STUDY ON SEISMIC PERFORMANCE OF RC FRAME CONVENTIONAL BEAM SLAB SYSTEM WITH DIFFERENT HEIGHT AND DIFFERENT ZONES

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Abstract

Reinforced concrete (RC) structures are common type of the structure constructed all over the world due to rapid progress of work.In this paper an attempt is made to understand the behaviour of RC frame with different heights and different earthquake zones. These studies have revealed the inadequacies in the current provisions for earthquake resistant design. The paper reports the results of Linear Static Analysis adopting Equivalent Static Load Method is adopted because of symmetry of the structure, both in geometry and in mass. This symmetrical RC frame subjected to four different earthquake ground motions. The main results of the analytical program work are here presented and discussed.

Keywords: *Equivalent Static Load, Masonry, Infill.*

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1. INTRODUCTION

Earthquake resistant design of RC buildings is a continuing area of research since the earthquake engineering has started not only in India but in other developed countries also. The buildings still fail due to some one or the other reason during earthquakes. In spite of the deficiencies in the structure, either due to code imperfections or error in analysis and design, the structural configuration system has played a vital role in catastrophe.

It is seen that the design of a multi-storey building is governed by lateral loads and it should be the prime concern of the designer to provide adequate safety to structures against lateral loads. The behavior of the building during earthquake depends critically on its overall size, geometry, and how the earthquake forces are carried to the ground. Symmetry in plan of building is more important as it reduces torsion in buildings, thus causing less damage to the columns. In addition to this, the building design must be such as to ensure that the building has adequate strength, high ductility and will remain as one unit, even while subjected to very large deformations. Hence, at the planning stage, Architects and Structural Engineers must work together to ensure that the unfavorable features for susceptible deficiency are avoided and a good building configuration is chosen.

2. MATERIALS AND METHODS

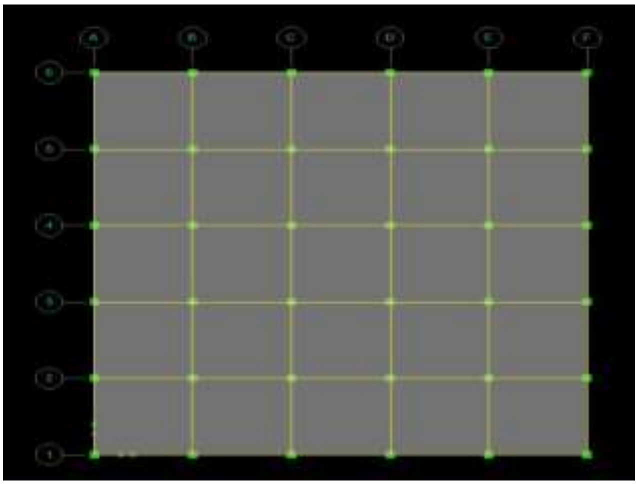


Fig 1 : plan of RC frame

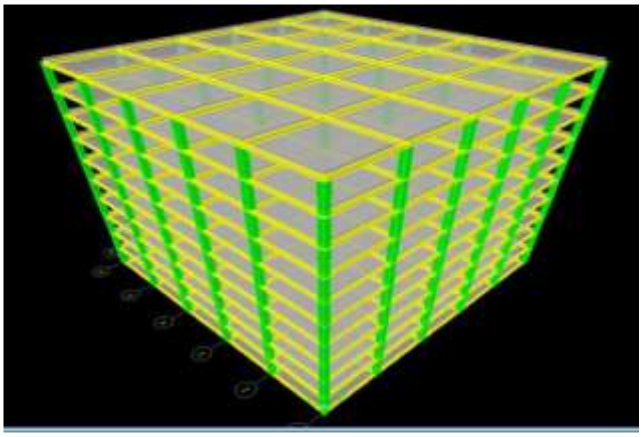


Fig 2 : 3D view of RC Frame

Grade of concrete = M 25
Grade of steel = Fe 500

CROSS SECTIONS OF STRUCTURAL ELEMENTS

i. COLUMN SIZE
Square columns for interior panels at the plinth and ground floor level: 700mmx700mm
Square columns for all other position: 600mmx600mm
Square columns are selected because they offer equal resistance in X and Y directions, irrespective of the direction of earthquake forces.

ii. BEAM SIZE
All beams are of uniform size of 450mmx600mm for all frames considered.

iii. PLINTH BEAM SIZE
All plinth beams are of uniform size of 450mmx600mm for all frames considered.

iv. SLAB THICKNESS
For Conventional RC Beam Slab System : 190mm

v. MASONRY WALL THICKNESS
For all frames considered: 230mm

vi. MASS SOURCE
As per Clause 7.3.1 & Table 8 of IS 1893 (Part I) : 2002, for uniformly distributed live loads intensities of upto 3kN/m^2, 25% of imposed loads has been considered and above 3kN/m^2, 50% of the imposed loads has been considered.

vii. SUPPORT CONDITION

The support is assumed to be fixed at the end.
TYPES OF PRIMARY LOADS

The structural systems are subjected to 3 types of Primary Load Cases as per the provisions of Indian Standard Code of Practice for Structural Safety of Buildings loading standards IS 872-1987 (Part I). They are:

1. Dead Load Case denoted as 'DL'
2. Live Load Case denoted as 'LL'
3. Wall Load Case denoted as 'WaL'
4. Seismic Load in X-direction (Lateral or Earthquake Load), denoted as 'EQX'
5. Seismic Load in Y-direction (Lateral or Earthquake Load), denoted as 'EQY'

The gravity loads (dead, superdead and live load) on the frame have been calculated based on the provisions of Indian Standard Code of Practice for Structural Safety of Buildings loading standards IS 872-1987 (Part II). The dead load consists of self-weight of structural elements and the superdead load consists of the masonry wall load acting on the structure. The live load is assumed to be varying as per different requirements as 3kN/m^2, 4kN/m^2 and 5kN/m^2.

The lateral loads (Seismic loads) on the frame have been calculated based on the provisions of IS 1893 (Part I):2000 that deals with 'Criteria for Earthquake Resistant Design of Structures'. The aim is to carry out the seismic analyses of all the structural systems by "Equivalent Static Frame Method".

Load Combinations

The structural systems were subjected to 14 types of Load Combinations are per the provisions of IS 1893 (Part I) Clause 6.3.1, that deals with "Criteria for Earthquake Resistant Design of Structures", they are:

a) Non-Seismic Load Combination:
1. 1.5(DL+LL)

b) Seismic Load Combination:
2. 1.2(DL+LL+EQX)
3. 1.2(DL+LL-EQX)
4. 1.2(DL+LL+EQY)
5. 1.2(DL+LL-EQY)
6. 1.5(DL+EQX)
7. 1.5(DL-EQX)
8. 1.5(DL+EQY)
9. 1.5(DL-EQY)
10. (0.9DL+1.5EQX)
11. (0.9DL-1.5EQX)
12. (0.9DL+1.5EQY)
13. (0.9DL-1.5EQY)
Also, the software by default creates a load combination as:
14. 1.5(DL)
15. CRITICAL – Combination created manually such that an envelope is created considering all the above mentioned load combinations to obtain maximum values for each parameter

3. METHOD OF ANALYSIS

Linear Static Analysis adopting Equivalent Static Load Method is adopted because of symmetry of the structure, both in geometry in mass.

3.1 Seismic Zone

The behavior of all models for different load combinations is studied considering all the 4 Seismic Zones of India, details of which are as per IS 1893(Part I):2002 are given below:

Table 1: Seismic Zones & Zone Factors as per IS 1893 (Part I)-2002

SEISMIC ZONE	II	III	IV	V
SEISMIC INTENSITY	LOW	MODERATE	SEVERE	VERY SEVERE
ZONE FACTOR (Z)	0.10	0.16	0.24	0.36

3.2 Maximum Allowable Horizontal Displacements & Storey Drifts Values

According to Clause 7.11.1 of IS 1893-Part I:2002 and Clause IS 456:2000, the maximum allowable drift is 0.04h for a partial safety factor of 1.0.

Hence, the allowable displacements of a particular height of the building and maximum allowable storey drifts are as per the table given below for a storey height of 3m.

Table 2: Limiting values of horizontal displacements and storey drifts for different heights of buildings

NO OF STOREYS	TOTAL HEIGHT OF THE BUILDING, H m	Maximum allowable deflection, H/250 mm	Maximum allowable storey drift, h/250 mm
6	18	72	12
8	24	96	12
10	30	120	12
15	45	180	12
20	60	240	12

4. RESULTS AND DISCUSSION

4.1 Tabulation of Analysis Results & Presentation of Charts

The values obtained after analyzing the models are tabulated below and correspondingly, their graphs are plotted.

Those models which do not satisfy the above conditions are highlighted in red color in the tables.

TYPE OF SLAB SYSTEM: Conventional Beam-Slab System
NO OF STOREYS: 06
HEIGHT OF BUILDING: 18m
ZONE: II and III

Table 3: Six storey Beam-slab system for Zone II and Zone III

ZONE: II				**ZONE : III**		
Live Load (kN/m^2)	**3**	**4**	**5**	**3**	**4**	**5**
Max Displacement mm	15.12	15.85	16.24	24.31	25.48	25.90
Storey Drift mm	3.13	3.30	3.36	4.99	5.23	5.34
Column Axial Force kN	4934	5189	5464	4911.19	5181.49	5451.80
Column Shear Force kN	192.72	202.48	208.17	301.46	317.	323
Column Bending Moment kNm	379	401	408	602.78	635	645
Beam Shear Force kN	215.92	2019.58	231.20	263.37	270	273
Beam Bending Moment kNm	124.92	135.35	145.77	131.64	140.5	151
Base Shear, kN	3590.38	3772.08	3836.16	5717	6015	6126

TYPE OF SLAB SYSTEM: Conventional Beam-Slab System
NO OF STOREYS: 06 HEIGHT OF BUILDING:18m
ZONE: IV and V

Table 4: Six storey Beam-slab system for Zone IV and Zone V

ZONE: IV				ZONE : V		
Live Load (kN/m^2)	3	4	5	3	4	5
Max Displacement mm	36.46	38.22	38.85	54.69	57.33	58.28
Storey Drift mm	7.47	7.85	8.00	11.21	11.78	11.99
Column Axial Force kN	4911.19	5181.49	5451.80	4911.19	5181.49	5451.80
Column Shear Force kN	451.79	475.23	484.07	677.29	712.44	725.71
Column Bending Moment kNm	903.81	950.69	968.37	1355.36	1425.68	1452.20
Beam Shear Force kN	327.06	336.60	340.11	422.59	436.60	442.16
Beam Bending Moment kNm	142.77	149.90	159.78	164.01	170.64	176.74
Base Shear, kN	8576.11	9021.80	9189.98	12864.17	13532.69	13784.97

TYPE OF SLAB SYSTEM: Conventional Beam-Slab System
NO OF STOREYS: 08 HEIGHT OF BUILDING:24m
ZONE: II &III

Table 5: 8 storey Beam-slab system for Zone II and Zone III

ZONE: II				ZONE : III		
Live Load (kN/m^2)	3	4	5	3	4	5
Max Displacement mm	22.18	23.30	23.72	35.49	37.29	37.95
Storey Drift mm	3.52	3.71	3.78	5.63	5.93	6.05
Column Axial Force kN	6456.83	6833.08	7211.33	6454.83	6833.08	67211.33
Column Shear Force kN	203.0	213.85	218.00	324.29	341.63	348.29
Column Bending Moment kNm	406.46	428.21	436.55	649.90	684.70	698.04
Beam Shear Force kN	229.16	234.02	244.14	284.18	291.96	294.93
Beam Bending Moment kNm	125.57	135.46	145.81	135.18	143.56	153.36
Base Shear, kN	3841.80	4036.90	4093.35	6146.88	6476.59	6585.16

TYPE OF SLAB SYSTEM: Conventional Beam-Slab System
NO OF STOREYS: 08 HEIGHT OF BUILDING:24m
ZONE: IV&V

Table 6: 8 storey Beam-slab system for Zone IV and Zone V

ZONE: IV				ZONE : V		
Live Load (kN/m^2)	3	4	5	3	4	5
Max Displacement mm	53.24	55.93	59.92	79.89	83.89	85.38
Storey Drift mm	8.46	8.91	9.08	12.68	13.35	13.61
Column Axial Force kN	6454.83	6833.08	7211.33	6454.83	6833.08	7211.33
Column Shear Force kN	486.00	512.02	521.99	728.56	767.59	782.56
Column Bending Moment kNm	974.47	1026.67	1046.68	1461.34	1539.63	1569.65
Beam Shear Force kN	357.54	369.21	373.66	467.58	485.09	491.76
Beam Bending Moment kNm	148.00	153.30	164.37	174.75	181.57	187.33
Base Shear, kN	9195.33	9714.89	9904.59	13830.48	14572.33	14816.61

TYPE OF SLAB SYSTEM: Conventional Beam-Slab System
NO OF STOREYS: 10 HEIGHT OF BUILDING:30m
ZONE: II &III

Table 7: 10 storey Beam-slab system for Zone II and Zone III

ZONE: II				ZONE : III		
Live Load (kN/m^2)	3	4	5	3	4	5
Max Displacement mm	29.81	31.36	31.94	47.69	50.17	51.10
Storey Drift mm	3.81	4.01	4.09	6.09	6.42	6.55
Column Axial Force kN	7987.79	8473.08	8958.38	7987.79	8473.08	8958.38
Column Shear Force kN	214.97	226.66	231.18	343.38	362.09	396.33
Column Bending Moment kNm	430.88	454.37	463.46	688.94	726.52	741.06
Beam Shear Force kN	237.59	242.98	252.33	297.03	305.66	308.99
Beam Bending Moment	126.93	136.60	146.28	137.33	145.38	155.23

kNm						
Base Shear, kN	406 4.73	4286. 82	437 2.8 0	6503 .56	685 8.92	6996. 48

TYPE OF SLAB SYSTEM: Conventional Beam-Slab System
NO OF STOREYS: 10 HEIGHT OF BUILDING:30m ZONE: IV&V

Table 8: Six storey Beam-slab system for Zone IV and Zone V

ZONE: IV				ZONE : V		
Live Load (kN/m^2)	3	4	5	3	4	5
Max Displacement mm	71.5 5	75.26	75. 65	107. 32	112 83	114.9 8
Storey Drift mm	9.14	9.63	9.8 3	13.7 0	14.4 5	14.74
Column Axial Force kN	798 7.79	8473. 08	895 8.3 8	7987 .79	847 3.08	8958. 38
Column Shear Force kN	514. 060	52.66	553 .52	771. 42	813. 51	829.8 0
Column Bending Moment kNm	103 3.01	1089. 39	111 1.2 0	1549 .13	163 3.69	1666. 41
Beam Shear Force kN	376. 28	389.2 2	394 .23	495. 51	514. 57	522.0 8
Beam Bending Moment kNm	152. 05	159.1 9	167 .17	181. 23	188. 19	194.1 6
Base Shear, kN	975 5.35	1028 8.38	104 66. 27	1459 3.36	153 90.7 5	1566 99.47

TYPE OF SLAB SYSTEM:
Conventional Beam-Slab System
NO OF STOREYS: 12
HEIGHT OF BUILDING:36m
ZONE: IV & V

Table 9: 12 storey Beam-slab system for Zone II and Zone III

ZONE IV		ZONE V
Live Load (kN/m^2)	5	3
Max Displacement mm	97.95	136.94
Storey Drift mm	10.45	14.57
Column Axial Force kN	10683.46	9501.97
Column Shear Force kN	580.44	808.14
Column Bending Moment kNm	1166.21	1624.22
Beam Shear Force kN	408.89	514.90
Beam Bending Moment kNm	169.52	185.87
Base Shear, kN	10996.74	15318.04

TYPE OF SLAB SYSTEM: Conventional Beam-Slab System
NO OF STOREYS: 15
HEIGHT OF BUILDING:45m
ZONE: IV & V

Table 10: 15 storey Beam-slab system for Zone IV and Zone V

ZONE IV		ZONE V
Live Load (kN/m^2)	5	3
Max Displacement mm	132.89	185.51
Storey Drift mm	11.29	15.72
Column Axial Force kN	13213.36	11724.00
Column Shear Force kN	615.08	855.51
Column Bending Moment kNm	1237.07	1721.22
Beam Shear Force kN	425.25	537.15
Beam Bending Moment kNm	172.58	191.19
Base Shear, kN	11640.75	16199.32

TYPE OF SLAB SYSTEM: Conventional Beam-Slab System
NO OF STOREYS: 20

HEIGHT OF BUILDING:60m
ZONE: IV & V

Table 11: 20 storey Beam-slab system for Zone IV and Zone V

ZONE IV		ZONE V
Live Load (kN/m^2)	3	4
Max Displacement mm	185.39	195.58
Storey Drift mm	11.58	12.25
Column Axial Force kN	15271.99	16259.75
Column Shear Force kN	614.27	648.98
Column Bending Moment kNm	1237.34	1307.34
Beam Shear Force kN	422.19	438.28
Beam Bending Moment kNm	163.07	170.52
Base Shear, kN	11607.13	12264.54

CONVENTIONAL BEAM-SLAB SYSTEM - 6 STOREY BUILDING FOR DIFFERENT ZONES AND DIFFERENT LIVE LOAD INTENSITIES

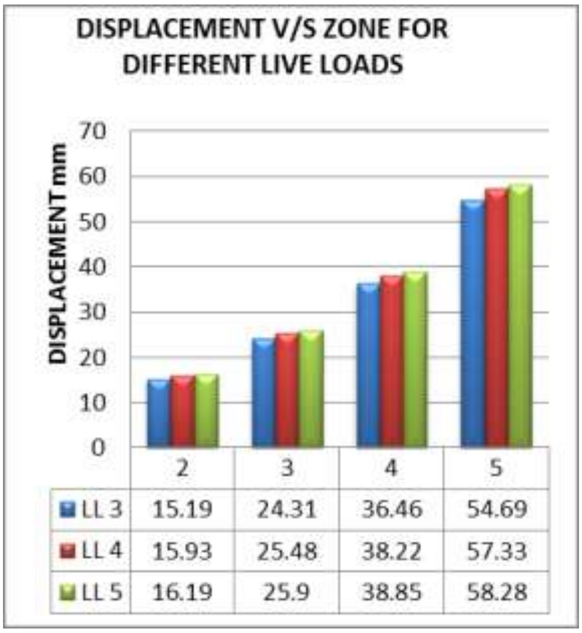


Chart 1: Displacement v/s Zone for Different Live Loads

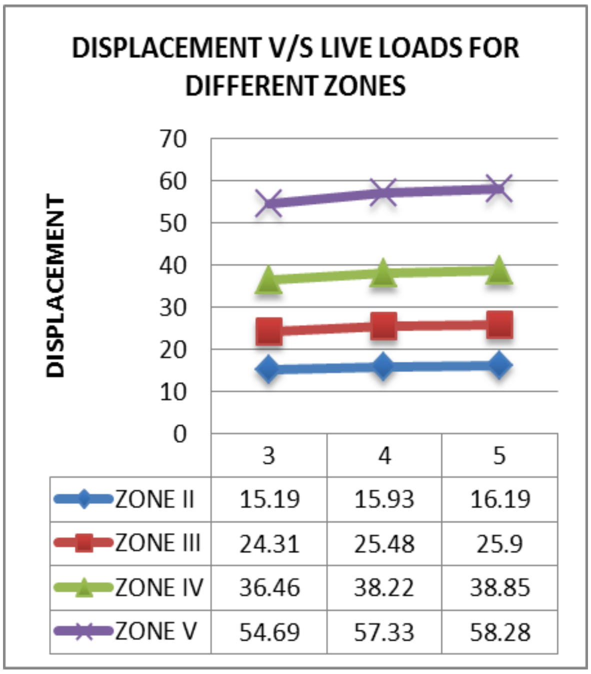


Chart 2: Displacement v/s Live Loads for Different Zones

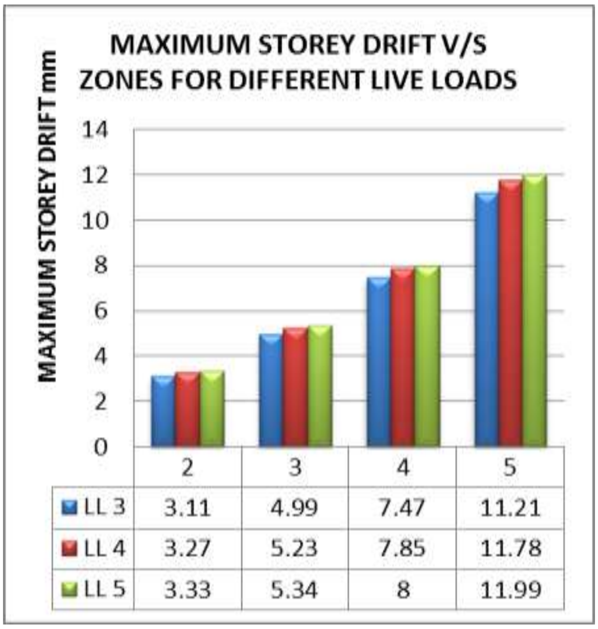
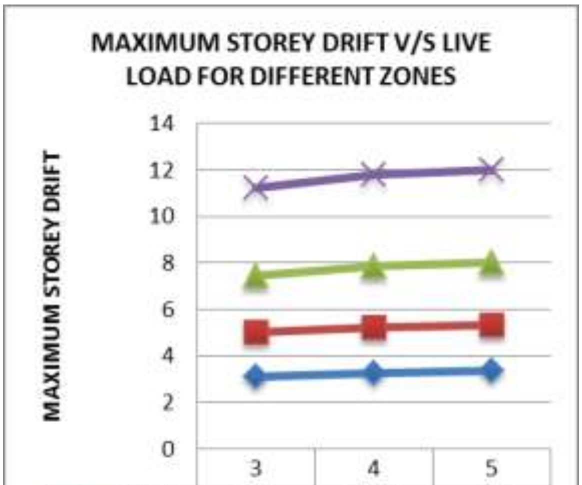
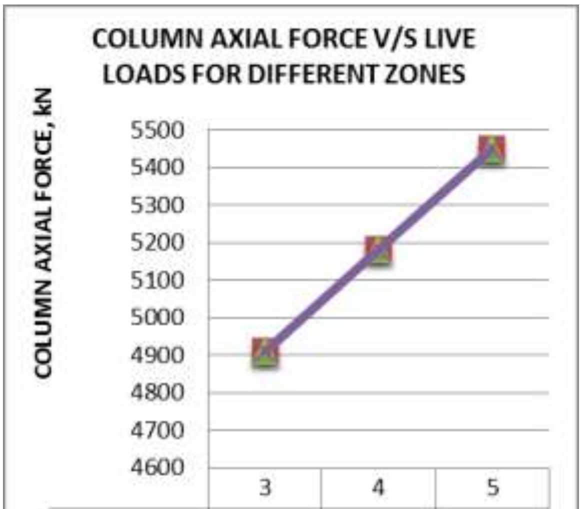


Chart3: Maximum Storey Drift v/s Zone for Different Live Loads



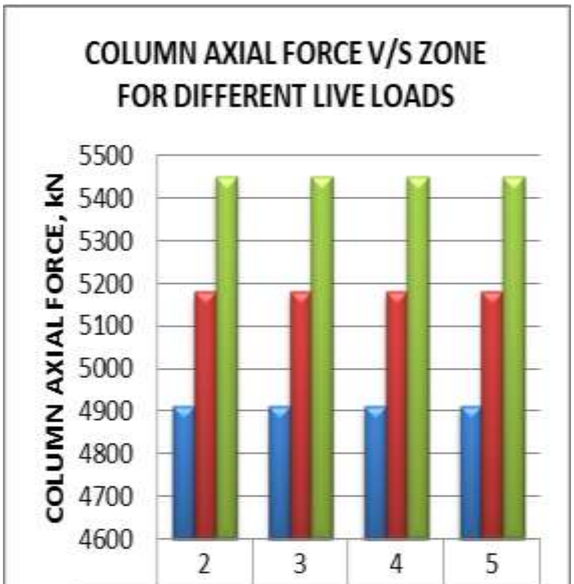
	3	4	5
ZONE II	3.11	3.27	3.33
ZONE III	4.99	5.23	5.34
ZONE IV	7.47	7.85	8
ZONE V	11.21	11.78	11.99

Chart 4: Maximum Storey Drift v/s Live Loads for Different Zones



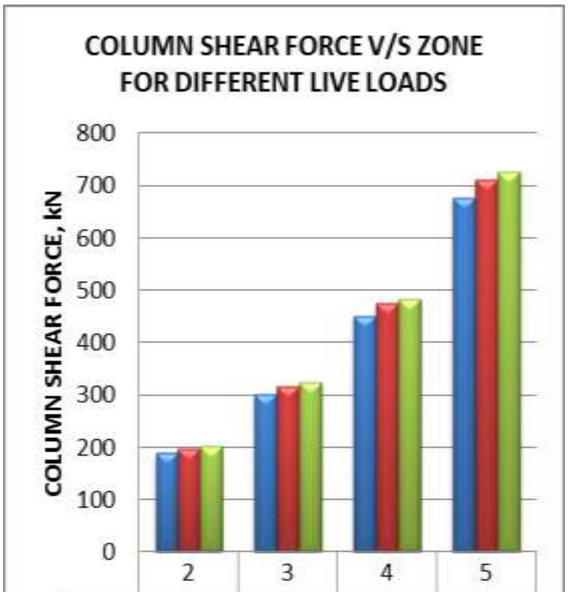
	3	4	5
ZONE II	4911.19	5181.49	5451.8
ZONE III	4911.19	5181.49	5451.8
ZONE IV	4911.19	5181.49	5451.8
ZONE V	4911.19	5181.49	5451.8

Chart 6: Column axial force v/s Live Loads for Different Zones



	2	3	4	5
LL 3	4911.19	4911.19	4911.19	4911.19
LL 4	5181.49	5181.49	5181.49	5181.49
LL 5	5451.8	5451.8	5451.8	5451.8

Chart 5: Column axial force v/s Zone for Different Live Loads



	2	3	4	5
LL 3	188.72	301.46	451.79	677.29
LL 4	198.48	317.09	475.23	712.44
LL 5	202.17	322.98	484.07	725.71

Chart 7: Column shear force v/s Zone for Different Live Loads

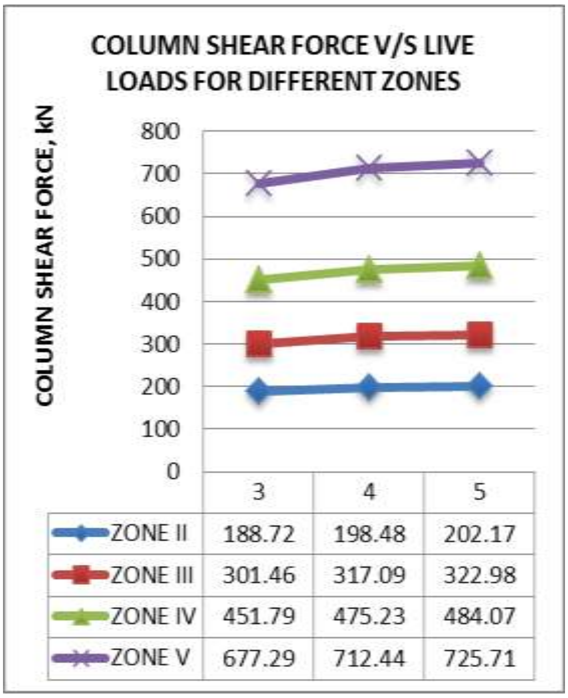


Chart 8: Column shear force v/s Live Loads for Different Zones

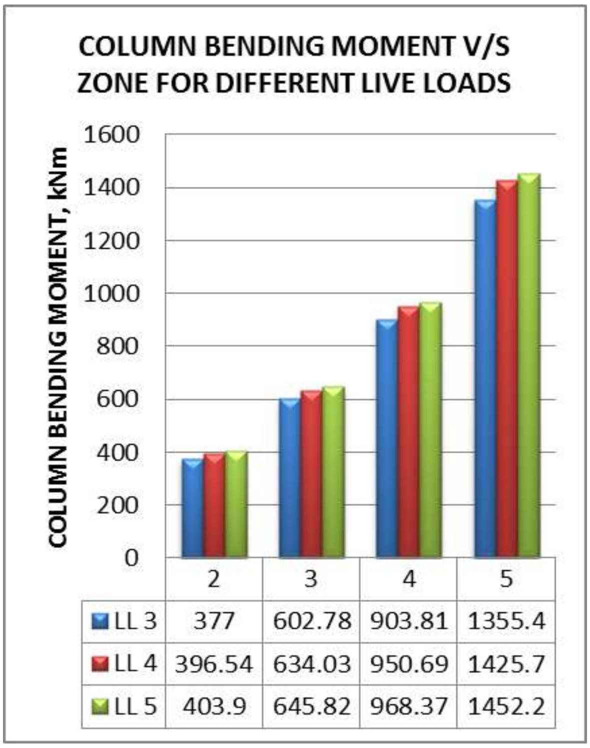


Chart 9: Column bending moment v/s Zone for Different Live Loads

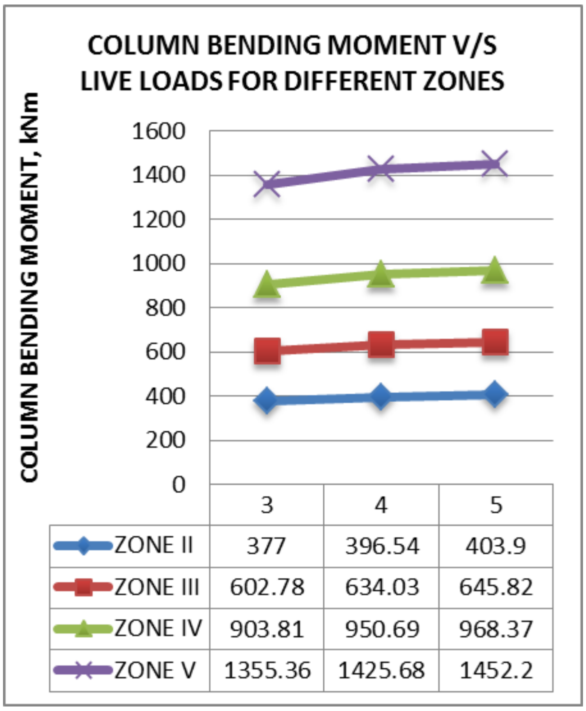


Chart 10: Column bending moment v/s Live Loads for Different Zones

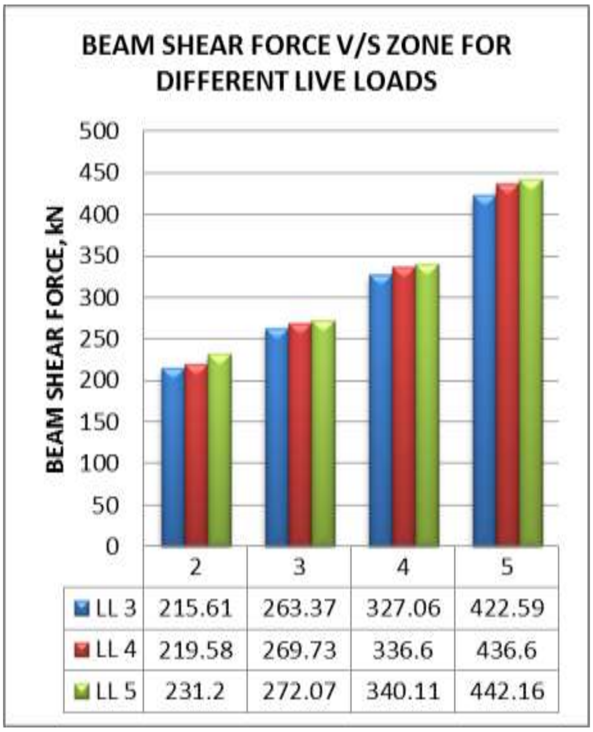


Chart 11: Beam shear force v/s Zone for Different Live Loads

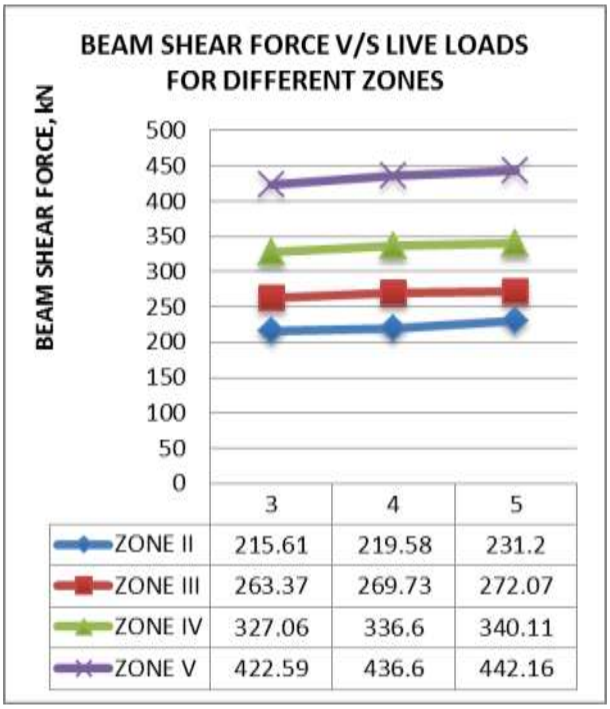


Chart 12: Beam shear force v/s Live Loads for Different Zones

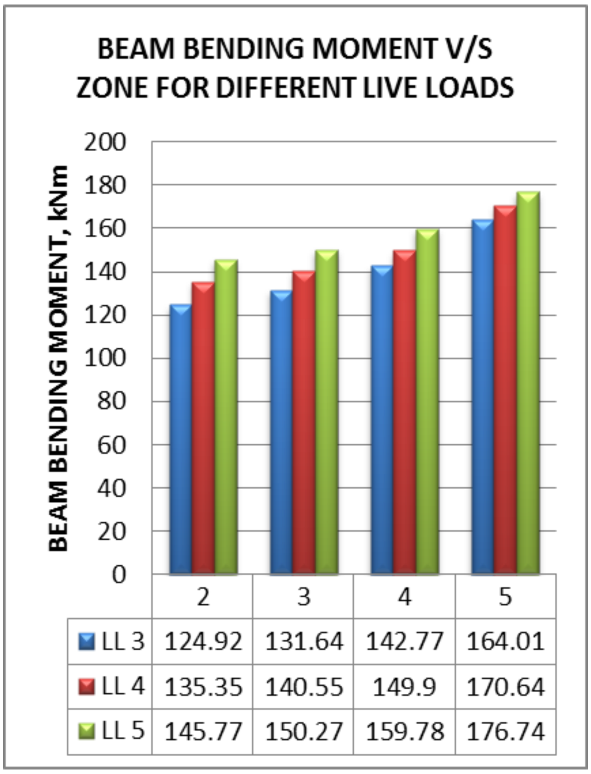


Chart 13: Beam bending moment v/s Zone for Different Live Loads

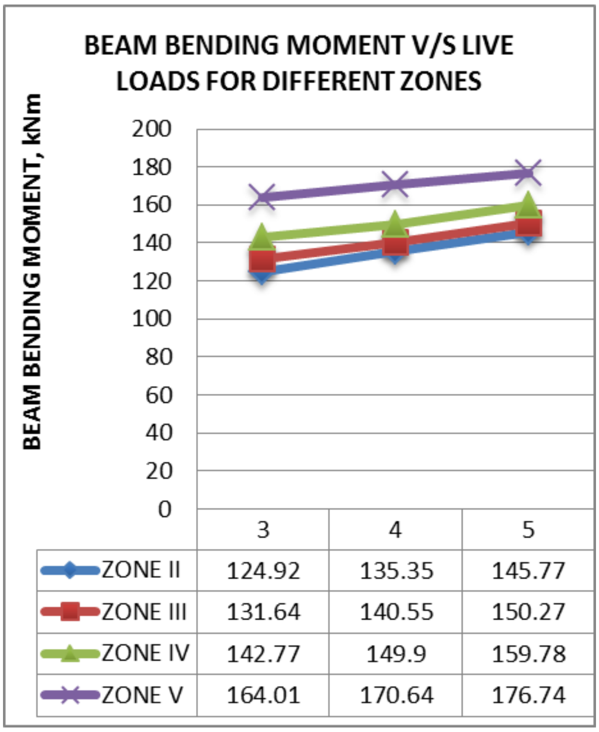


Chart 14: Beam bending moment v/s Live Loads for Different Zones

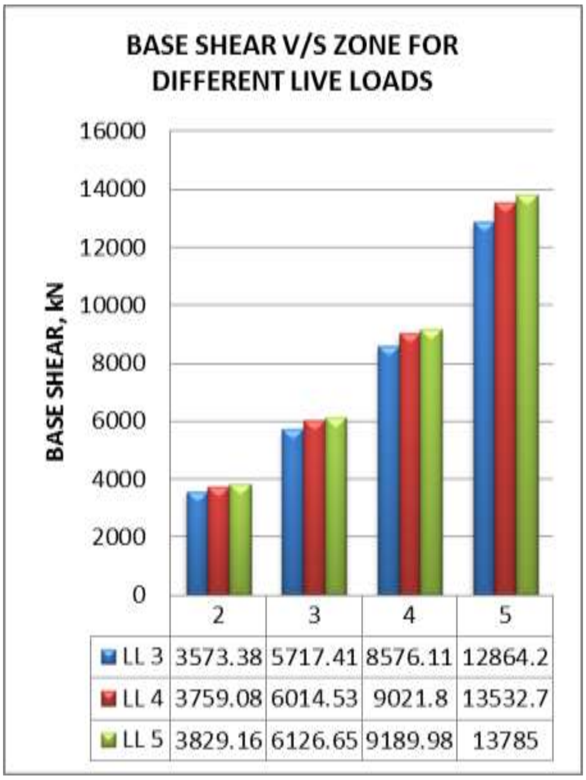


Chart 15: Base shear v/s Zone for Different Live Loads

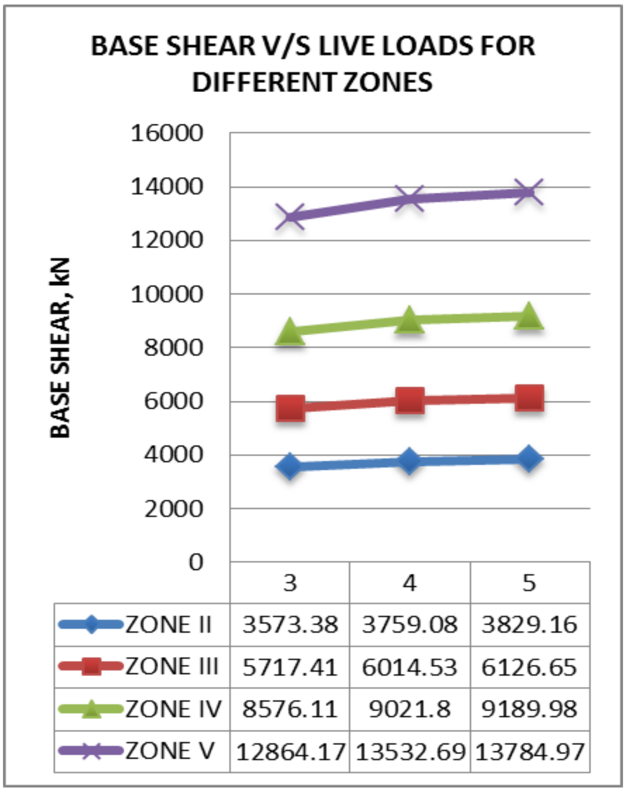


Chart 16: Base shear v/s Live Loads for Different Zones

5. CONCLUSION

In the present investigation, an attempt has been made to understand the behavior of conventional beam-slab for varying live load intensities, storey heights, seismic zone factors .The variation of all the models with respect to their maximum displacements, maximum storey drifts, column axial forces, column shear forces, column bending moments, beam shear forces, beam bending moments and base shears are tabulated in order to predict an order of preference of the slab systems for any particular case.

1. As a increasing zones like zone II, III, IV, V of particular model, displacement of structure will gradually increase.
2. If the increase of height of the building, base shear will decrease and displacement will gradually increases.
3. If we increase the live load intensity of particular model with respect to different zones, the displacement will gradually increases.
4. If increase the live load intensity of particular model, and particular column and beam, column axial force, column shear force, column bending moment, beam shear force and beam bending moment will increases with gradual increase of live load intensity and with respect to different zones.

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