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Seismic Analysis & Design of Ductile Detailed Reinforced Concrete Structure with reference to IS13920:1993(Old Code) & IS13920:2016 (Revised Code)

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Abstract— An Earthquake resistant structure demands reinforcement detailing to be as per IS 13920. With the provision of ductile detailing on RCC frame it becomes a special moment resisting frame. Now with the new published code of ductile detailing provide a sufficient changes in the structure detailing. Hence the building made in past with the old code will be less detailed for a high seismic forces in comparison to the new building to be analyze as per the new revised code of IS 13920. Deflection will be considered for analysis and comparison. In this paper seismic analysis is done by using STAAD-Pro software for a non-ductile structure using IS 456:2000, for a ductile detailed structure using IS 13920:1993 (old version) and a ductile detailed structure using IS 13920:2016 (new version) of a G+10 storied building

Index Terms— Ductility, Earthquake resistant structures, ductile detailed structures, Deformation, STAAD-Pro.

I. INTRODUCTION

It is uneconomical to design structures to withstand major earthquakes elastically. Therefore, the trend of design is that the structure should have sufficient strength and ductility to withstand large tremors in elastically. Ductility can be defined as the —ability of material to undergo large deformations without rupture before failure. For earthquake resistant structures, ductility provides enough scope in making the structure more resistant. If ductile members are used to form a structure, the structure can undergo large deformations before failure. This is beneficial to the users of the structures, as in case of overloading, if the structure is to collapse, it will undergo large deformations before failure and thus provides warning to the occupants. This gives a notice to the occupants and provides sufficient time for taking preventive measures; this will reduce loss of life. This project is proposed to critically study provision of the IS 13920-1993, analyze the structure with and without ductile detailing and to study implications of ductile detailing.

II. STUDY OF IS CODES

IS 13920: Ductile Detailing of Reinforced Concrete Structures subjected to seismic Forces – Code of Practice

I. **Clause 1.1.1**: Provisions of IS 13920-1993 shall be adopted in all reinforced concrete structures which are located in seismic zone III, IV or V.

II. **Clause 3.4**: Hoop – It is closed stirrup having a 135 degree hook with 10 diameter extension (but less than 75mm) at each end that is embedded in the confined core of the section.

III. **Clause 3.6**: Shear Wall- A wall that is primarily designed to resist lateral forces in its own plane.

IV. **Clause 5.2**: For all buildings which are more than 3 storeys in height, the minimum grade of concrete shall be M20 (fck = 20 MPa).

V. **Clause 5.3**: Steel reinforcements of grade Fe 415 (see IS 1786: 1985) or less only shall be used. However, high strength deformed steel bars, produced by the thermo mechanical treatment process, of grades Fe 500 and Fe 550, having elongation more than 14.5 percent and conforming to other requirements of IS 1786 : 1985 may also be used for the reinforcement.

Flexure Members:

Clause 6.1.2: The member shall preferably have a width-to-depth ratio of more than 0.3.

Clause 6.1.3: The width of the member shall not be less than 200 mm.

Clause 6.1.4: The depth D of the member shall preferably be not more than 1/4 of the clear span.

Longitudinal Reinforcement:

Clause 6.2.1: The top as well as bottom reinforcement shall consist of at least two bars throughout the member length. The tension steel ratio on any face, at any section, shall not be less than ρmin = 0.24(fck)1/2 /fy ; where fck and fy are in MPa. Beams shall have at least 12mm diameter bars each at the top and bottom faces.

Clause 6.2.2: The maximum steel ratio on any face at any section, shall not exceed ρmax = 0.025.

Clause 6.2.3: The positive steel at a joint face must be at least equal to half the negative steel at that face.

Clause 6.2.5: In an external joint, both the top and the bottom bars of the beam shall be provided with anchorage length, beyond the inner face of the column, equal to the development length in tension plus 10 times the bar diameter minus the allowance for 90 degree bend. In an internal joint, both face bars of the beam shall be taken continuously through the column.

Special Confining Reinforcement

Clause 7.4.1: Special confining reinforcement shall be provided over a length l0 from each joint face, towards mid-span, and on either side of any section, where flexural yielding may occur under the effect of earthquake forces. The length l0 shall not be less than larger lateral dimension of the member at the section where yielding may occurs 1/6 of the clear span of the member 450mm.

Clause 7.4.2: When a column terminates into a footing or mat, special confining reinforcement shall extend at least 300 mm into the footing or mat.

Clause 7.4.6: The spacing of hoops used as special confining reinforcement shall be1/4 of minimum member dimension of the beam and column, 6 times diameter of the smallest longitudinal reinforcement bars, or 100mm link.

Joints of Frames

Clause 8.1: The special confining reinforcement as required at the end of column shall be provided through the joint as well, unless the joint is confined as specified by 8.2.

Clause 8.2: A joint, which has beams framing into all vertical faces of it and where each beam width is at least ¾ of the column width, may be provided with half the special confining reinforcement required at the end of the column. The spacing of the hoops shall not exceed 150 mm.

III. MODELING OF STRUCTURE

Plan of Structure – 5 x 5 bays of 5m & 4m for G+10 storeys.

Details of Building:

1) Length of Building in X direction - 25m
2) Width of Building in Z direction - 20m
3) Height of Floor – 3.2m
4) Dimensions of column- 0.60m x 0.30m
5) Dimensions of beam - 0.6m x 0.30m
6) Thickness of Slab - 0.120m
7) Dead Load on Building – 4 KN/m2
8) Dead Load on Building for 0.23m thick wall – 11.96KN/m
9) Dead Load on Building for 0.125m thick wall – 6.24 KN/m
10) Live Load on Floor and Roof of Building – 3 KN/m2 & 1.5 KN/m2
111) Seismic load as per Zone factor and Response Reduction Factor.
a) Earthquake load in X- Direction
b) Earthquake load in Z- Direction
12) Thickness of Shear wall – 0.23m
13) Response Reduction Factor –For SMRF – 5

This plan modeled in STAAD-Pro for analyzing and design of G+10 storied building. This building is analyze for different Zones (Zone II, Zone III, Zone IV, and Zone V).

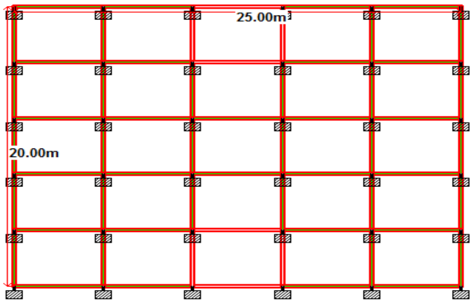


Fig. Plan of Structure.

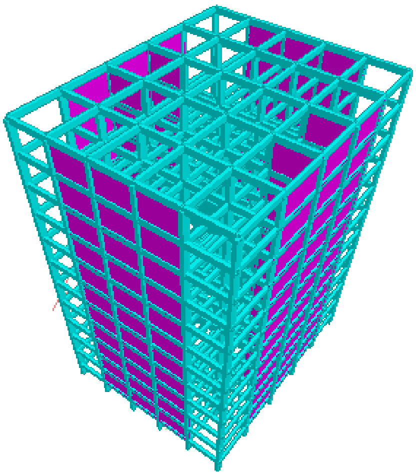


Fig.3-D View of the Structure.

IV. ANALYSIS & DESIGN OF STRUCTURE

For analysis of structure, 7 load combinations were considered

1) 1.5(DL+LL)
2) 1.2(DL+LL+EQX)
3) 1.2(DL+LL+EQZ)
4) 1.5(DL+EQX)
5) 1.5(DL+EQZ)
6) 0.9DL+1.5EQX
7) 0.9DL+1.5EQZ

However it was found that 2 load combinations are critical for columns. These are 1.5(DL+EQX) or 1.5(DL+EQZ) depending on orientation of columns.

During analysis, it was found that the deflection at top story levels was very high over these loading combinations. So it was decided to provide Shear wall to take care of excessive horizontal forces and reduced the deflections. By providing Shear wall, it was found that the displacements were reduced considerably, so also axial forces in various columns.

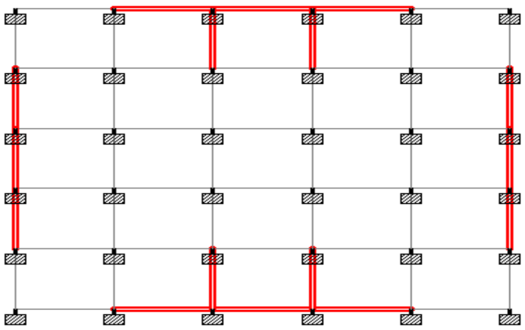


Fig.-Position of Shear Wall in the Structure

V. ANALYSIS & COMPARISION OF RESULT

For Uniaxial Column with Shear Wall 1.5(DL + EQX)

Uniaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	**8.186**	**13.150**	**18.722**	**32.997**
Floor 9	**7.813**	**12.554**	**17.838**	**31.517**
Floor 8	**7.244**	**11.640**	**16.512**	**29.258**
Floor 7	**6.557**	**10.537**	**14.93**	**26.497**
Floor 6	**5.803**	**9.327**	**13.204**	**23.439**
Floor 5	**5.022**	**8.071**	**11.417**	**20.239**
Floor 4	**4.236**	**6.809**	**9.626**	**17.005**
Floor 3	**3.462**	**5.565**	**7.863**	**13.806**
Floor 2	**2.701**	**4.342**	**6.133**	**10.666**
Floor 1	**1.941**	**3.12**	**4.404**	**7.552**
GF	**1.142**	**1.835**	**2.59**	**4.344**

For Biaxial Column with Shear Wall 1.5(DL + EQX)

Biaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	**5.386**	**8.658**	**12.23**	**21.848**
Floor 9	**5.009**	**8.053**	**11.373**	**20.334**
Floor 8	**4.597**	**7.39**	**10.434**	**18.642**
Floor 7	**4.178**	**6.717**	**9.452**	**16.896**
Floor 6	**3.753**	**6.634**	**8.515**	**15.101**
Floor 5	**3.328**	**5.35**	**7.549**	**13.289**
Floor 4	**2.909**	**4.677**	**6.598**	**11.491**
Floor 3	**2.505**	**4.027**	**5.679**	**9.748**
Floor 2	**2.122**	**3.412**	**4.811**	**8.1**
Floor 1	**1.768**	**2.842**	**4.006**	**6.588**
GF	**1.478**	**2.377**	**3.349**	**5.341**

For Triaxial Column with Shear Wall 1.5(DL + EQX)

Triaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	**8.182**	**13.143**	**18.713**	**33.009**
Floor 9	**7.793**	**12.519**	**17.791**	**31.49**
Floor 8	**7.224**	**11.609**	**16.471**	**29.235**
Floor 7	**6.539**	**10.509**	**14.892**	**26.475**
Floor 6	**5.789**	**9.303**	**13.171**	**23.419**
Floor 5	**5.069**	**8.051**	**11.389**	**26.222**
Floor 4	**4.226**	**6.793**	**9.604**	**16.991**
Floor 3	**3.454**	**5.552**	**7.847**	**13.795**
Floor 2	**2.697**	**4.335**	**6.122**	**10.658**
Floor 1	**1.939**	**3.118**	**4.401**	**7.549**
GF	**1.146**	**1.843**	**2.601**	**4.355**

For Uniaxial with Shear Wall 1.5(DL + EQZ)

Uniaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	**5.386**	**8.658**	**12.229**	**20.841**
Floor 9	**4.995**	**8.029**	**11.337**	**19.331**
Floor 8	**4.587**	**7.373**	**10.41**	**17.737**
Floor 7	**4.169**	**6.702**	**9.461**	**16.09**
Floor 6	**3.746**	**6.021**	**8.499**	**14.408**
Floor 5	**3.322**	**5.341**	**7.536**	**12.714**
Floor 4	**2.905**	**4.669**	**6.587**	**11.040**
Floor 3	**2.501**	**4.021**	**5.671**	**9.418**
Floor 2	**2.119**	**3.408**	**4.804**	**7.886**
Floor 1	**1.769**	**2.843**	**4.008**	**6.483**
GF	**1.46**	**2.347**	**3.307**	**5.265**

For Biaxial Column with Shear Wall 1.5(DL + EQZ)

Biaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	5.386	8.658	12.23	21.848
Floor 9	5.009	8.053	11.373	20.334
Floor 8	4.597	7.39	10.434	18.642
Floor 7	4.178	6.717	9.452	16.896
Floor 6	3.753	6.634	8.515	15.101
Floor 5	3.328	5.35	7.549	13.289
Floor 4	2.909	4.677	6.598	11.491
Floor 3	2.505	4.027	5.679	9.748
Floor 2	2.122	3.412	4.811	8.1
Floor 1	1.768	2.842	4.006	6.588
GF	1.478	2.377	3.349	5.341

For Triaxial Column with Shear Wall 1.5(DL + EQZ)

Triaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	8.182	13.143	18.714	31.226
Floor 9	7.8	12.531	17.807	29.752
Floor 8	7.234	11.624	16.492	27.592
Floor 7	6.548	10.523	14.912	24.972
Floor 6	5.797	9.316	13.188	22.09
Floor 5	5.015	8.062	11.404	19.09
Floor 4	4.23	6.801	9.616	16.07
Floor 3	3.46	5.559	7.855	13.091
Floor 2	2.7	4.339	6.128	10.168
Floor 1	1.939	3.119	4.403	7.263
GF	1.144	1.839	2.595	4.253

For Uniaxial Column without Shear Wall 1.5(DL + EQX)

Uniaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	29.992	47.481	71.22	106.832
Floor 9	28.867	45.727	68.591	102.885
Floor 8	27.223	43.134	64.701	97.051
Floor 7	25.088	39.768	59.652	89.478
Floor 6	22.557	35.773	53.66	80.49
Floor 5	19.721	31.291	46.937	70.407
Floor 4	16.664	26.454	32.072	59.523
Floor 3	13.463	21.382	24.262	48.109
Floor 2	10.181	16.174	16.393	36.393
Floor 1	6.878	10.928	8.651	24.589
GF	3.626	5.767	1.792	12.976

For Biaxial Column without Shear Wall 1.5(DL + EQX)

Biaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	29.68	47.481	71.233	106.848
Floor 9	28.578	45.727	68.585	102.877
Floor 8	26.959	43.134	64.7	97.05
Floor 7	24.855	39.768	59.651	89.477
Floor 6	22.358	35.773	53.659	80.488
Floor 5	19.557	31.291	46.937	70.405
Floor 4	16.534	26.454	39.681	59.522
Floor 3	13.363	21.382	32.071	48.106
Floor 2	10.108	16.174	24.261	36.39
Floor 1	6.83	10.928	16.391	24.586
GF	3.60	5.767	8.64	12.96

For Triaxial Column with Shear Wall 1.5(DL + EQX)

Triaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	29.988	47.98	71.971	107.955
Floor 9	28.869	46.185	69.276	103.915
Floor 8	25.089	43.557	65.336	98.003
Floor 7	25.224	40.142	60.213	90.32
Floor 6	22.557	36.091	54.138	81.206
Floor 5	19.721	31.553	47.33	70.996
Floor 4	16.665	26.663	39.996	59.993
Floor 3	13.464	21.541	32.313	48.468
Floor 2	10.182	16.29	24.436	36.655
Floor 1	6.879	11.006	16.509	24.763
GF	3.63	5.807	8.711	13.067

For Uniaxial without Shear Wall 1.5(DL + EQZ)

Uniaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	29.992	47.481	71.22	106.832
Floor 9	28.867	45.727	68.591	102.885
Floor 8	27.223	43.134	64.701	97.051
Floor 7	25.088	39.768	59.652	89.478
Floor 6	22.557	35.773	53.66	80.49
Floor 5	19.721	31.291	46.937	70.407
Floor 4	16.664	26.454	32.072	59.523
Floor 3	13.463	21.382	24.262	48.109
Floor 2	10.181	16.174	16.393	36.393
Floor 1	6.878	10.928	8.651	24.589
GF	3.626	5.767	1.792	12.976

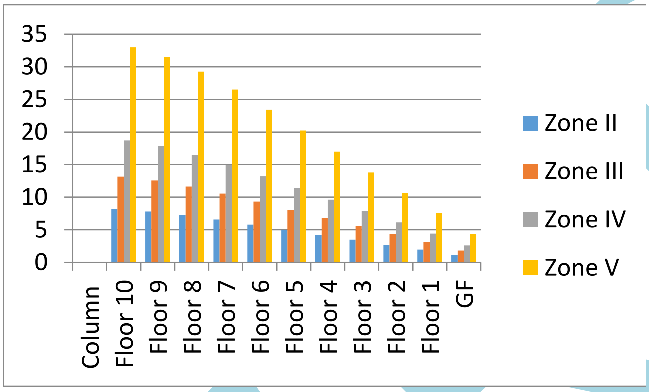
For Biaxial Column without Shear Wall 1.5(DL + EQZ)

Biaxial Column	Zone II	Zone III	Zone IV	Zone V
Floor 10	29.68	47.481	71.233	106.848
Floor 9	28.578	45.727	68.585	102.877
Floor 8	26.959	43.134	64.7	97.05
Floor 7	24.855	39.768	59.651	89.477
Floor 6	22.358	35.773	53.659	80.488
Floor 5	19.557	31.291	46.937	70.405
Floor 4	16.534	26.454	39.681	59.522
Floor 3	13.363	21.382	32.071	48.106
Floor 2	10.108	16.174	24.261	36.39
Floor 1	6.83	10.928	16.391	24.586

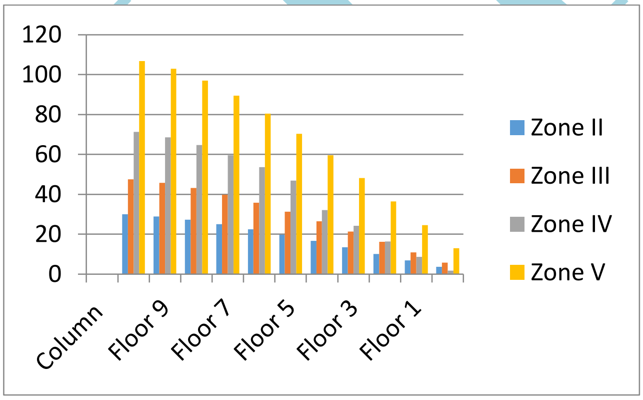
GF	**3.60**	**5.767**	**8.64**	**12.96**

For Triaxial Column without Shear Wall 1.5(DL + EQZ)

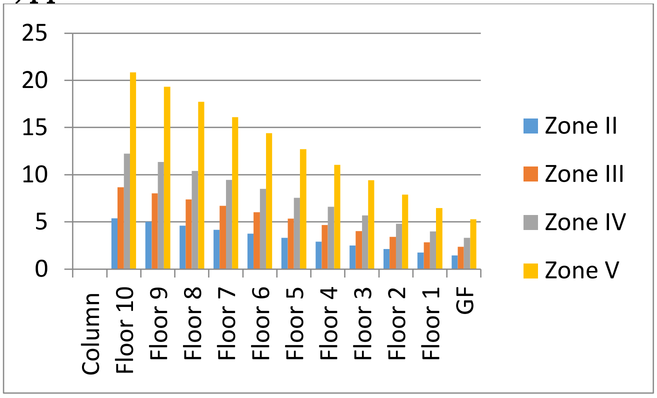
Triaxial Column	**Zone II**	**Zone III**	**Zone IV**	**Zone V**
Floor 10	**29.988**	**47.98**	**71.971**	**107.955**
Floor 9	**28.869**	**46.185**	**69.276**	**103.915**
Floor 8	**25.089**	**43.557**	**65.336**	**98.003**
Floor 7	**25.224**	**40.142**	**60.213**	**90.32**
Floor 6	**22.557**	**36.091**	**54.138**	**81.206**
Floor 5	**19.721**	**31.553**	**47.33**	**70.996**
Floor 4	**16.665**	**26.663**	**39.996**	**59.993**
Floor 3	**13.464**	**21.541**	**32.313**	**48.468**
Floor 2	**10.182**	**16.29**	**24.436**	**36.655**
Floor 1	**6.879**	**11.006**	**16.509**	**24.763**
GF	**3.63**	**5.807**	**8.711**	**13.067**



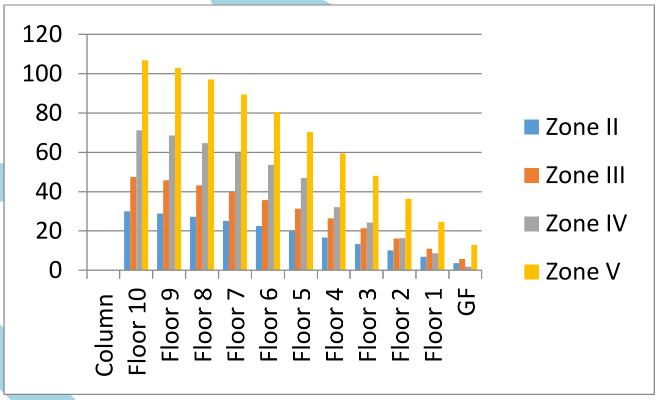
I. Deflection in zone 4 vs. deflection in other zones for Uniaxial column with shear wall in 1.5(DL + EQX).



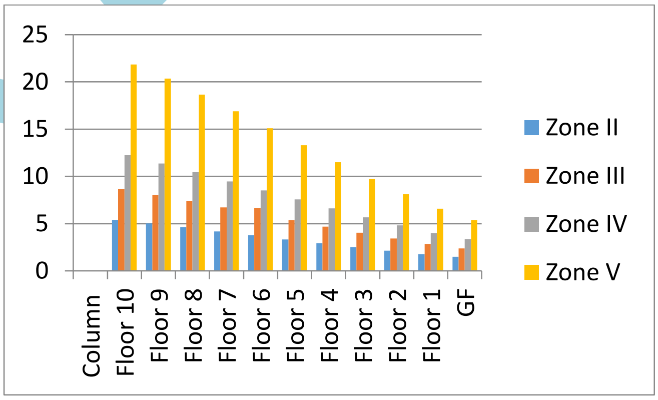
II. Deflection in zone 4 vs. deflection in other zones for Uniaxial column with shear wall in 1.5(DL + EQX).



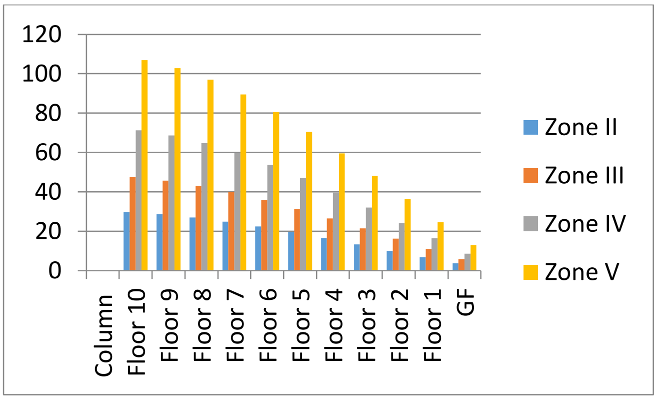
III. Deflection in zone 4 vs. deflection in other zones for Uniaxial column with shear wall in 1.5(DL + EQZ).



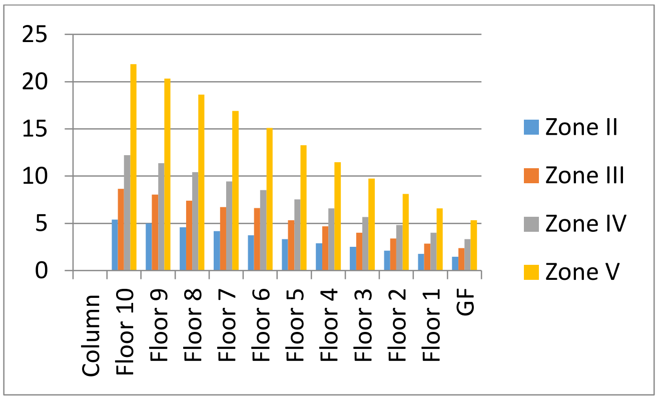
IV. Deflection in zone 4 vs. deflection in other zones for Uniaxial column with shear wall in 1.5(DL + EQZ).



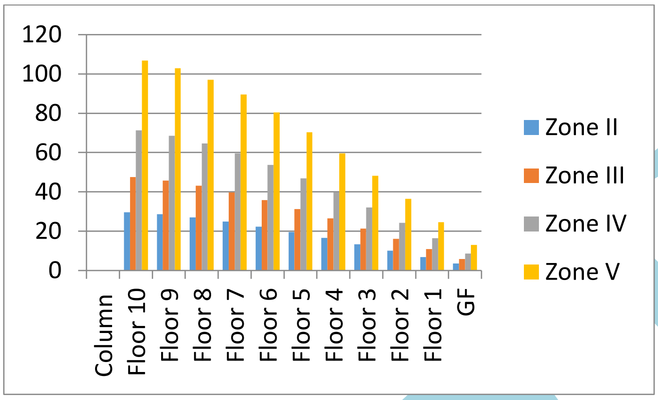
V. Deflection in zone 4 vs. deflection in other zones for Biaxial column with shear wall in 1.5(DL + EQX).



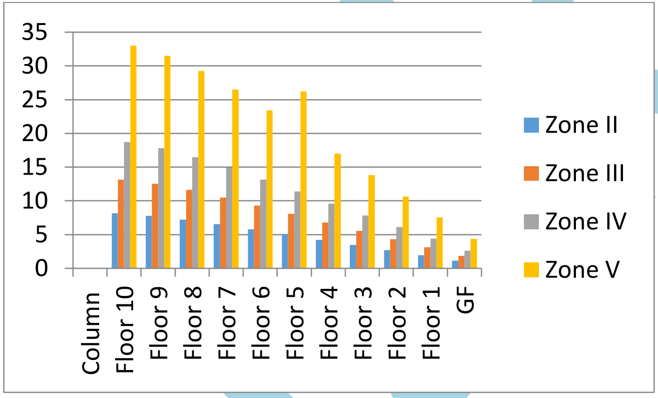
VI. Deflection in zone 4 vs. deflection in other zones for Biaxial column with shear wall in 1.5(DL + EQX).



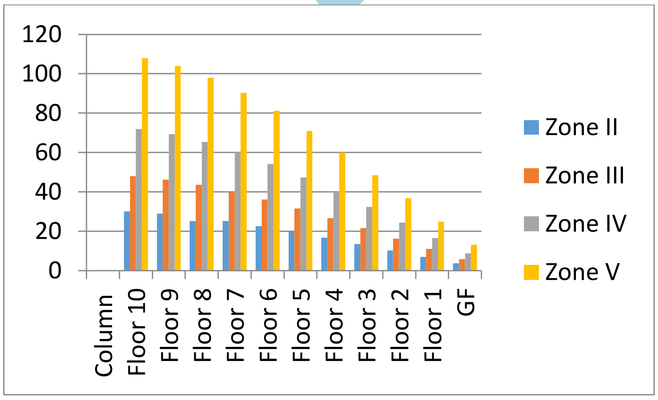
VII. Deflection in zone 4 vs. deflection in other zones for Biaxial column with shear wall in 1.5(DL + EQZ).



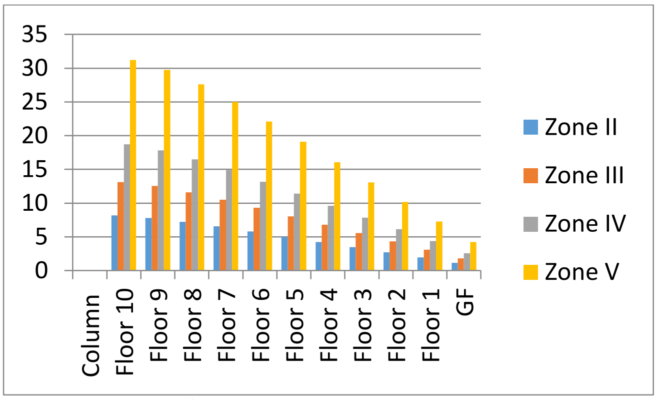
VIII. Deflection in zone 4 vs. deflection in other zones for Biaxial column with shear wall in 1.5(DL + EQZ).



IX. Deflection in zone 4 vs. deflection in other zones for Triaxial column with shear wall in 1.5(DL + EQX).



X. Deflection in zone 4 vs. deflection in other zones for Triaxial column with shear wall in 1.5(DL + EQX).



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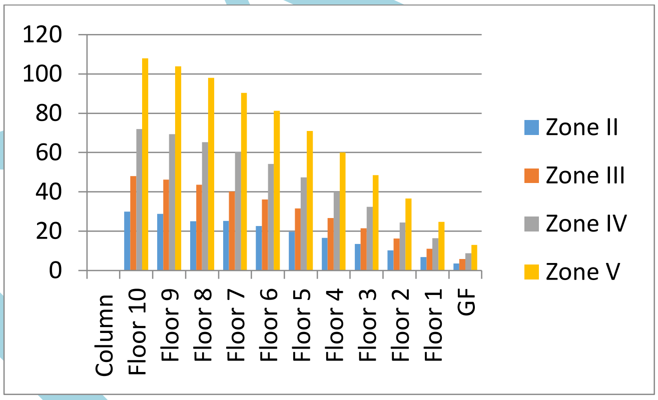

XII. Deflection in zone 4 vs. deflection in other zones for Triaxial column with shear wall in 1.5(DL + EQZ).

VI. CONCLUSION

The following conclusions may be drawn from the study.

1. Provision of shear wall is essential for reducing displacements at various nodes. The displacements were found to reduce by 60 to 70%.
2. Critical load combinations were found, are 1.5(DL+EQX) or 1.5(DL+EQZ) depending on orientation of columns.
3. with the provision of ductile detailing, reduction in displacement are-

Column Type	L/C	% Reduction in displacements
Uniaxial column	1.5(DL+EQX)	3.2 to 5.6
	1.5(DL+EQZ)	2.4 to 5.4
Biaxial column	1.5(DL+EQX)	3 to 4.9
	1.5(DL+EQZ)	4.7 to 5.2
Triaxial column	1.5(DL+EQX)	3.2 to 3.7
	1.5(DL+EQZ)	3.4 to 3.6

4. Though it is observed that the reduction in deflections is not significant but due to ductile detailing of joints, the structure can undergo more displacement to reduce the possibility of collapse.

REFERENCES

[1] P. C. Vasani and Bhumika B. Mehta, 'Ductility Requirements for Buildings.' Applied mechanics department, L.D. college of Engineering.
[2] Swajit Singh Goud and Ramancharla Pradeep Kumar, 'Seismic Design Provisions for Ductile Detailed Reinforced Concrete Structures.' 15SEE Report No: IIIT/TR/2014/-1
[3] Anil K. Patnaik and Sudhir K. Jain, 'Ductility Requirements in Indian Codes for a Seismic Design of a R.C. Frame Structures.'
[4] Ahmed Sayed Tawfik, Mohamed Ragaee Badr and Ashraf Elzanaty, 'Behaviour and Ductility of High Strength Reinforced Concrete Frames.' HBRC 2014, pg. 215.
[5] Sudhir K. Jain and C.V.R. Murthy, 'Some Views on Code for Ductile Detailing for Seismic Design of R.C. Structures.' BISET, June 1989, pg. 11.
[6] M.S. Medhekar, Sudhir K. Jain and Anand S. Arya, 'Proposed Draft For IS 4326 on Ductile Detailing of Reinforced Concrete Structures.'
[7] N. Lakshmanan, 'Seismic Evaluation and Retrofitting of Buildings and Structures.' ISET, June 2016, pg. 469, vol. 43.
[8] Dr. Ashok K. Jain, a retd. Professor of Civil Engineering, IIT Roorkee proposed 'A Critical Review of IS 13920-2016.'
[9] IS 13920 - 1993 Indian Standard 'Ductile detailing of reinforced concrete structures subjected to seismic forces-Code of practice', Bureau of Indian Standards, October 1993.
[10] IS 13920 - 2016 Indian Standard 'Ductile design and detailing of reinforced concrete structures subjected to seismic forces-Code of practice', Bureau of Indian Standards, October 2016.
[11] Reinforced concrete (Limit state design) by Ashok K. Jain.
[12] Earthquake Resistant Design of Structures by S.K. DUGGAL.
[13] Earthquake Resistant Design of Structures by Pankaj Agarwal & Manish Shrikhande.