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Seismic Analysis of Flat Slab Structure

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Abstract

Flat slab structure represents easy construction and elegant representation of floored building. As this structure means flat slab and having there types) are compared more flexible than conventional concrete frame structure, therefore becoming more vulnerable to earthquake loading. Thus, the seismic behavior of flat slab buildings suggests that some more additional guidelines required for analysis and design of these in various seismic zones.In this paper five different structures of G+5 story are modeled and analyzedi.e models of one is conventional structure and other four are types of flat slab (flat slab, flat slab with drop, flat slab with column head and combination of drop and column head). These models are analyzed in ETABS 2015 by using linear static method and response spectrum method i.e linear dynamic method. And results are interrupted for all seismic zone factor (zone II, zone III, zone IV, zone V).
Keywords: flat slab structure, drop, column head, response spectrum analysis, seismic zone factor

I. INTRODUCTION

Flat slab structures are those structures having slab rested directly on column members without the use of beams.

Fig.1: Flat slab

Similarly the other definition is flat slab means a reinforced concrete slab with or without drops, supported generally without beam members, by columns with or without column head. A flat slab may be solid slab or may have recesses formed on the soffit therefore the soffit comprises a series of ribs in two directions.

There are various types of flat slab structures used now a days for commercial structures, malls, car parking and many more therefore it becomes it becomes one of the most popular floor system.

A. *Column head uses:*

- Shear strength of slab increases
- It reduce moment in the slab by reducing clear span

B. *Drop panel uses:*

- Shear strength of slab increases
- Negative moment capacity of slab increases
- Stiffen the slab by reducing deflection

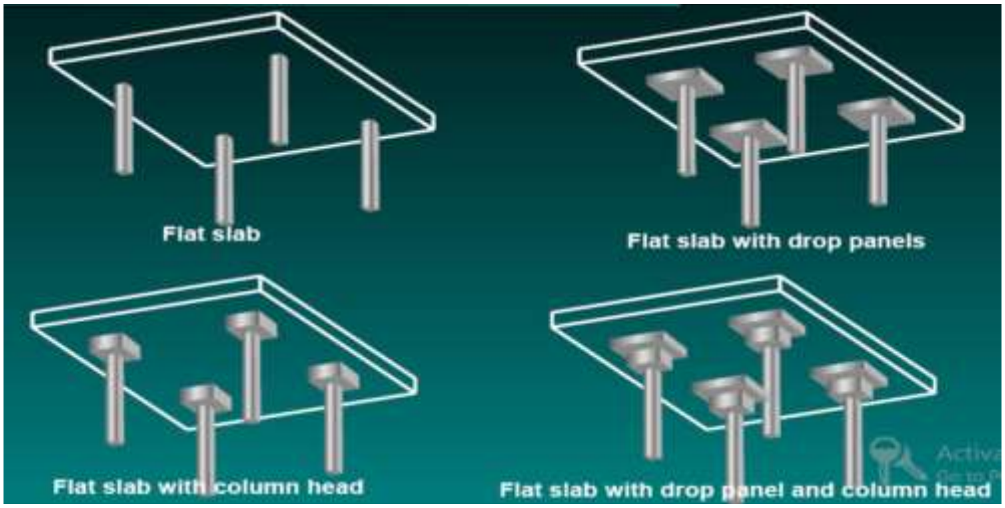


Fig.2 Types of flat slab

II. OBJECTIVES

- To evaluate lateral load stiffness and strength
- Seismic analysis of flat slab structure by linear static method and response spectrum method
- Seismic response of torsion
- The parametric studies comprise of base shear of structure. Maximum lateral displacement, story drift, axial forces generated in the column
- G+5 buildings are analyzed for all four seismic zone factor

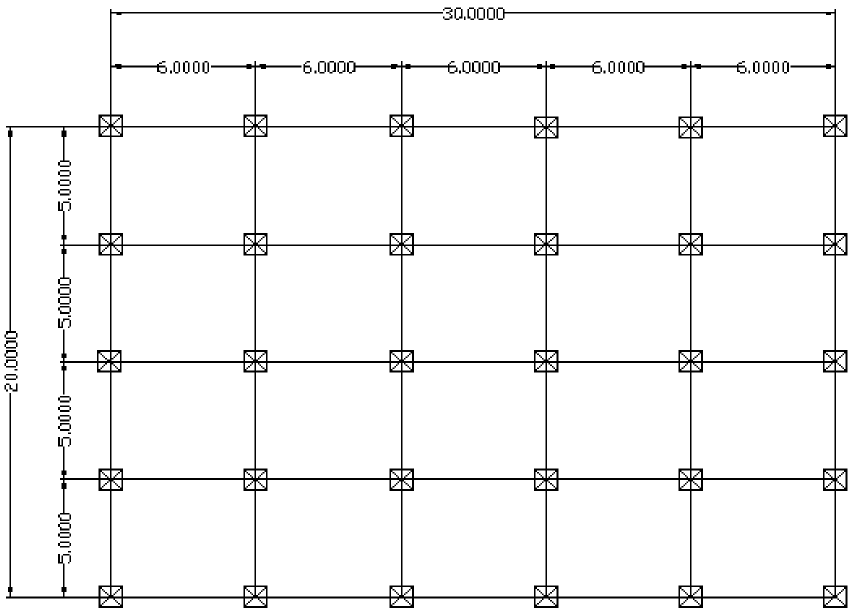
III. METHODOLOGY

- 5 different types of slab models are considered (conventional slab, flat slab, flat slab with drops, flat slab with column heads and combination of drop and column head). Used in Linear static analysis and Linear dynamic analysis (Response Spectrum Method) for different zone factor
- 5 models are to be examined under dynamic loading.
- Analyzing by software ETABS 2015.
- Comparing flat slab with conventional slab.

Preliminary data	*Seismic data*
No of stories = G+5	*Seismic load = as per IS1893 part1*
plan dimension = 30 x 20 m	*Type of soil = medium*
Type of structure = commercial building	*Seismic zone I = 0.10*
Floor to floor height = 4 m	*Zone II= 0.16*
Total height = 24 m	*Zone IV= 0.24*
Column = 400 x 400 mm	*Zone V = 0.36*
Beam = 300 x 300 mm	*Importance factor = 1*
Live load = 4 KN/m2 (IS 875 part2)	*Response reduction factor = 3*
Floor finish = 0.75 KN/m2	
Roof live = 1.5 KN/m2	
M25, Fe415	

Thickness of flat slab (IS456-2000, clause no- 31.2.1)
=6000/(0. 5(20+26)1.6) = 163.04 mm
Total thickness = 163.04+15+16/2 = 186 mm
Drop size (IS456-2000, clause no- 31.2.2)
= 1/3 x 6, 1/3x 5
= 2 m , 1.6 m= 2 x 2 m. Thickness of drop = 1.25 x 186 = 233 mm

IV. PLAN



Distance in each bay = 6 m in x direction
Distance in each ay = 5 m in y direction
Fig.3 plan of model

V. ELEVATION

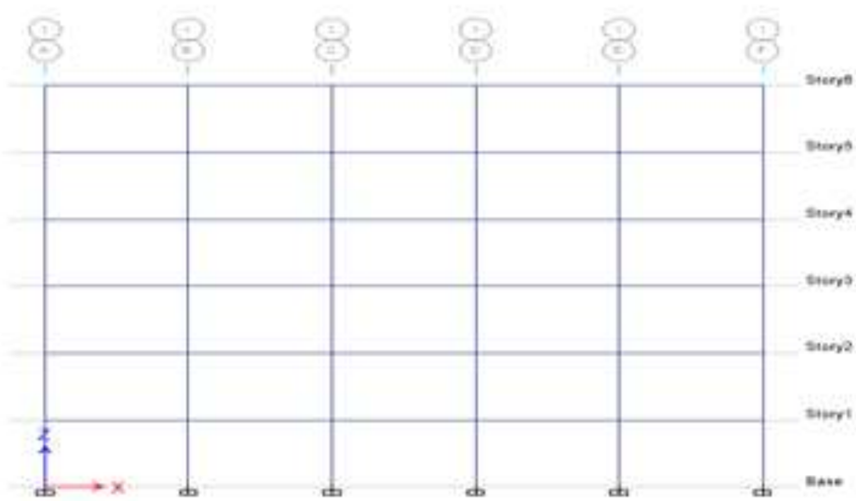


Fig. 4: Elevation of model

VI. 3D VIEW

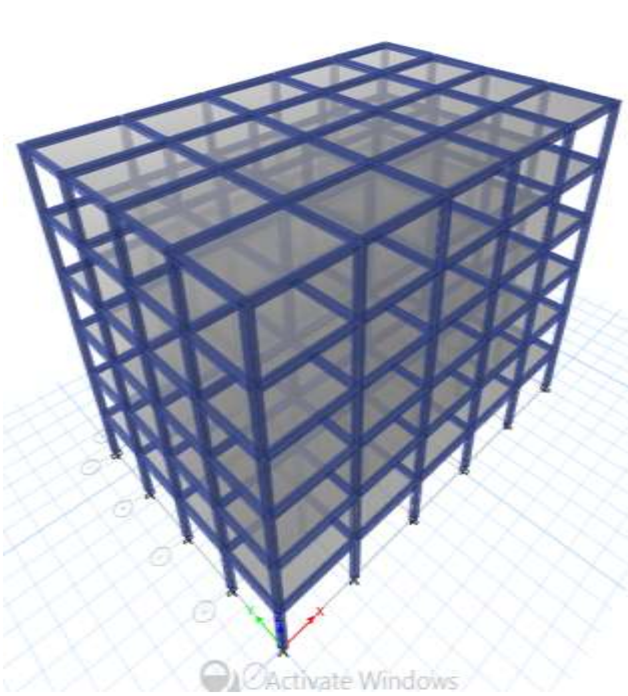


Fig. 5: Convential structure

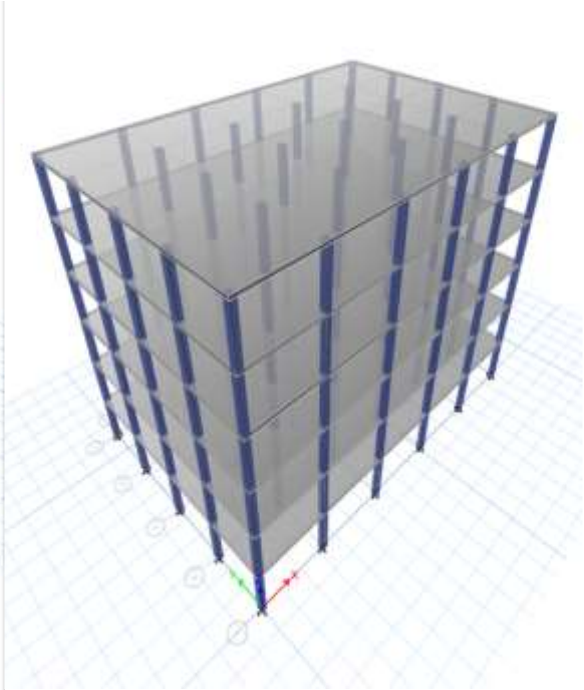


Fig. 6: flat slab structure

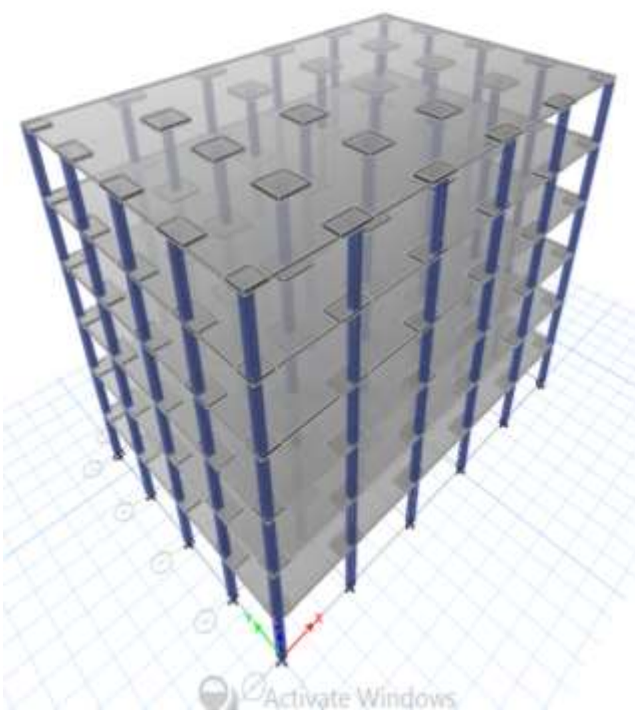


Fig. 7: Flat slab with drop

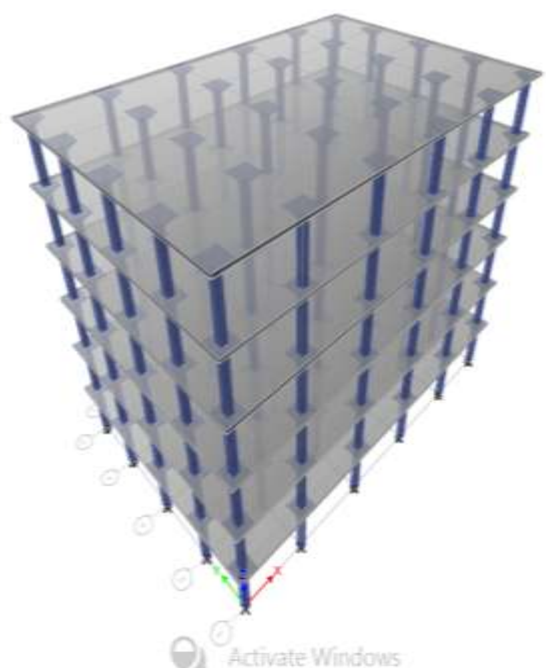


Fig. 8: flat slab with column head

A. Dead Load Calculation:

Thickness of slab =186 mm
Density of concrete = 25kN/m^3
Self-Weight of slab = Density of concrete x Thickness of slab
=25 * 0.186
= 4.63 KN/m^2 * 30*20 = 2790 KN

Floor Finish at floor level = 0.75 KN/m^2
Total floor load = 0.75*30*20 = 450 KN
Load on beam = 3645 KN
Load on column= 2640KN

B. Live Load and Roof Live Load Calculation:

Live Load Intensity specified = 4 kN/m^2
(50% load is considered)
LL= 4*.5*30*20 = 1200 KN
RL = 1.5*0.5*30*20 = 450 KN
Seismic loading:
Seismic load is given as per IS 1893-2002,
Seismic parameters calculated as
Ta = 0.8132 s
The building is located on medium soil site therefore the value of ,S_a/g =1.6724 Design horizontal seismic coefficient (A_h) = 0.02787Base shear V_B = 871.63 kN

VII. RESULTS AND DISCUSSIONS

The analyses are carried out on the ETABS 2015 software and compared. The variations in base shear, effect of adsorption of drop, column head parameters were calculated and there trends with load variation is plotted and analyzed. The various performance parameters are compared between conventional structure and flat slab structure. The results of above measured parameters are plotted and discussed below.

A. Effect of seismic load on base shear in KN:

base shear (KN) in X dir	zone II	zone III	zone IV	zone V
conventional str	871.9585	1395.1335	2092.7003	3139.0505
flat slab str	768.8059	1230.0894	1845.1342	2767.7012
flat slab with drop	875.7048	1401.1277	2101.6915	3152.5373
flat slab with col head	799.5636	1279.3018	1918.9526	2878.4289
flat slab with drop and col hea	904.86	1447.776	2171.664	3257.496

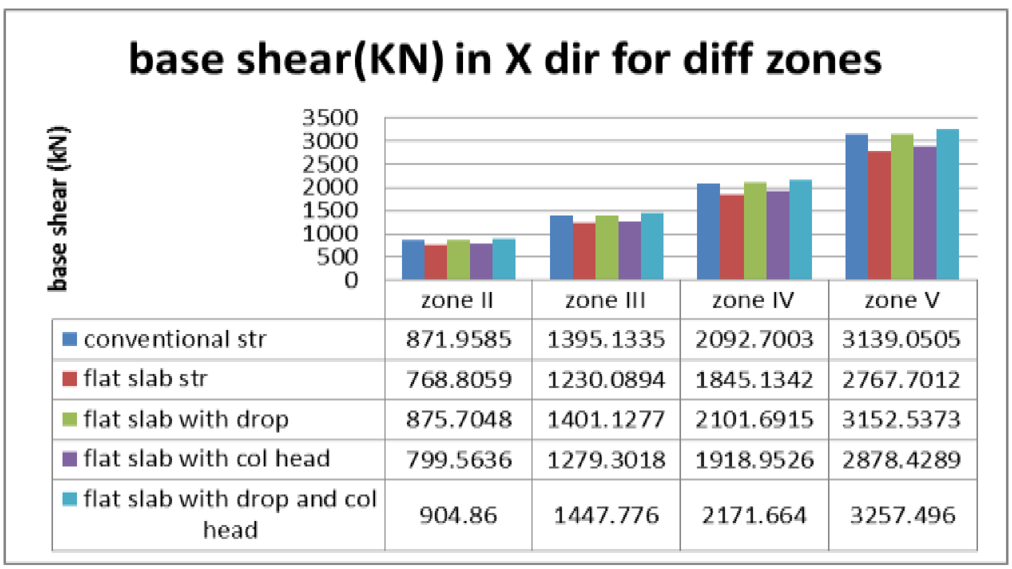


Fig. 9: Variation in base shear for diff zones in X dir.

base shear (KN) in Y dir	zone II	zone III	zone IV	zone V
conventional str	872.5027	1396.0043	2094.0064	3141.0096
flat slab str	764.3425	1222.948	1834.4219	2751.6329
flat slab with drop	874.4915	1399.1864	2098.7797	3148.1695
flat slab with col head	799.0373	1278.4596	1917.6894	2876.5341
flat slab with drop and col h	903.0433	1444.8692	2167.3038	3250.9557

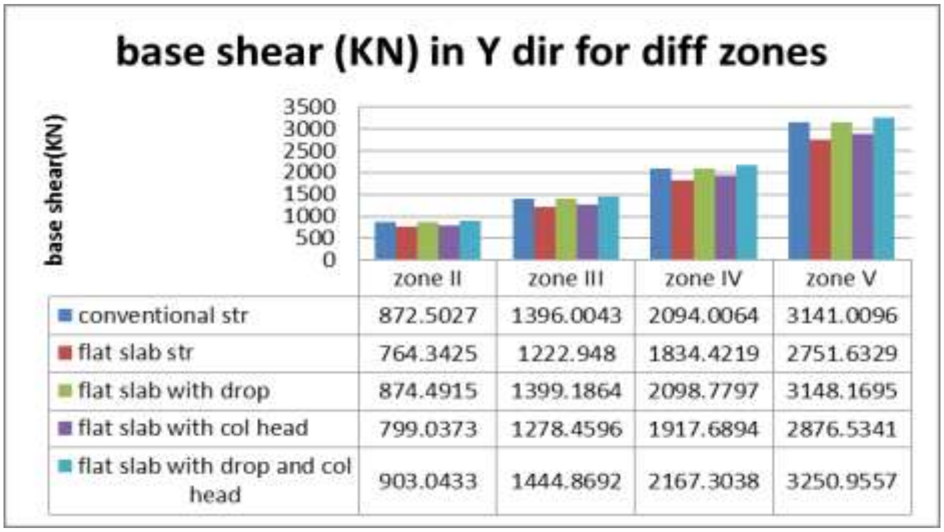


Fig. 10: Variation in base shear for diff zones in Y dir.

Fig.9 shows variations in base shear for diff zones in X dir. And Fig.10 shows variations in base shear for diff zones in Y dir. The base shear is the important parameters to evaluate performance structural system. In structural system this parameters is depend dead weight of building and A_h factor. As dead weight of building gas is increases the base shear of structure is also increases. This will results in resisting lateral forces and with increase in zone factor base shear will also increases. The maximum base shear is occurred in flat slab with drop and column head. There is not much difference in base shear in X and Y dir.

B. Effect of modal period in sec

mode no	conventional str	flat slab str	flat slab with drop	flat slab with col head	flat slab with drop and col heac
1	1.805	2.223	1.799	2.135	1.698
2	1.761	2.187	1.739	2.083	1.642
3	1.591	2.014	1.584	1.917	1.487
4	0.58	0.686	0.578	0.657	0.535
5	0.567	0.676	0.561	0.642	0.519
6	0.51	0.617	0.508	0.59	0.47
7	0.329	0.368	0.328	0.349	0.295
8	0.324	0.364	0.32	0.343	0.287
9	0.289	0.327	0.287	0.313	0.259
10	0.225	0.236	0.224	0.221	0.193
11	0.222	0.235	0.22	0.217	0.19
12	0.196	0.208	0.195	0.198	0.17

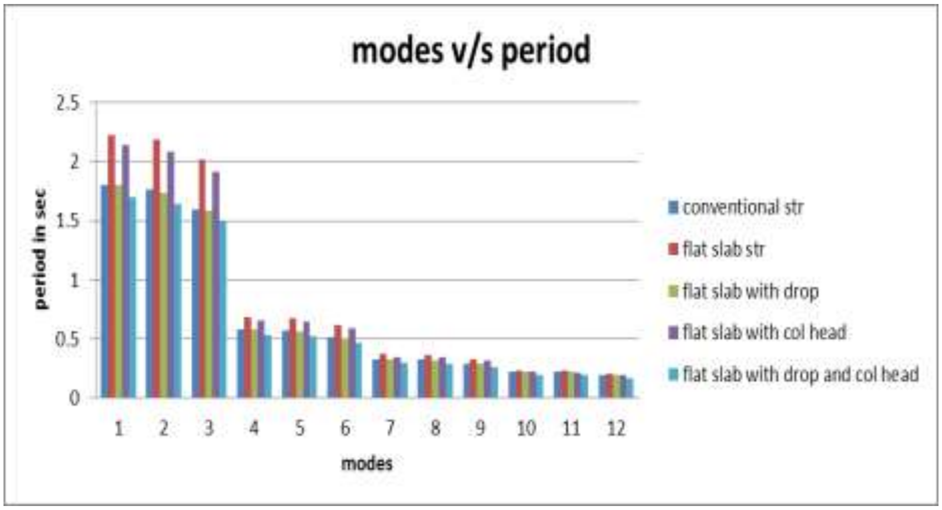


Fig. 11: Variation in modal period

Fig.11shows trends of various modal periods at diff modes from 1 to 12. In above graph at mode no 1 maximum modal periods occurred at flat slab structure means slab with column. This wills same for all modes but there is drastic change from 4 to 12. This case is same for all different type of seismic zone factor.

C. *Effect on joint displacement in mm in X dir.*

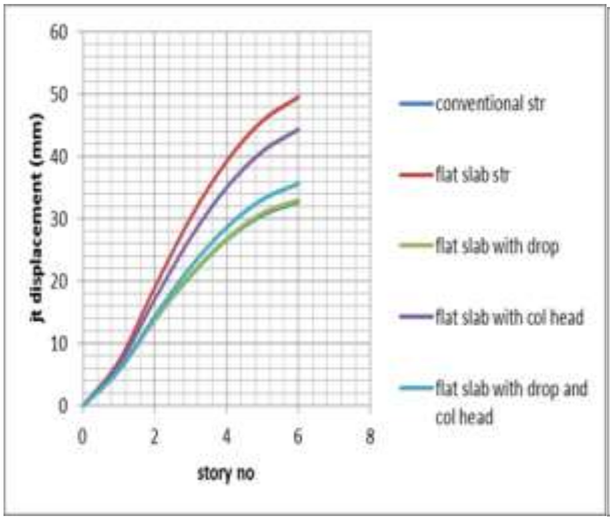


Fig. 12: jt displacement for zone II

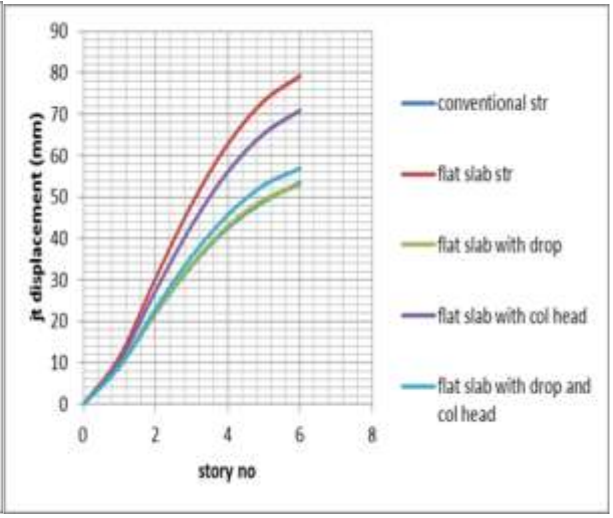


Fig.13: jt displacement for zone III

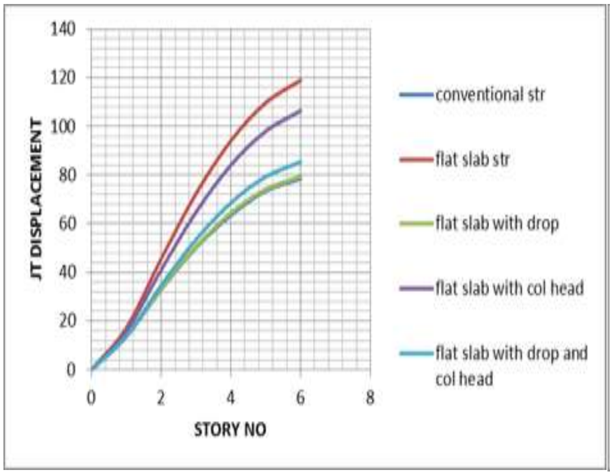


Fig. 14: jt displacement for zone IV

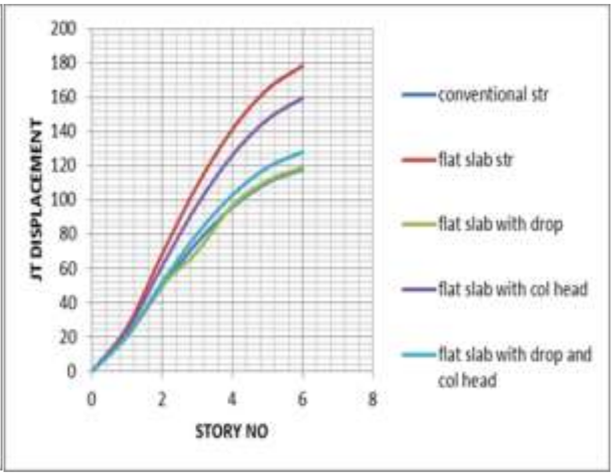


Fig. 15: jt displacement for zone V

The joint displacements are shown above with different zone factors and the results gives, as the zone factor increases joint displacement will also increases. This means as if the seismic load is more, more will be displacement takes place. If the connectivity between joint is stiff then the displacement is less there by reducing effect of seismic load. In this case joint displacement is less for flat slab with drop.

D. Effect of story drift in X and Y dir. For zone II

story drift in X dir					
story no	conventional str	flat slab str	flat slab with drop	flat slab with col head	flat slab with drop and col head
6	0.00071	0.001257	0.000718	0.001137	0.000809
5	0.001223	0.001953	0.001235	0.001738	0.001333
4	0.001587	0.002495	0.001603	0.00221	0.00173
3	0.001861	0.002886	0.001879	0.002554	0.002027
2	0.002034	0.002979	0.002051	0.002648	0.00217
1	0.001424	0.001794	0.001433	0.001648	0.001451

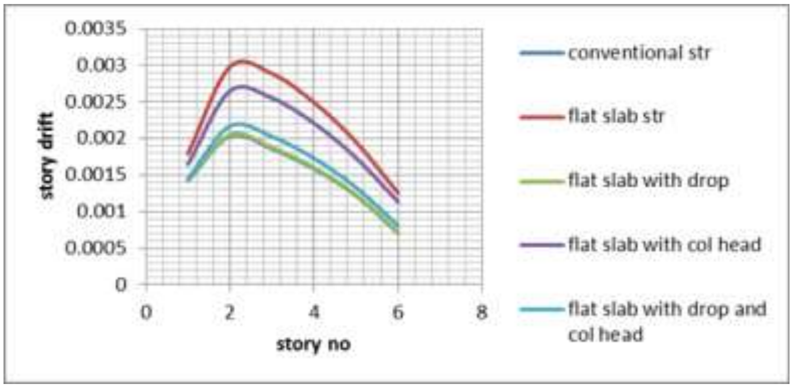


Fig. 16: story drift in X dir. For zone II

story no	conventional str	flat slab str	flat slab with drop	flat slab with col head	flat slab with drop and col head
6	0.000673	0.001205	0.000664	0.001079	0.00075
5	0.001164	0.001879	0.001149	0.001654	0.001241
4	0.001509	0.002399	0.00149	0.002098	0.001613
3	0.001766	0.002773	0.001742	0.002421	0.001889
2	0.001935	0.002872	0.001909	0.002518	0.002027
1	0.001377	0.001744	0.001364	0.001584	0.001375

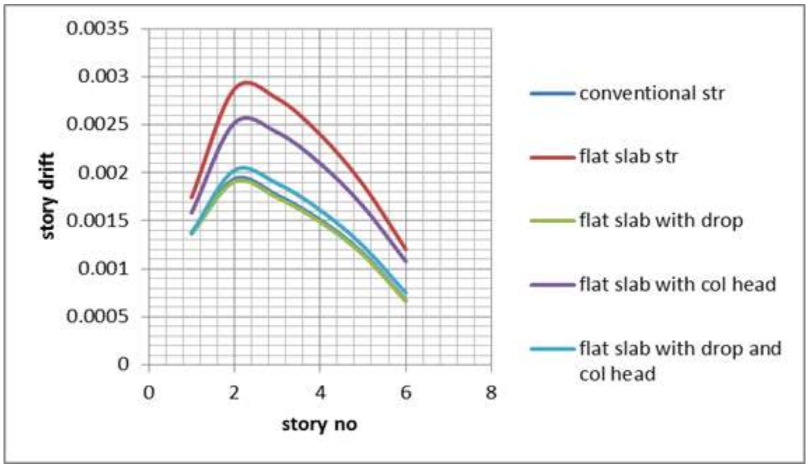


Fig. 17: story drift in Y dir. For zone II

E. Effect on torsional moment on bottom, z= 16m, on top for all diff zones

bottom slab torsion (KN-m/m)	zone II	zone III	zone IV	zone v
conventional str	28.452	47.807	79.733	127.62
flat slab str	85.468	136.153	215.036	333.361
flat slab with drop	37.057	66.838	108.428	170.84
flat slab with col head	85.188	146.24	227.643	349.74
flat slab with drop and col head	31.336	51.027	77.282	116.665

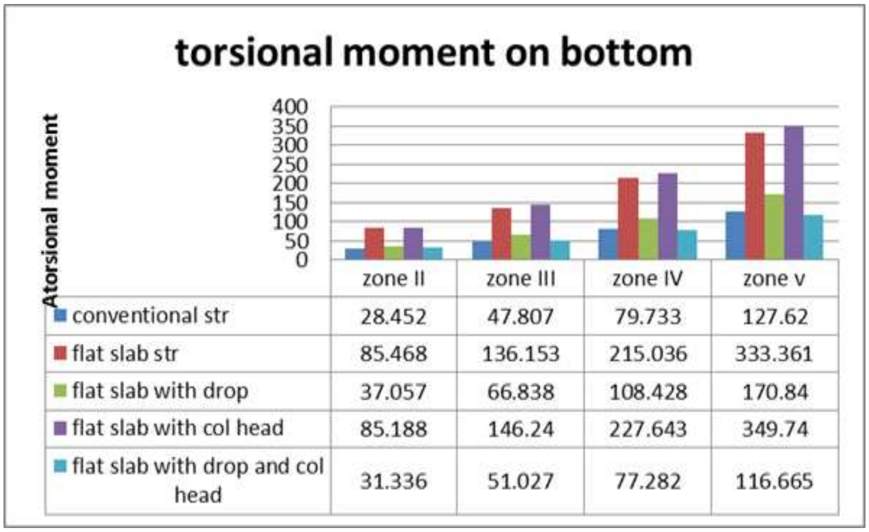


Fig. 18: torsional moment on bottom

4th slab torsion (KN-m/m)	zone II	zone III	zone IV	zone v
conventional str	24.531	36.849	55.274	83.954
flat slab str	81.819	108.909	173.283	269.845
flat slab with drop	30.736	49.178	75.996	121.026
flat slab with col head	70.142	119.456	186.618	287.36
flat slab with drop and col head	20.063	36.547	56.048	85.299

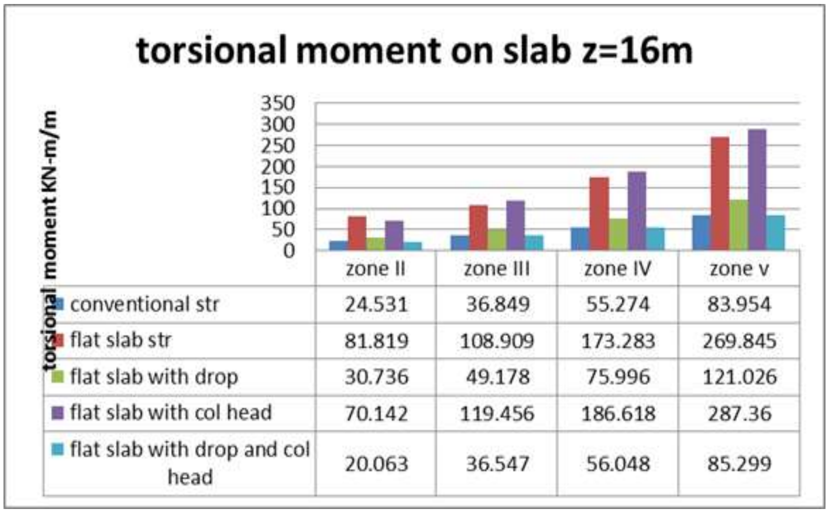


Fig. 19: torsional moment z=16 m

top slab torsion (KN-m/m)	zone II	zone III	zone IV	zone v
conventional str	14.995	15.577	16.557	24.835
flat slab str	46.332	57.682	72.815	104.562
flat slab with drop	15.345	17.627	20.668	30.082
flat slab with col head	35.349	47.099	73.893	117.37
flat slab with drop and col head	12.746	13.924	20.081	30.868

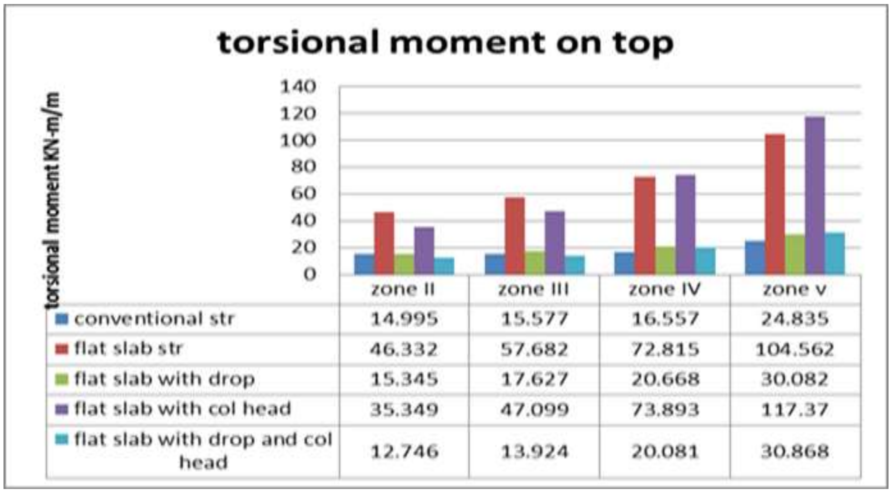
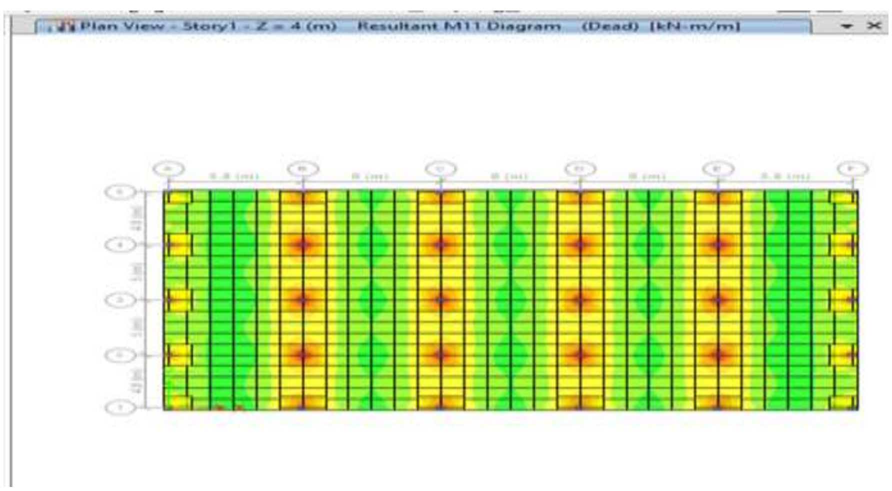


Fig. 20: torsional moment on top

Fig 18, 19, 20 shows effect of torsional moment in KN-m/m on bottom, z=16m, on top for different types of zone factor. This shows that the value of torsional moment on bottom for all zones is more compared to the z=16m and on top. This result is because of gravitational load that making torsional moment is more on bottom and as the zone factor increases the torsional shear increases.

F. Stress dia. For torsional moment on bottom for zone II flat slab with drop



G. Effect on shear force XZ on bottom, z= 16m, on top for all diff zones

bottom slab V13(KN/m)	zone II	zone III	zone IV	zone v
conventional str	68.447	80.554	96.783	127.052
flat slab str	632.705	909.398	1278.321	1831.707
flat slab with drop	79.285	110.18	151.817	214.301
flat slab with col head	150.435	204.364	286.073	408.63
flat slab with drop and col head	54.737	77.522	107.903	153.475

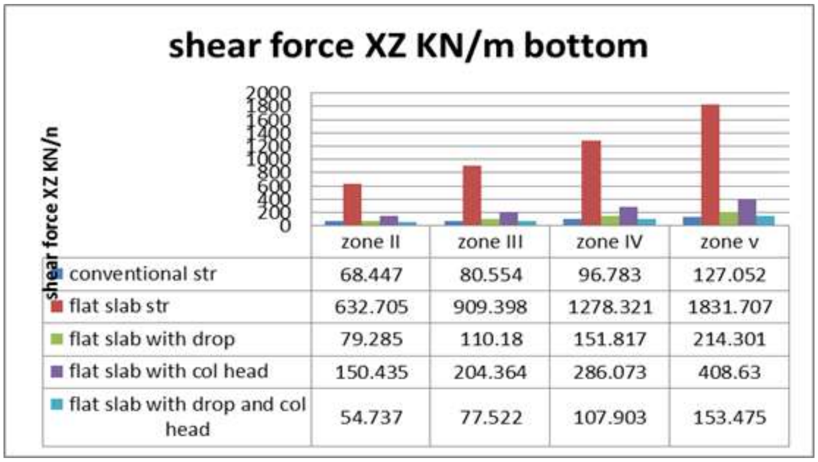


Fig. 21: shear force on bottom

4th slab V13(KN/m)	zone II	zone III	zone IV	zone v
conventional str	65.643	73.661	84.352	100.387
flat slab str	548.928	771.6	1068.495	1513.837
flat slab with drop	63.833	84.44	114.38	159.37
flat slab with col head	142.172	176.465	244.043	345.4
flat slab with drop and col head	49.868	65.299	87.795	121.539

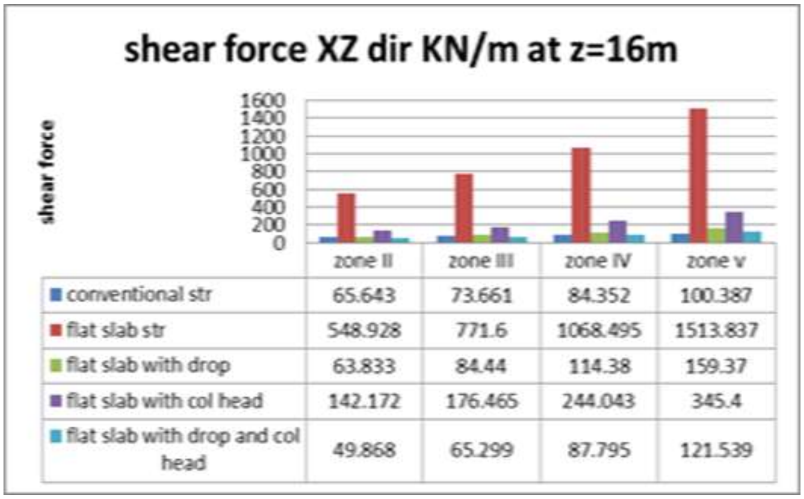


Fig. 22: shear force Z=16m

top slab V13(KN/m)	zone II	zone III	zone IV	zone v
conventional str	37.448	40.594	44.788	51.08
flat slab str	305.502	401.527	529.559	721.608
flat slab with drop	34.146	40.823	49.726	63.091
flat slab with col head	82.366	96.864	123.51	167.43
flat slab with drop and col head	26.135	32.106	40.068	52.01

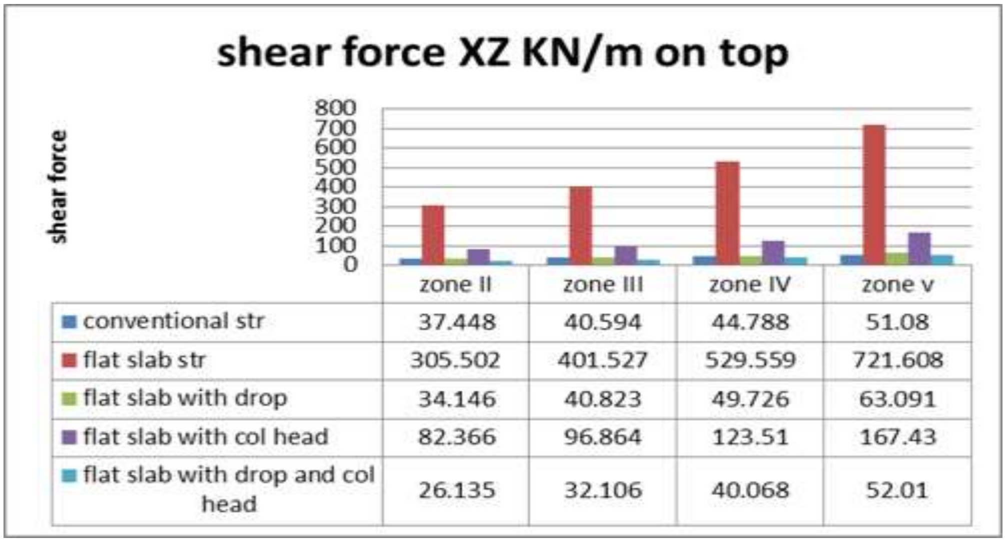


Fig. 23: shear force on top

H. *Effect on shear force YZ on bottom, z= 16m, on top for all diff zones*

bottom slab V23(KN/m)	zone II	zone III	zone IV	zone v
conventional str	65.696	78.295	96.569	128.067
flat slab str	549.999	847.797	1244.862	1840.459
flat slab with drop	77.707	108.915	150.525	213.374
flat slab with col head	147.677	209.046	293.463	420.09
flat slab with drop and col head	52.004	75.838	107.615	155.281

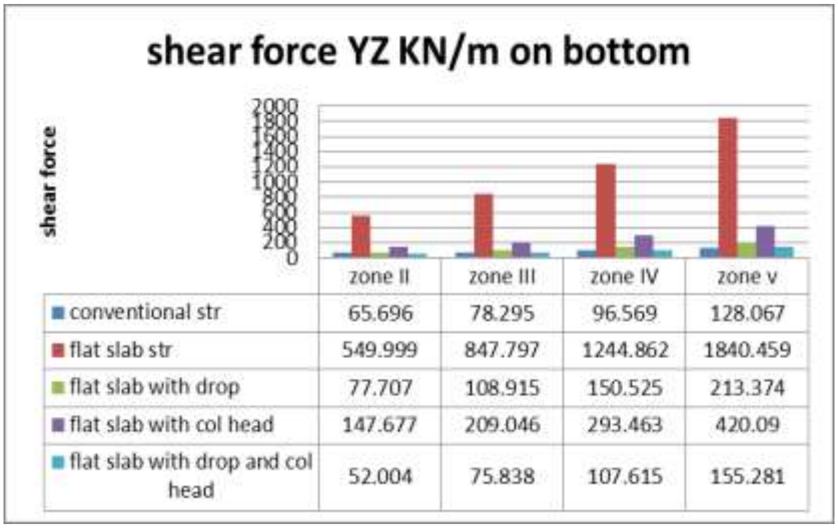


Fig. 24: shear force on bottom

4th slab V23(KN/m)	zone II	zone III	zone IV	zone v
conventional str	61.15	69.661	81.009	99.632
flat slab str	495.635	696.843	1013.251	1487.863
flat slab with drop	62.847	83.293	115.975	154.997
flat slab with col head	136.013	177.304	246.253	349.67
flat slab with drop and col head	44.872	62.024	84.894	119.198

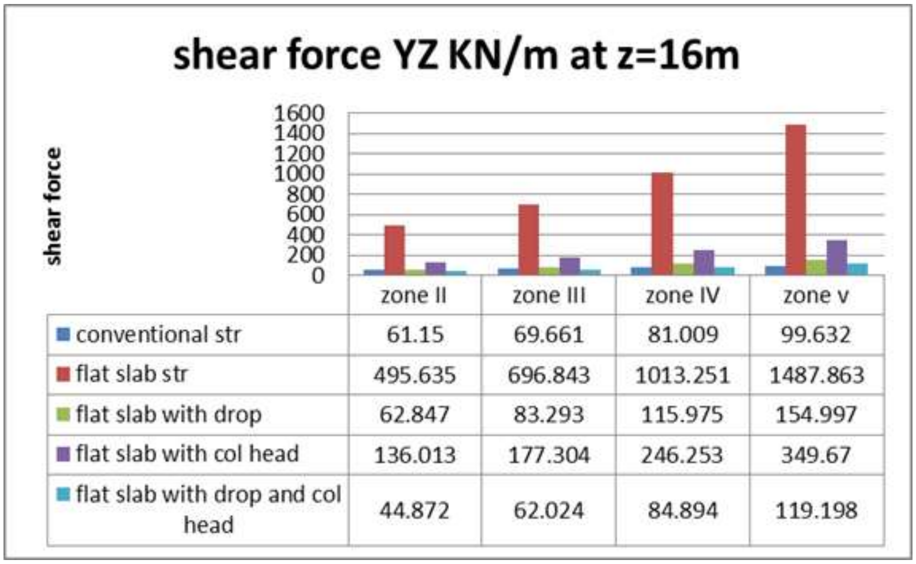


Fig. 25: shear force z=16 m

top slab V23(KN/m)	zone II	zone III	zone IV	zone v
conventional str	34.73	37.914	42.16	48.529
flat slab str	281.551	338.769	456.665	657.691
flat slab with drop	33.291	39.733	48.322	61.565
flat slab with col head	78.666	93.637	121.059	164.986
flat slab with drop and col head	22.797	28.55	36.22	47.726

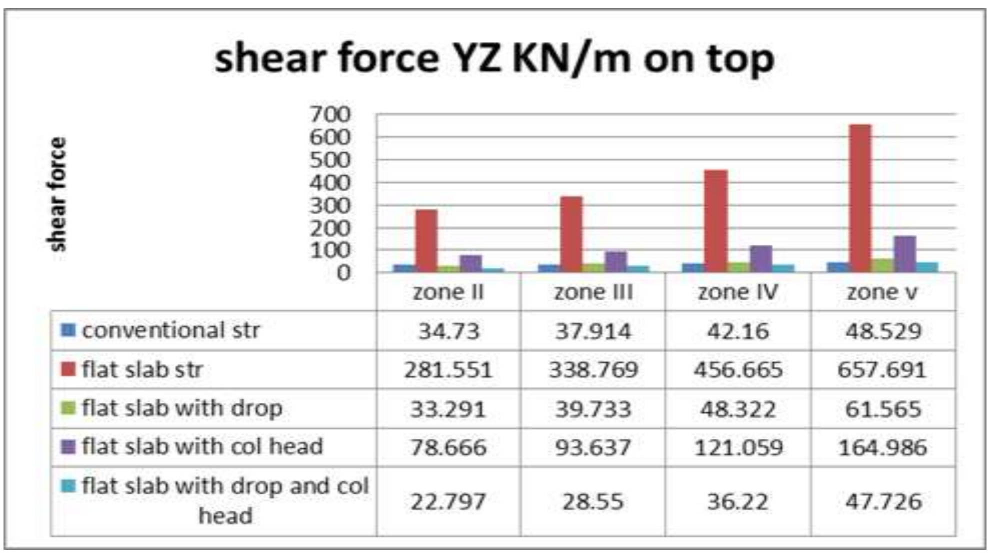
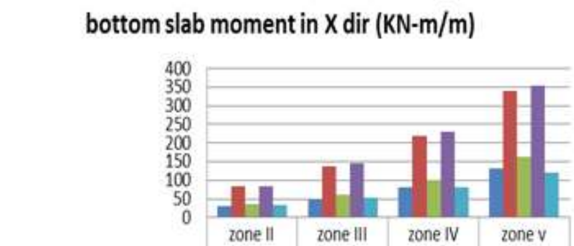


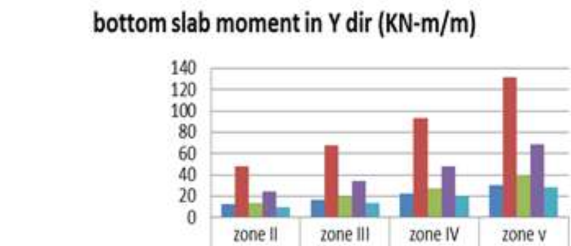
Fig. 26: shear force on top

I. *Slab Moment in X and Y Dir.*



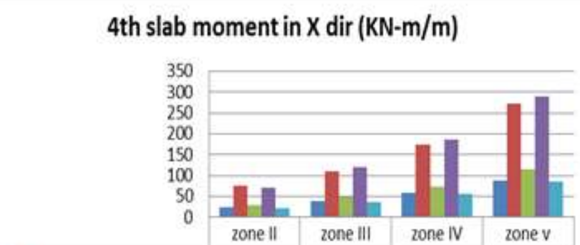
	zone II	zone III	zone IV	zone v
conventional str	30.304	48.486	81.716	132.934
flat slab str	83.418	136.799	217.674	338.986
flat slab with drop	37.048	60.393	101.488	163.81
flat slab with col head	84.475	146.882	230.091	354.9
flat slab with drop and col head	33.764	53.622	80.1	119.816

Fig. 27: BM on bottom in X dir.



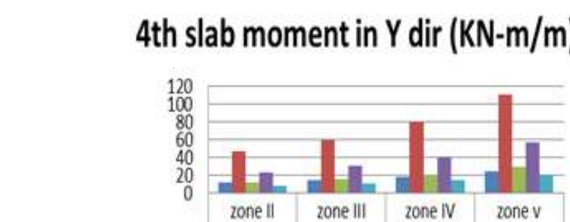
	zone II	zone III	zone IV	zone v
conventional str	12.97	16.574	22.271	30.81
flat slab str	48.45	67.233	93.16	132.05
flat slab with drop	13.819	19.725	27.6	39.897
flat slab with col head	24.358	34.577	48.203	68.64
flat slab with drop and col head	9.27	13.473	19.286	28.335

Fig. 28: BM on bottom in Y dir.



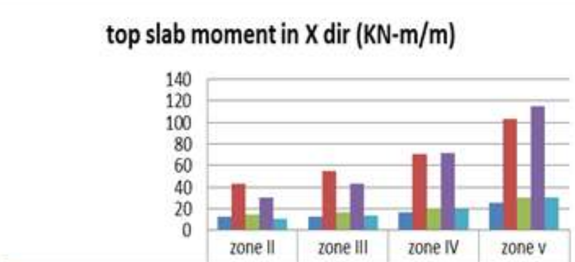
	zone II	zone III	zone IV	zone v
conventional str	24.191	38.706	58.058	87.087
flat slab str	76.567	109.482	174.865	272.94
flat slab with drop	30.193	48.309	72.464	114.177
flat slab with col head	70.771	119.48	187.254	288.91
flat slab with drop and col head	22.888	37.252	56.404	85.131

Fig. 29: BM Z=16m in X dir.



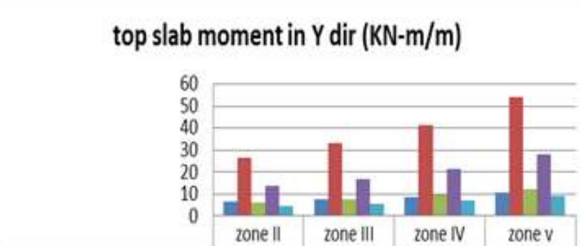
	zone II	zone III	zone IV	zone v
conventional str	12.893	15.288	18.48	24.43
flat slab str	46.981	59.375	80.103	111.196
flat slab with drop	12.54	16.083	21.569	29.798
flat slab with col head	23.455	30.541	41.457	57.83
flat slab with drop and col head	8.297	11.273	15.312	21.572

Fig. 30: BM Z=16m in Y dir.



	zone II	zone III	zone IV	zone v
conventional str	12.773	13.077	16.82	25.3
flat slab str	42.898	54.906	70.917	102.735
flat slab with drop	14.729	16.563	20.422	30.631
flat slab with col head	30.123	43.418	72.058	115.017
flat slab with drop and col head	10.314	13.26	19.973	30.042

Fig. 31: BM on top in X dir.



	zone II	zone III	zone IV	zone v
conventional str	6.437	7.445	8.789	10.805
flat slab str	26.685	33.008	41.438	54.09
flat slab with drop	6.231	7.649	9.54	12.377
flat slab with col head	13.668	17.007	21.46	28.168
flat slab with drop and col head	4.582	5.596	6.948	9.013

Fig. 32: BM on top in Y dir.

VIII. CONCLUSION

- Base shear of beam slab building is less when compared with both flat slab with drop building and flat slab with drop and column head. This is same for all types of zone

- As the seismic level increases all parameters like displacement, base shear intensities are increases.
- Story displacement is Maximum at roof level than at base, and story displacement of flat slab structure is greater than conventional slab, there will be an average displacement variation in each seismic zone for all structures.
- For all the cases considered drift values follow a parabolic path along story height with maximum value lying somewhere near the middle story.
- Story drift in buildings with flat slab without drop is significantly high as compared to beam slab building. This is due to rigidity of the beam slab structure.
- As a result of high drift ratios in flat slab building, additional moments will be developed. Columns of such buildings should be designed by considering additional moments.

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