Analysis and Design Considering Ductile Detailing of Reinforced Concrete Structure

M. R. Wagh, A.R.Nikhade, H.R.Nikhade

***Abstract*—** Earthquake safety requirements demand RCC structure, reinforcement detailing to be as per IS 13920. With the provision of Ductile detailing on RCC Frame becomes a Special Moment Resisting Freame. A G+10 storied building with well defined architectural plan was analyse using STAAD-Pro. During analysis, it was realised that the deflections at top levels were excessively on higher side. Shear walls were provided to reduce these excessive deflections. For comparison of result,Corner Column was chosen. Two load combinations found to be critical were 1.5(DL+EQX) or 1.5(DL+EQZ Deflection was considered for analysis and comparison.

Index Terms— Ductility, Earthquake resistant structure, Deformation.

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 inelastically. 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.

Prof.M.R.Wagh ,Department of C.E.,G.H.Raisoni Academy of engineering technology,RTMNU,M.H.09764442530,
Prof..A.R.Nikhade,Department of C.E.,G.H.Raisoni Academy of engineering technology,RTMNU,M.H.09764442530,
Prof.H.R.Nikhade,Department of C.E.,Yashwanrao chavan collage of engineering,RTMNU,M.H.08180946956, India ,nagpur

II .STUDY OF IS CODES

IS 13920-1993 : **Ductile Detailing of Reinforced Concrete Structures subjected to seismic Forces – Code of Practice**

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.

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.

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

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).

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 thermomechanical 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.

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

Clause 7.4 : 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 not exceed ¼ of minimum member dimension but needs not be less than 75mm nor more than 100mm.

Clause 8 : 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 - Impressa Classic, at Koradi Road, Nagpur.

Modeling of the building is done as per proposed plan of the building of Impressa Classic, at Koradi Road, Nagpur. This is the plan for G+10 storied building.

Details of Building:

1) Length of Building - 56.78m
2) Width of Building - 20.42m
3) Height of Building - 33m
4) Dimensions of column- (0.50m x 0.45m) and (0.45m x 0.5m)
5) Dimensions of beam - 0.45m x 0.45m
6) Thickness of Slab - 0.1m
7) Dead Load on Building for 0.23m thick wall - 14KN/m
8) Dead Load on Building for 0.15m thick wall – 7 KN/m
9) Live Load on Building – 2.5 KN/m2
10) Seismic load as per Zone factor and Response Reduction Factor.
    a) Earthquake load in X- Direction
    b) Earthquake load in Z- Direction
11) Thickness of Shear wall – 0.2m
12) Response Reduction Factor –
    a) For SMRF – 5
    b) For OMRF - 3

This plan modeled in STAAD-Pro for analyzing and design of G+10 storied building.

This building is analyse for different Zones (Zone II, Zone III, Zone IV, Zone V).

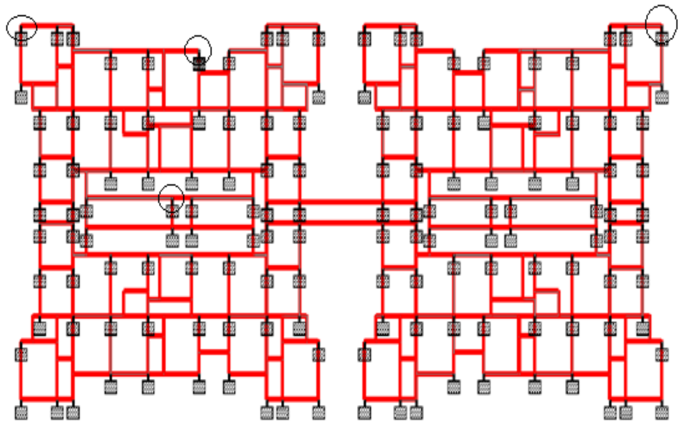


Fig. Plan of Structure

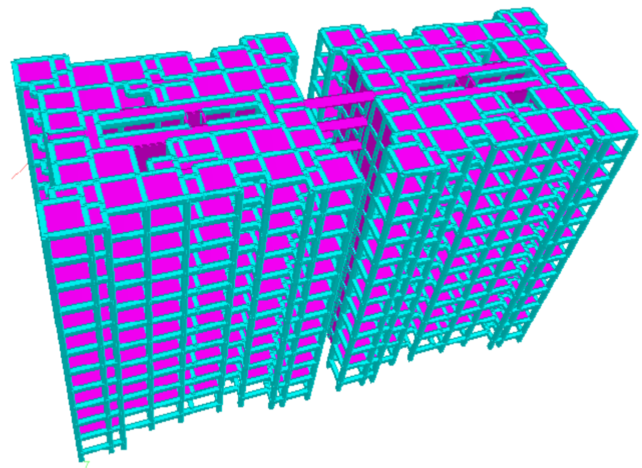


Fig-3-D view of the Strucure

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.

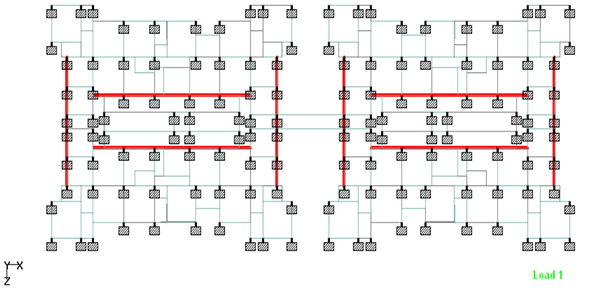


Fig.-Position of Shear Wall in the Structure

V ANALYSIS & COMPARISION OF RESULT

For Corner Column 1.5(DL + EQX)

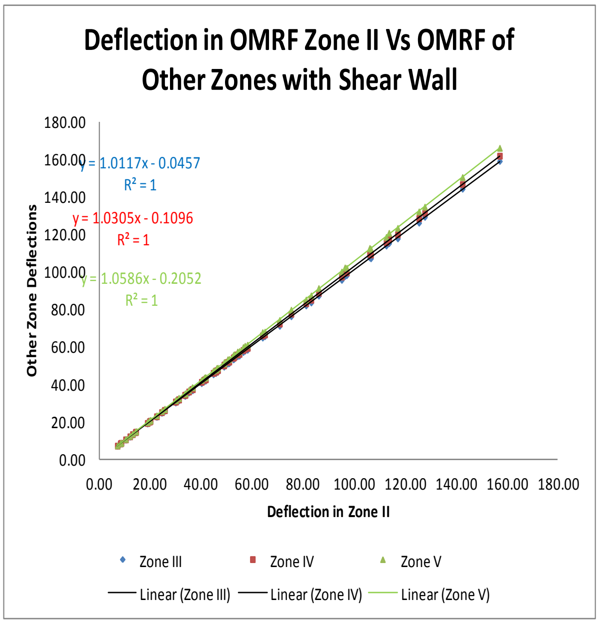
FL	With Shear Wall							
	II OMRF	III OMRF	IV OMRF	V OMRF	II SMRF	III SMRF	IV SMRF	V SMRF
0	8.34	8.42	8.53	8.69	8.29	8.33	8.40	8.50
1	14.27	14.42	14.62	14.92	14.17	14.26	14.38	14.56
2	19.94	20.16	20.46	20.90	19.79	19.93	20.10	20.37
3	25.56	25.86	26.26	26.86	25.36	25.54	25.78	26.14
4	31.06	31.44	31.94	32.70	30.80	31.03	31.34	31.79
5	36.33	36.79	37.41	38.33	36.03	36.30	36.67	37.22
6	41.32	41.86	42.58	43.66	40.96	41.28	41.72	42.37
7	45.97	46.59	47.41	48.65	45.56	45.93	46.43	47.17
8	50.27	50.96	51.88	53.26	49.80	50.22	50.77	51.60
9	54.13	54.88	55.88	57.39	53.62	54.08	54.68	55.58
10	57.06	57.86	58.91	60.50	56.53	57.01	57.64	58.60

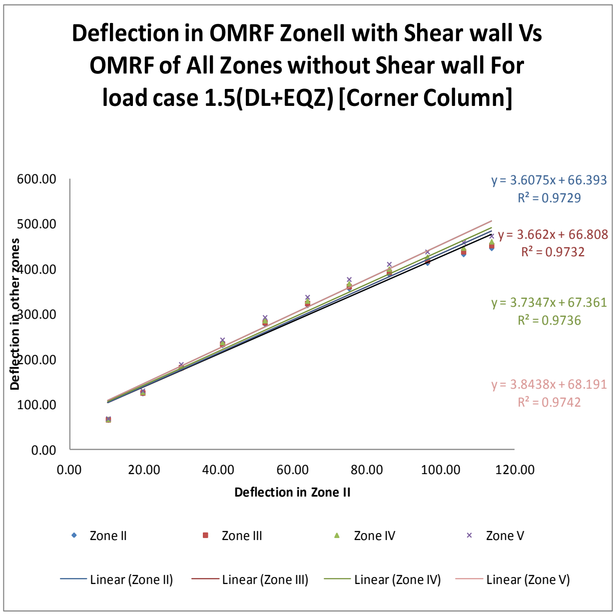
Without Shear Wall							
II OMRF	III OMRF	IV OMRF	V OMRF	II SMRF	III SMRF	IV SMRF	V SMRF
55.51	56.10	56.88	58.05	55.12	55.48	55.94	56.65
109.16	110.36	111.97	114.38	108.35	109.08	110.04	111.49
163.97	165.85	168.37	172.14	162.71	163.84	165.35	167.62
217.11	219.71	223.18	228.38	215.38	216.94	219.02	222.14
266.50	269.81	274.22	280.84	264.29	266.28	268.93	272.90
310.89	314.88	320.20	328.18	308.23	310.62	313.82	318.61
349.66	354.28	360.45	369.69	346.58	349.35	353.05	358.60
382.60	387.78	394.69	405.06	379.14	382.25	386.40	392.62
409.75	415.41	422.95	434.27	405.98	409.38	413.90	420.69
431.25	437.27	445.31	457.36	427.23	430.85	435.67	442.90
447.23	453.51	461.88	474.45	443.04	446.81	451.84	459.37

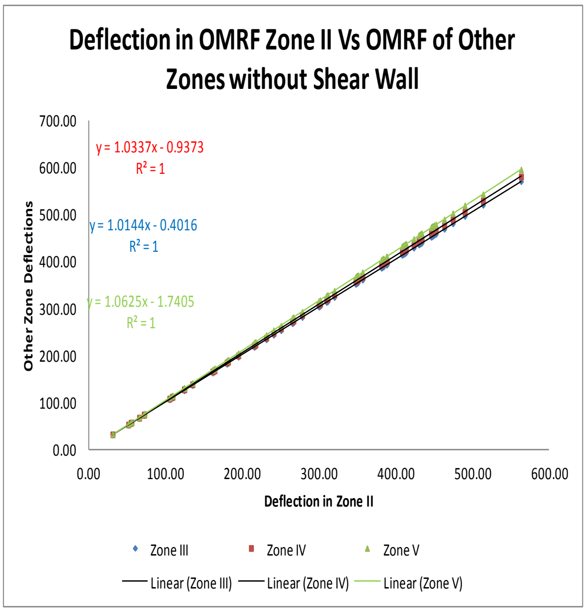
For Corner Column 1.5(DL + EQZ)

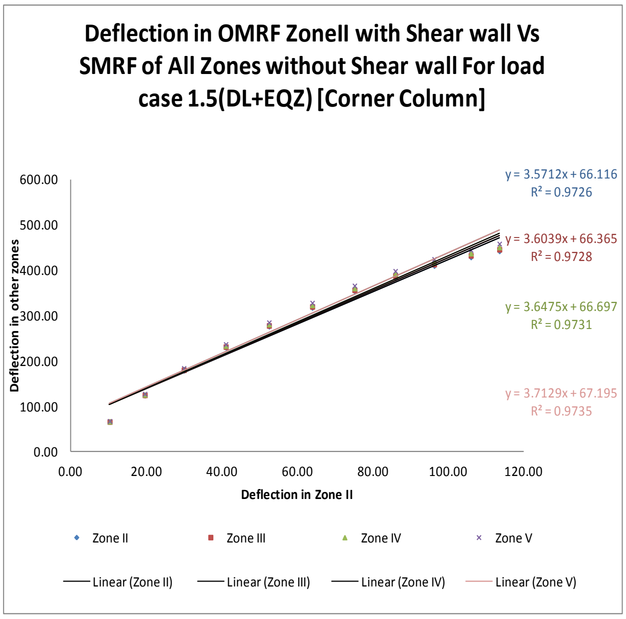
FL	With Shear Wall							
	II OMRF	III OMRF	IV OMRF	V OMRF	II SMRF	III SMRF	IV SMRF	V SMRF
0	10.24	10.36	10.51	10.74	10.17	10.24	10.33	10.47
1	19.55	19.78	20.09	20.56	19.40	19.54	19.72	20.00
2	29.91	30.28	30.77	31.52	29.66	29.88	30.18	30.63
3	41.03	41.56	42.27	43.33	40.68	41.00	41.42	42.05
4	52.50	53.20	54.13	55.52	52.03	52.45	53.01	53.85
5	63.97	64.84	66.00	67.75	63.38	63.91	64.61	65.66
6	75.19	76.24	77.64	79.74	74.49	75.12	75.96	77.22
7	86.00	87.22	88.85	91.29	85.18	85.92	86.89	88.36
8	96.31	97.70	99.55	102.33	95.39	96.22	97.33	98.99
9	106.04	107.58	109.64	112.72	105.01	105.93	107.17	109.02
10	113.60	115.26	117.48	120.80	112.50	113.49	114.82	116.81

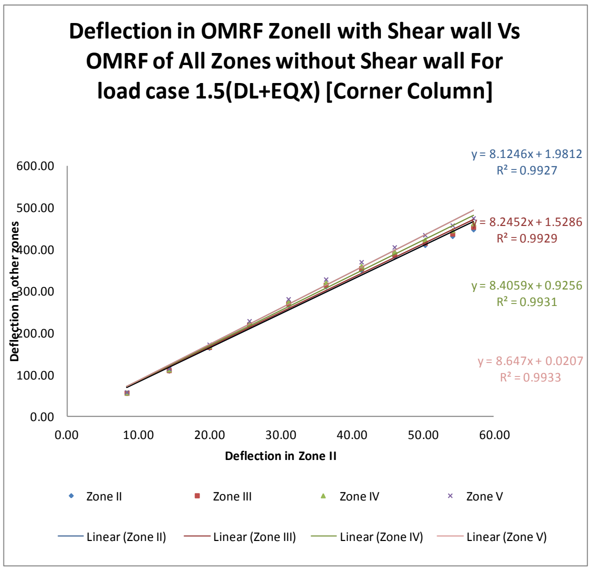
Without Shear Wall							
II OMRF	III OMRF	IV OMRF	V OMRF	II SMRF	III SMRF	IV SMRF	V SMRF
65.66	66.35	67.27	68.65	65.20	65.61	66.16	66.99
124.45	125.82	127.63	130.36	123.55	124.36	125.45	127.09
179.87	181.92	184.66	188.77	178.50	179.73	181.38	183.84
231.17	233.92	237.59	243.10	229.33	230.99	233.19	236.49
277.95	281.39	285.98	292.86	275.66	277.72	280.47	284.60
319.87	323.97	329.44	337.65	317.13	319.60	322.88	327.80
356.60	361.31	367.61	377.04	353.45	356.28	360.06	365.72
387.81	393.08	400.10	410.62	384.30	387.46	391.67	397.99
413.22	418.93	426.56	437.99	409.41	412.84	417.41	424.27
432.53	438.58	446.65	458.75	428.50	432.13	436.97	444.23
446.02	452.28	460.62	473.14	441.85	445.60	450.61	458.12

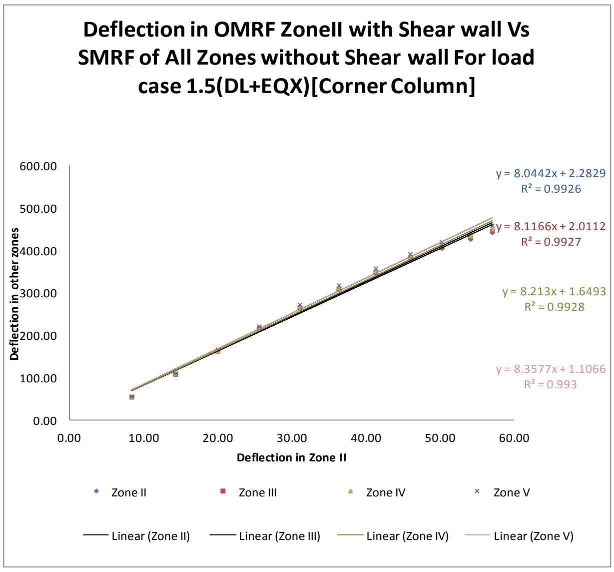

Deflection in OMRF Zone II Vs OMRF of Other Zones with Shear Wall
y = 1.0117x - 0.0457
R² = 1
y = 1.0305x - 0.1096
R² = 1
y = 1.0586x - 0.2052
R² = 1
Other Zone Deflections
Deflection in Zone II
Zone III
Zone IV
Zone V
Linear (Zone III)
Linear (Zone IV)
Linear (Zone V)


Deflection in OMRF ZoneII with Shear wall Vs OMRF of All Zones without Shear wall For load case 1.5(DL+EQZ) [Corner Column]
y = 3.6075x + 66.393
R² = 0.9729
y = 3.662x + 66.808
R² = 0.9732
y = 3.7347x + 67.361
R² = 0.9736
y = 3.8438x + 68.191
R² = 0.9742
Deflection in other zones
Deflection in Zone II
Zone II
Zone III
Zone IV
Zone V
Linear (Zone II)
Linear (Zone III)
Linear (Zone IV)
Linear (Zone V)


Deflection in OMRF Zone II Vs OMRF of Other Zones without Shear Wall
y = 1.0337x - 0.9373
R² = 1
y = 1.0144x - 0.4016
R² = 1
y = 1.0625x - 1.7405
R² = 1
Other Zone Deflections
Deflection in Zone II
Zone III
Zone IV
Zone V
Linear (Zone III)
Linear (Zone IV)
Linear (Zone V)


Deflection in OMRF ZoneII with Shear wall Vs SMRF of All Zones without Shear wall For load case 1.5(DL+EQZ) [Corner Column]
y = 3.5712x + 66.116
R² = 0.9726
y = 3.6039x + 66.365
R² = 0.9728
y = 3.6475x + 66.697
R² = 0.9731
y = 3.7129x + 67.195
R² = 0.9735
Deflection in other zones
Deflection in Zone II
Zone II
Zone III
Zone IV
Zone V
Linear (Zone II)
Linear (Zone III)
Linear (Zone IV)
Linear (Zone V)


Deflection in OMRF ZoneII with Shear wall Vs OMRF of All Zones without Shear wall For load case 1.5(DL+EQX) [Corner Column]
y = 8.1246x + 1.9812
R² = 0.9927
y = 8.2452x + 1.5286
R² = 0.9929
y = 8.4059x + 0.9256
R² = 0.9931
y = 8.647x + 0.0207
R² = 0.9933
Deflection in other zones
Deflection in Zone II
Zone II
Zone III
Zone IV
Zone V
Linear (Zone II)
Linear (Zone III)
Linear (Zone IV)
Linear (Zone V)


Deflection in OMRF ZoneII with Shear wall Vs SMRF of All Zones without Shear wall For load case 1.5(DL+EQX)[Corner Column]
y = 8.0442x + 2.2829
R² = 0.9926
y = 8.1166x + 2.0112
R² = 0.9927
y = 8.213x + 1.6493
R² = 0.9928
y = 8.3577x + 1.1066
R² = 0.993
Deflection in other zones
Deflection in Zone II
Zone II
Zone III
Zone IV
Zone V
Linear (Zone II)
Linear (Zone III)
Linear (Zone IV)
Linear (Zone V)

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 70 to 88%.
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
Corner column	1.5(DL+EQX)	0.65 to 3.2
	1.5(DL+EQZ)	0.75o 3.3

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 reduced the possibility of collapse.

REFERENCES

[1] Reinforced concrete (Limit state design) by Ashok K. Jain.
[2] Elementary reinforced concrete by H.J.Shah.
[3] IS 13920-1993, Ductile detailing of reinforced concrete structures subjected to seismic forces.
[4] Applied Technology Council (ATC), 1996. *Seismic Evaluation and Retrofit of Concrete Buildings*, volumes 1 and 2, *Report No. ATC-40,* Redwood City, CA.
[5] Vamvatsikos D. and Cornell C.A., Incremental Dynamic Analysis, *Earthquake Engineering and Structural Dynamics*, Vol.31, pp 491.514, 2002
[6] Paulay, T. and Priestley, M.J.N., 1992, Seismic Design of Reinforced Concrete and Masonry Buildings, pp. 420-440
[7] Bertero, V. V., "State of the Art in Seismic Resistant Construction of Structures," Volume II , Chapter 17
[8] Wallace, J. W.; McConnell, S. W.; Gupta, P.; and Cote, P. A., "Use of Headed Reinforcement in Beam-Column Joints Subjected to Earthquake Loads," *ACI Structural Journal*, V. 95, No. 5, Sept.-Oct. 1998, pp. 590-606.
[9] A.G.Tsonos, I.A.Tegos and G.Gr.Penelis[1992]. "Seismic resistance of Type 2 Exterior Beam column joints reinforced with inclined bars" The ACI structural Journal, Title No.89S1, JanFeb 1992.
[10] Altoontash, A., 2005. Simulation and Damage Models for Performance Assessment of Reinforced Concrete Beam-Column Joints, *Ph.D. Thesis*, Stanford University.

