the deflection also increases.Although buildings with low b/d ratios are nearly safe, those that are not are made earthquake resistant by increasing the steel quantities in order to increase the ductility of the buildings. From the results obtained, the best b/d ratio which ensures safety against earthquakes is 0.79.

Keywords:*b/d ratio, Base shear, seismic analysis,STAAD.Pro*

I INTRODUCTION

Experience in past earthquakes has demonstrated that many common buildings and typical methods of construction lack basic resistance to earthquake forces. Three methods of earthquake response analysis of simple structures and equipment modeled as single degree of freedom (SDOF) system are available.

1. Response spectrum method
2. Time-history method

The SDOF response spectrum method can be used as long as the structure or equipment can be modeled by a single degree of freedom system consisting of a spring, mass and damping. The SDOF response spectrum method usually gives less conservative results than simplified procedures, yet easy to perform. It is far easier to perform than time history analysis that requires structural dynamic analysis computer software. Time history analysis provides both the time history of the response (for example, displacement, velocity and acceleration) and maximum value of the response. Response spectrum method provides only the maximum value of response. (Plot of response versus time is called response time history).

II LITERATURE REVIEW

Raul D. Bertero (1999) explained redundant as ‘‘exceeding what is necessary or natural; superfluous.’’ The same loose definition not only could probably be applied to over-strength, but could also be misleading, because, in the particular context of EQ engineering, redundancy is not superfluous. Clearly, for the purpose of engineering design, a more precise definition is needed. The reliability of a multi component system will be a function of the redundancy of the system; indeed, the analysis of reliability depends on whether the system is redundant or non-redundant.

To obtain the quantitative effect of redundancy on the probability of structural failure, four simplified cases will be considered:

1. Strength-based design and PHs with infinite deformation capacity
2. Strength-based design and PHs with finite deformation capacity
3. Displacement-based design and PHs with finite deformation capacity
4. Energy-based design

PraneshMurnal and Ravi Sinha (2002) discussed the essential properties of sliding isolators used for earthquake resistant design are period shift, energy dissipation, and the restoring mechanism in their paper. Isolation systems using a curved surface incorporate all of these in a single unit. The writers have recently proposed a new isolator called the variable frequency pendulum isolator ~VFPI which overcomes these limitations while retaining the advantages. The oscillation frequency of the VFPI continuously decreases with increase in sliding displacement, and the restoring force has an upper bound so that the force transmitted to the structure is bounded. The mathematical formulation for the response of multi degree-of-freedom ~MDOF structures isolated using the VFPI has been discussed in this paper. Parametric studies have been carried out to examine the behavior of MDOF structures and structure-equipment systems isolated with the VFPI, friction pendulum system, and pure friction isolator.

Mark Grigorian and Carl E. Grigorian (2012) in their paper explained Earthquake resisting moment frames (ERMFs) as specially detailed structures with prequalified beam-to-column connections that are designed to sustain large inelastic displacements during strong ground motion. Bending moments caused by code-level gravity loads have little or no effect on the drift and ultimate carrying capacity of ERMFs designed for moderate to severe earthquakes. This statement is equally valid for multistory moment frames.

III OBJECTIVE AND SCOPE OF THE PROJECT

This paper presents the design and analysis of a multistory building to resist earthquakes taking all seismic zones for various b/d ratios. A 10 storied building is designed as per National Building Code and Building Bye laws and then the earthquake analysis is performed based on the Response Spectrum Method. First the design

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and analysis is done manually and then it is verified by STAAD.Pro.Various Loads and their combinations considered in the study are as follows.

Loads

DL	-	Dead Load
IL	-	Imposed Load
EXTP (+ve torsion)	-	Clockwise torsion due to Earthquake
EXTN (-ve torsion)	-	Anti clockwise +x torsion due to earthquake
EZTP (+ve torsion)	-	+ve clockwise torsion due to Earthquake
EZTN (-ve torsion)	-	+z Anti clockwise torsion due to Earthquake
EL	-	Earthquake Load

Combinations

1.5×(DL+IL)	1.2×(DL+IL+EZTP)
1.2×(DL+IL+EL)	1.5×(DL+EXTP)
0.9×DL+/-EL	1.5×(DL+EXTN)
1.2×(DL+IL+EXTP)	1.5×(DL-EXTP)
1.2×(DL+IL-EXTN)	1.5×(DL-EXTN)
1.2×(DL+IL+EXTN)	1.5×(DL-EZTP)
1.2×(DL+IL-EXTP)	1.5×(DL+EZTP)
1.2×(DL+IL+EZTN)	

IV DESIGN METHODOLOGY OF THE BUILDING

4.1 Site layout

A site within the compound of MVGR College of Engineering, Vizianagaram is considered for this study.Preliminary survey is done within the MVGR. College Campus and the required site plot is obtained. The following figure shows the area surveyed.

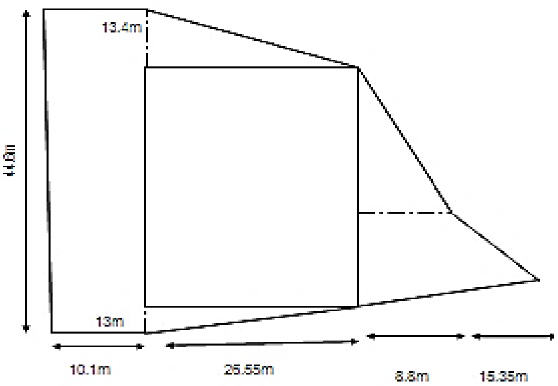

Fig. 1 Site lay out

Total area surveyed : 1582.515m ^{2}

Bearing capacity : 25T/m^2

Importance of building (Purpose) : Residential

Importance factor : 1.0

4.2 b/d ratio: 0.79

Area : 781.75 m^2

Built up area : 434.75 m^2

Dimensions : 23.5m × 18.5m

Setbacks :

Front : 6m

Rare : 2m

Sides : 3m each

Ground Floor : Parking

No. of flats per Floor : 6

Area of each floor : 59.5 m^2

No. of floors : G+9

Wall Thickness:

Outer wall : 250mm

Inner wall : 150mm

The location of the columns and beams is identified from the plan.

No. of beams : 22beams per floor (Continuous beams)

No. of columns : 48 for each floor

4.3 Total steel obtained for the building by manual calculation:

Slabs:

Floor	Diameterof bars	No. of bars	Weight of Steel
Terrace	10mm	126	17703 kg
Floors 1-9	10mm	756	98548 kg
Total	10mm	1890	116251 kg

Table 1. Steel required for Slabs

Beams:

Floor	Diameterof bars	No. of Bars	Weight
Terrace	12mm	308	18284 kg
Floors 1-9	12mm	2772	120982 kg
Total	12mm	3050	139266 kg

Table 2. Steel required for Beams

Columns:

Floor	Diameterof bars	No. of Bars	Length	Weight
1	20mm	266	3m	16965 kg
2	20mm	216	3m	14596 kg
3	20mm	176	3m	12300 kg
4	20mm	158	3m	9867 kg
5	20mm	154	3m	9837 kg
6	20mm	152	3m	9823 kg
7	20mm	156	3m	9852 kg
8	20mm	164	3m	9911 kg
9	20mm	164	3m	9911 kg
10	20mm	196	3m	1248 kg

Table 3. Steel required for Columns

Total steel:

Structure	Diameter of bars	No. of Bars	Weight of Steel
Slab	10mm	1890	116251 kg
Beams	12mm	3050	139266 kg
Columns	20mm	1840	115110 kg
Shear Reinforcement	8mm		164624 kg
Total		6740	419000 kg

Table 4. Total Steel required

4.4 Calculation of Storey Shear and Base Shear

Base Shear

$V_b = A_h \times W$

W = Total weight Considered

A_h = $ZIS_a/2Rg$

Where

A_h= Design horizontal Acceleration spectrum

Z = Zone Factor

I = Importance Factor

S_a/g = Average Response Acceleration Coefficient

R = Response Reduction Factor

Effective weight at each floor except roof : Dead load +weight of partition +25%of live load

Effective weight at roof level : (D.L × plinth area)+(weight of beams of floor and roof)+ 0.5×(weight of column)

Step: 1

Size of the column = 300×450

Size of the beam = 230×300

Step: 2

Floor area = 23.5×18.5m

Dead load = $4kN/m^2$

Weight of partitions = $2kN/m^2$

For live load upto including = $3kN/m^2$

Total seismic weight

Weight of beams = length × breadth × depth × unit weight

= (6×23.5)×(0.3×0.23)×(25)= 243.225

Weight of columns =length × breadth × depth × unit weight

= 3 × 48 × 0.3 × 0.45 × 25

Effective weight of each floor = Dead load +weight of partition +25%of live load

= 4+2+(0.25×3)= 6.75

Equivalent load at roof level = Dead load ×plinth area +weight of beams floorand roof +0.5×(weight of columns)

= (4+25%×3)×434.75)+243.225+351.8375+0.5(486)

= 2902.325

Equivalent load at floor level = (6.75×434.75)+241.225+351.075+486= 4014.8625

Step 3: Design parameter for calculation of base shear

The total design lateral force or design seismic base shear (V_B) along any principal directionshall be determined by the following expression:-

$V_B = A_h \times W$ **[Clause 7.5.3 IS-1893-2002]**

Where

A_h = Design horizontal acceleration spectrum value

T_a = Fundamental natural period **[Clause 7.6 IS-1893-2002]**

W = Seismic weight of the building **[Clause 7.4.2 IS-1893-2002]**

T_a = $0.075h^{0.75}$ **[Clause 7.6.1 IS-1893-2002]**

h = height of building in metres

Ta = $0.075\ h^{0.75} = 0.075(30)^{0.75}$

Design seismic coefficient $A_h = (ZIS_a)/2Rg$ =0.10×1×.04/2×3 = 0.0173 **[Clause 6.4.2 IS-1893-2002]**

Base shear = 0.0173×39036.0875= 675.32kN

4.5 Storey shear and Base Shear calculations for zone-V

Storey shear and base shear in Zone V for three b/d ratio's are calculated and as follows.

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4.5.1 b/d ratio 0.79

Table 5. Storey hear and Base Shear in Zone-V for b/d ratio 0.79

Storey level	w_i	h_i	$w_ih_i^2$	$w_ih_i^2$/sum of $w_ih_i^2$	Storey shear	Base Shear
10	2902.5	30	2612250	0.2	487.17	487.17
9	4014.86	27	2926832	0.22	535.89	1023.06
8	4014.86	24	2312559	0.179	436.02	1459.07
7	4014.86	21	1770553.26	0.137	333.59	1792.79
6	4014.86	18	1300814.64	0.1	243.59	2036.37
5	4014.86	15	9063343.5	0.06	146.15	2182.52
4	4014.86	12	578139.84	0.044	107.18	2289.69
3	4014.86	9	325203.66	0.025	60.89	2350.59
2	4014.86	6	144534.96	0.011	26.79	2377.33
1	4014.86	3	36133.74	0.00274	6.79	2384.15

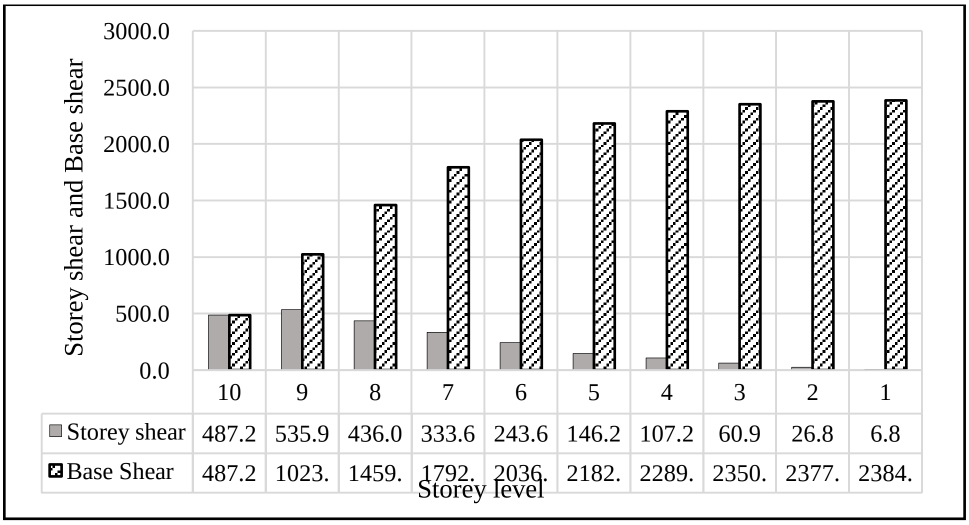

Fig.2. Storey shear and Base Shear in Zone-V for b/d ratio 0.79

4.5.2 b/d ratio 0.66

Table 6. Base shear and storey shear in Zone-V for b/d ratio 0.66

Storey level	w_i	h_i	$w_ih_i^2$	$w_ih_i^2$/sum of $w_ih_i^2$	Storey shear	BaseShear
10	2802.28	30	2522052	0.2096	473.06	473.06
9	3707.43	27	2702716.47	0.22	496.52	969.59
8	3707.43	24	2135479.68	0.17	383.68	1353.27
7	3707.43	21	1634976.63	0.13	293.40	1646.67
6	3707.43	18	1201207.32	0.09	203.13	1849.79
5	3707.43	15	834171.75	0.06	135.42	1985.21
4	3707.43	12	533869.92	0.044	99.31	2084.51

3	3707.43	9	300301.83	0.025	56.42	2140.94
2	3707.43	6	133467.48	0.011	24.83	2165.76
1	3707.43	3	33366.87	0.00279	6.29	2172.07

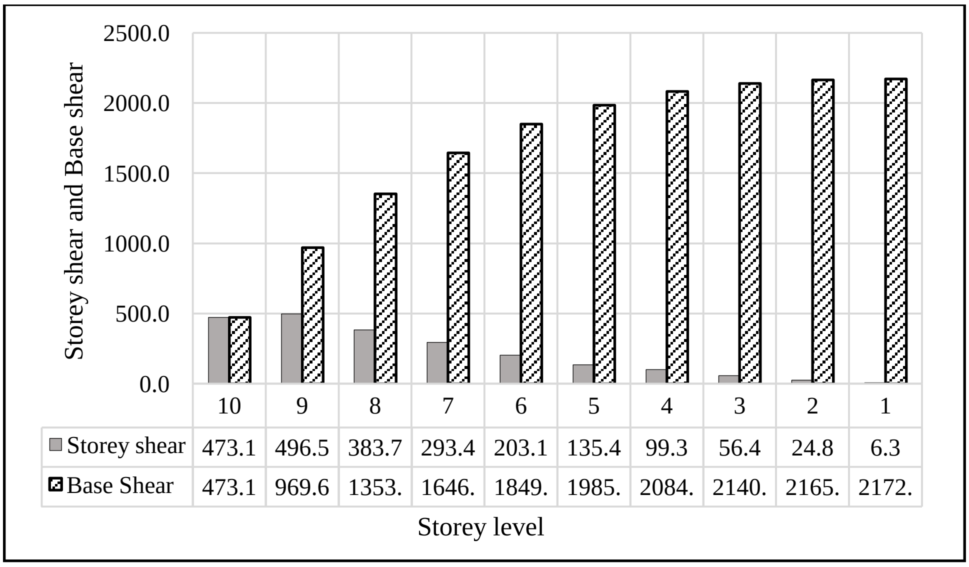

Fig. 3.Storey shear and Base shear in Zone-V for b/d ratio 0.66

4.5.2 b/d ratio 1.03

Table 7. Base shear and storey shear in Zone-V for b/d ratio 1.03

Storeylevel	w_i	h_i	$w_ih_i^2$	$w_ih_i^2$/sum of $w_ih_i^2$	Storey shear	BaseShear
10	3484.41	30	3135969	0.2	582.65	582.65
9	4823.61	27	3516411.69	0.22	640.92	1223.57
8	4823.61	24	2778399.36	0.179	521.48	1745.05
7	4823.61	21	2127212.01	0.137	399.12	2144.17
6	4823.61	18	1562849.64	0.1	291.33	2435.49
5	4823.61	15	1085312.25	0.06	174.79	2610.28
4	4823.61	12	694599.84	0.044	128.18	2738.47
3	4823.61	9	390712.41	0.025	72.83	2811.31
2	4823.61	6	173649.96	0.011	32.05	2843.35
1	4823.61	3	43412.49	0.0027	7.87	2851.22

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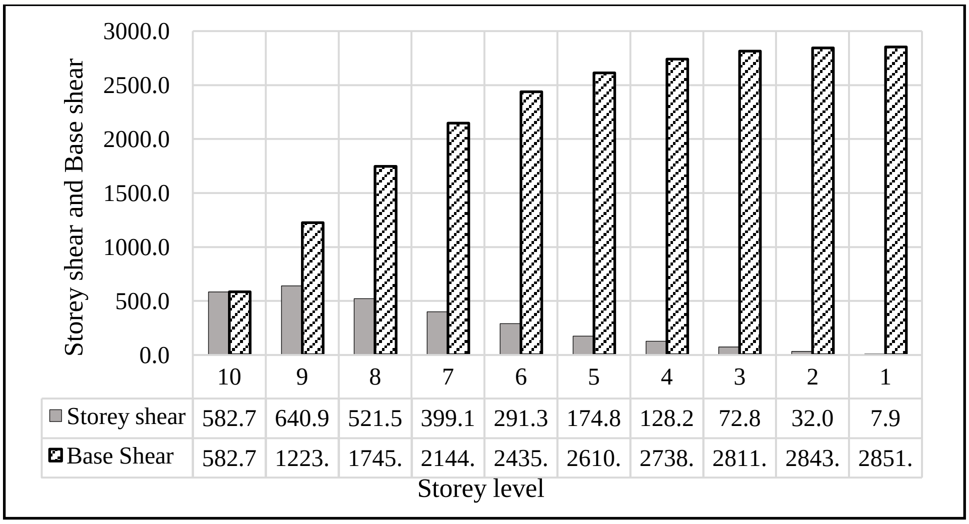

Fig.4. Storey shear and Base shear in Zone-V for b/d ratio 1.03

In the same manner, Storey shear and Base shear values for the remaining seismic zones IV, III and II are determined for b/d ratios of 0.79, 0.66 and 1.03 and tabulated.

V STAAD.Pro ANALYSIS

5.1 STAAD.Pro results for b/d ratio 0.79 for seismic Zone-V

Beams:

Table 8. Steel required for beams in Zone-V for b/d ratio 0.79

Floor	Diameter of Bars	No. of Bars	Weight
Terrace	12mm	336	12393 kg
Floors 1-9	12mm	2894	142859kg
Total	12mm	3230	155252 kg

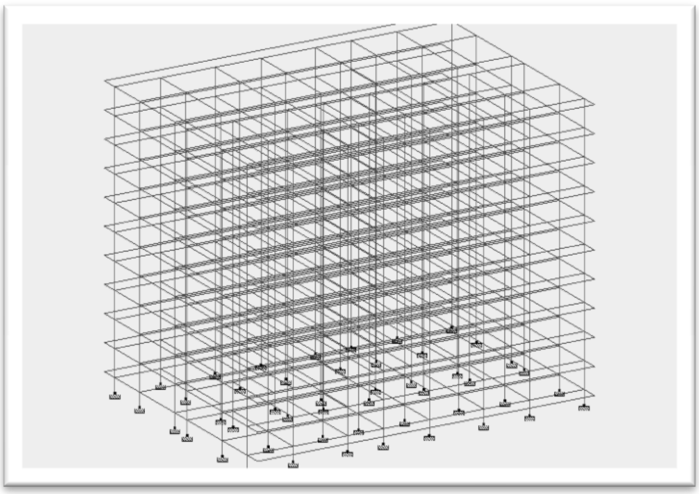

Fig.5. Isometric view of the building for b/d ratio:0.79

Columns:

Table 9. Steel requires for columns in Zone-V for b/d ratio 0.79

Floor	Diameter of Bars	No. of Bars	Length	Weight
1	20mm	428	3 m	18242 kg
2	20mm	402	3 m	16885 kg
3	20mm	352	3 m	14982 kg
4	20mm	306	3 m	13653 kg
5	20mm	306	3 m	13653 kg
6	20mm	306	3 m	13653 kg
7	20mm	306	3 m	13653 kg
8	20mm	306	3 m	13653kg
9	20mm	306	3 m	13653 kg
10	20mm	306	3 m	13653 kg

Total steel:

Table 10. Total steel required the building in Zone-V for b/d ratio 0.79

Structure	Diameter of Bars	No. of Bars	Weight of Steel
Beams	12mm	3230	155252 kg
Columns	20mm	3324	141016 kg
Shear Reinforcement	8mm		161759 kg
Total			458027 kg

Total weight of steel required = 458027 kg

Volume of concrete required = 508.97 cubic meters

Deflection = 14.120mm

5.2 STAAD.Pro results for b/d ratio 0.66 for seismic Zone-V

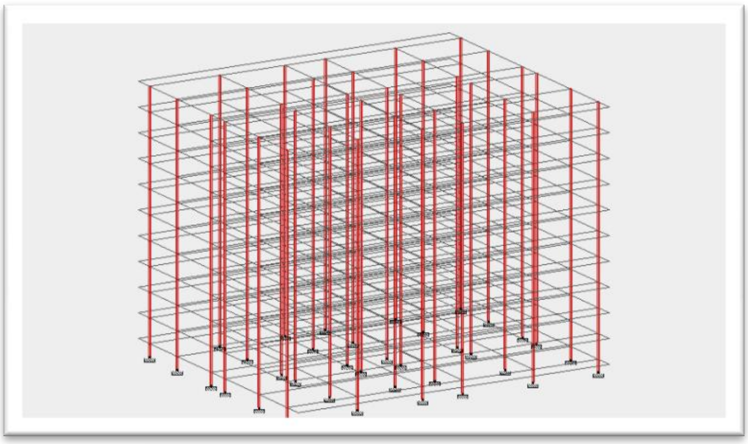

Fig.6. Isometric View of Building in STAAAD-PRO for b/d ratio 0.66

Beams:

Table 11. Steel required for beams in Zone-V for b/d ratio 0.66

Floor	Diameter of Bars	No. of Bars	Weight
Terrace	12mm	168	805 kg
Floors 1-9	12mm	1676	22659 kg
Total	12mm	1844	23464 kg

Columns:

Table 12. Steel required for columns in Zone-V for b/d ratio 0.66

Floor	Diameter of Bars	No. of Bars	Length	Weight
1	20mm	208	3 m	7234 kg
2	20mm	202	3 m	7213kg
3	20mm	202	3 m	7213 kg
4	20mm	152	3 m	6203 kg
5	20mm	152	3 m	6203 kg
6	20mm	152	3 m	6203 kg
7	20mm	152	3 m	6203 kg
8	20mm	152	3 m	6203 kg
9	20mm	152	3 m	6203 kg
10	20mm	152	3 m	6203 kg

Total steel:

Table 13. Total steel required for the building in Zone-V for b/d ratio 0.66

Structure	Diameter of Bars	No. of Bars	Weight of Steel
Beams	12mm	1844	23464 kg
Columns	20mm	1674	64729 kg
Shear Reinforcement	8mm		73968 kg
Total			162161 kg

Total weight of steel required = 162161 kg

Volume of concrete required = 154.49 cubic meters

Deflection = 152.016mm

5.3 STAAD.Pro results for b/d ratio 1.03 for seismic Zone-V

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IJARSE
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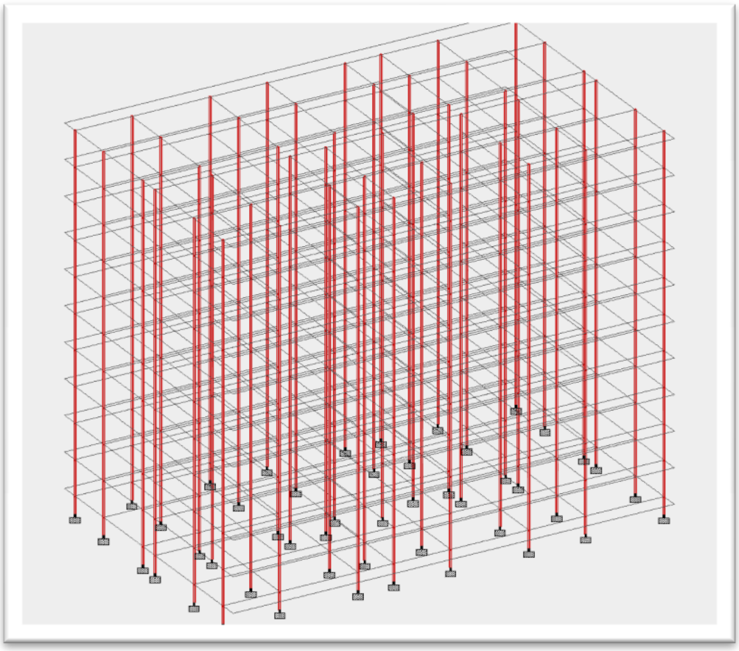

Fig. 7. Isometric view of the building in STAAD-PRO for b/d ratio 1.03

Beams:

Table 14. Steel required for beams in Zone-V for b/d ratio 1.03

Floor	Diameter of Bars	No. of Bars	Weight
Terrace	12mm	358	12985 kg
Floors 1-9	12mm	3064	150694 kg
Total	12mm	3422	163679 kg

Columns:

Table 15. Steel required for columns in Zone-V for b/d ratio 1.03

Floor	Diameter of Bars	No. of Bars	Length	Weight
1	20mm	526	3 m	36664kg
2	20mm	472	3 m	32697kg
3	20mm	426	3 m	25689kg
4	20mm	362	3 m	19598 kg
5	20mm	362	3 m	19598 kg
6	20mm	362	3 m	19598 kg
7	20mm	362	3 m	19598 kg
8	20mm	362	3 m	19598kg
9	20mm	362	3 m	19598 kg
10	20mm	362	3 m	19598kg

Total steel:

Table 16. Total Steel required for building in Zone-V for b/d ratio 1.03

Structure	Diameter of Bars	No. of Bars	Weight of Steel
Beams	12mm	3422	163679 kg
Columns	20mm	3958	232236 kg
Shear Reinforcement			145663 kg
Total			541578 kg

Total weight of steel required = 541578 kg

Volume of concrete required = 417.39 cubic meters

Deflection = 608.628mm

Similarly, STAAD.Pro analysis is done to the normal R C building including the remaining seismic zones IV, III and II with b/d ratios of 0.79, 0.66 and 1.03. The quantity of steel required for different b/d ratios for different seismic zones are tabulated below:

Table 17. Steel required for Building in various seismic zones

b/d ratio	Normal R C building	Zone-II	Zone-III	Zone-IV	Zone-V
0.79	422350 kg	425688 kg	434741 kg	457186 kg	458027 kg
0.63	161173 kg	162678 kg	162161 kg	162644 kg	162161 kg
1.03	526818 kg	542895 kg	542042 kg	542042 kg	541578 kg

Table 18. Variation in steel quantities for all seismic zones

b/d ratio	% Change in steel from zone-II to zone-III	% Change in steel from zone-III to zone-IV	% Change in steel from zone-IV to zone-V
0.79	2.08	4.91	0.18
0.63	0.32	0.29	0.29
1.03	0.16	0	0.87

Table 19. Deflection s for Various Buildings

b/d ratio	Normal RC building	Zone-II	Zone-III	Zone-IV	Zone-V
0.79	11.202mm	13.396mm	13.513mm	13.729mm	14.120mm
0.63	57.000mm	63.298mm	66.780mm	108.368mm	152.016mm
1.03	132.620mm	134.658mm	135.560mm	326.23mm	608.628mm

VI RESULTS AND CONCLUSIONS

Based on the study conducted, the following specific conclusions are drawn.

1) The manual and STAAD.Pro analysis is done for 3 different b/d ratios in all the 4 different seismic zones in India.
2) The manual calculations and staad-pro analysis vary with a maximum variation of 5%.
   There is no significant variation in the volume of concrete required for the buildings with the variation in seismic zone as the dimensions of beams and columns have not been varied.
3) The above results show that the quantities required for the earthquake resistant buildings in various zones increase with the intensity of zone in most cases.
4) The variation in the reinforcement is high and increasing in the bottom floor columns than in top floor columns whereas there is no significant change in the reinforcement of beams.
5) The Base shear values of the buildings are increasing with the increase in seismic zone factors.
6) As the b/d ratio is decreasing, the deflection occurring is increasing. Hence, while designing the earthquake resistant buildings, adequate b/d ratio is to be adopted.
7) The buildings with low b/d ratios are nearly safe but can made earthquake resistant by increasing the steel quantities in order to increase the ductility of the buildings.
8) From the results obtained, the b/d ratio which is safe against earthquakes is 0.79

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