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Comparative Analysis of a G+4 Structure Considering Slab Stiffness on Structural Behaviour of L Shaped Building Plan

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ABSTRACT

Slab is considered as a very important structural elements. The slabs are generally functioned to minimize the weight coming normal to its plane. In general practise, the weight/load exerted on a beam by a slab is considered in the analysis without considering slab stiffness. In our study we will consider a G+4 L shape structure considering case with and without consideration of slab stiffness using analysis tool STAAD.Pro This software is capable to apply gravity and seismic loads. Shear force, storey displacements, axial force, bending moment and support reactions are considered to prepare comparative study to present the effect of slab stiffness. The results shows that there is a good reduction in forces, bending moment which will reduce reinforcement requirement and displacement of the storey due to consideration of slab stiffness. Also visible reduction is seen in case of forces and bending moment at supports. The slab stiffness results in reduction in reinforcement requirement and providing proper stability to the building frame. In present work approximately 20% lesser reinforcement is required when stiffness of slab is taken into account in the analysis resulting in an economical design.

Keywords : L shaped building, slab stiffness, lateral resistance, STAAD.Pro

I. INTRODUCTION

Slabs are the flooring systems of most structures including office, commercial, residential buildings, bridges, sports stadiums and other facilities building. The main function of slab is to carry gravity forces, such as loads from human weight, goods, furniture, vehicles etc. While designing a reinforced concrete structure, the aim is to provide a safe, serviceable, durable, economical and aesthetically pleasing structure. In general practise, designers neglects the effect of slab stiffness in structural behaviour of building due to complexity involve in the analysis, however the floor load is considered on the beams. Therefore this ignorance of slab stiffness may change the structural behaviour of a building under gravity and seismic loads. So to study the behaviour of a R.C. structure, consideration of slab stiffness is very necessary. The work done by various researchers in this field is mentioned below : -

Nakashima et al (1983) investigated the diaphragm effect of R.C. floor slabs on building response based upon experiment and finite element analysis. A R.C.C. building frame with seven stories, six bays in width and one bay in depth was selected for the purpose of analysis. Dimensions were choosen intentionally by the author so that the floor slabs would play a significant role in the distribution of lateral force to the vertical elements. The model structure is analysed for 3 cases. Linear elastic analysis with rigid slab, linear elastic analysis and non linear elastic analysis with consideration of slab stiffness. Results were compared in terms of maximum displacement, acceleration and base shear.

Kunnath et al (1991) studied the effect of seismic response on R.C. buildings with inelastic floor diaphragms. The author presented that the assumption of rigid floor could be useful for simple buildings but for certain buildings such as long narrow buildings, building with horizontal offsets (L shaped or T shaped) and building with vertical offsets produces erroneous results and cannot be disregarded. Seismic response of a set of long narrow rectangular buildings subjected to El-centro earthquake for diaphragm flexibilty were studied through stiffness degradation models. The results obtained from the study depicted that the inplane deflection of floor slabs imposes a higher demand on ductility and strength of flexible frames than the values predicted by assuming rigid or elastic slabs with special emphasis on risk of failure they may cause to the gravity load supporting system.

Moon (1994) analysed inplane floor slab flexibility of a multistorey building structure and results are summarised through parametric study in terms of floor displacement of the roof, seismic base shear and the distribution of seismic base shear. Through his work he concluded that the inplane floor slab flexibility may result in a longer vibration period leading to reduced base shear however part of the structure may be subjected to increased forces caused by the inplane deformation of the slab. Therefore it is desirable to include the inplane flexibilty of floor slabs in the seismic analysis of building structure for economical and safe design.

Hamary (1994) investigated the benefits of the flexibility of horizontal diaphragms under P-delta method of analysis especially when the loads are applied to the intermediate frame that are not part of the lateral force resisting system. Analysis were made for structural systems with different number of bays, storeys, and diaphragm stiffnesses.

Colunga and Abrams (1996) discussed the effect of floor flexibility on the sesimic response of building structure by comparing a structure with flexible diaphragms to their hypothetical counterparts with rigid diaphragms. Case study of three existing building with flexible diaphragms subjected to 1989 loma prieta earthquake were compared with the analogous hypothetical buildings with rigid diaphragms. Results depicted that there is an increase in shear wall accelerations and decrease in torsional forces as the diaphragm flexibilty increases.

Bari et al (2004) presented a finite element analysis of slab. Two square plate system were considered, one with the assumption of fix supports and another one with the assumption of simple supports. A generalised computer program in fortan77 was developed for the purpose of analysis and for determining the solution of finite element equations. Results in terms of deflection and bending moment were compared with the analytical solutions previously developed by the other authors. A deviation in displacement and moments by an order of 20% compared to the analytical result was observed.

Barron and Hueste (2004) evaluated the effect of diaphragm flexibility on the structural response of typical RC rectangular building using a performance based approach. Linear static, linear dynamic, and non linear dynamic analysis were conducted for a 3 storey and a 5 storey structure for different aspect ratio (2:1 and 3:1). A comparison between rigid diaphragm and the flexible diaphragm behaviour of the models was studied indicating that for a low rise reinforced concrete building frame flexible design should be considered for 3:1 or larger aspect ratios.

Gardneir et al (2008) studied the magnitude and trend of forces in concrete floor diaphragms with prominence on transfer forces under seismic loading. The main objective of the research was to identify appropriate methods for design of floor forces and to determine the trend assosciated with transfer of floor forces. In 1st part of his research a new pseudo-equivalent static analysis (pESA) method for determination of inertial forces in floor diaphragms was studied wheres in 2nd part the total forces within reinforced concrete floor diaphragms with varying stiffness of vertical elements were investigated using non linear time history analysis. Results indicated that the inertial forces predicted by pESA method were more accurate than that by ESA method.

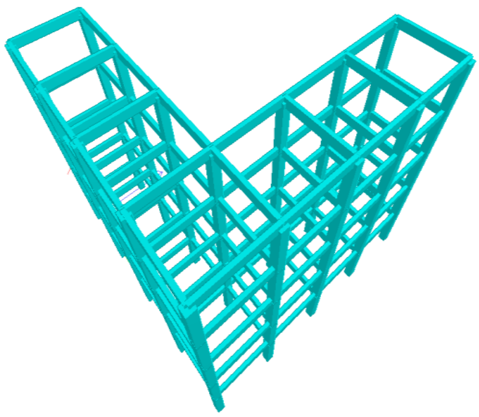
Fouad et al (2012) investigated the flexibility effect of floor slabs by studying the effect of horizontal seismic action on the deformability of the floor. Three different plan buildings of 5, 10, and 15 storey height with rigid and flexible diaphragms were analysed using response spectrum method to study the effect of floor slab on seismic response. Results indicated that the effect of flexural stiffness is relatively insignificant in taller buildings. If flexural stiffness of the slab is totally ignored, the lateral displacement may be overestimated and base shear may be significantly underestimated.

Yadav and Kushwaha (2016) studied the influence of floor diaphragms on seismic response of building frames. Three R.C. building frames, without diaphragm, with rigid and semi rigid diaphragms were analysed using staad pro software. Results are compared in terms of maximum moment in beams, axial force, shear force, and max displacement. Results indicated that rigid diaphragm is more effective as compared to other diaphragms in reducing moment, storey displacement and peak displacement.

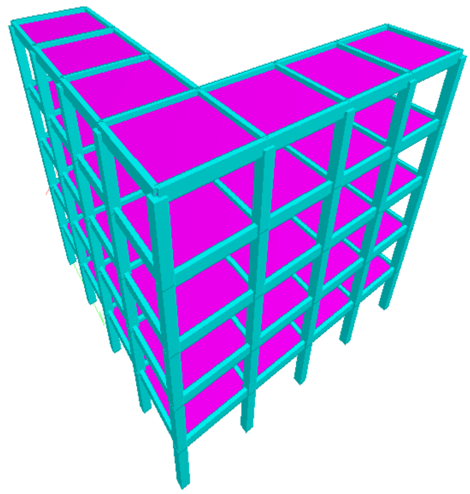
Objectives of the present work is to study the effect of slab stiffness on frame forces, nodal displacement and support reactions under gravity and seismic loads.

II. STRUCTURAL MODELLING AND ANALYSIS

The present study investigates the structural behaviour of a G+4 L shaped plan building frame with and without consideration of slab stiffness under the effect of gravity and seismic forces. The structure is analysed for seismic load in all directions but for the purpose of comparison results are considered only in one direction. STAAD Pro software is used for the purpose of modelling and analysis of building frames. The isometric view, plan and elevation of building frames are shown in figure 1 and 2.

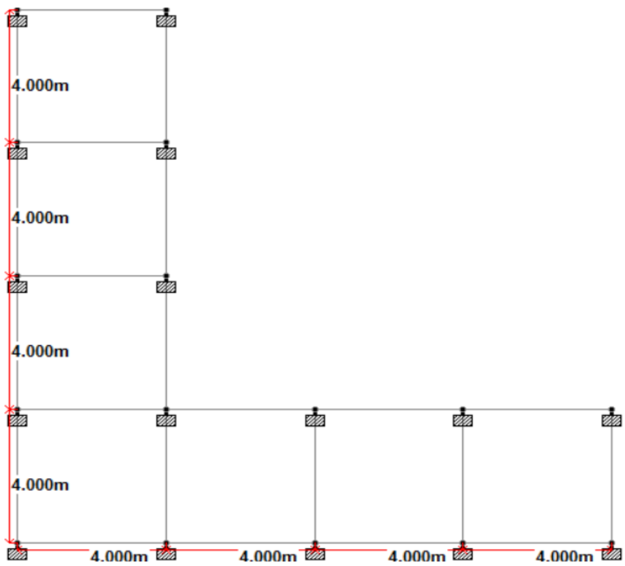


Frame without slab

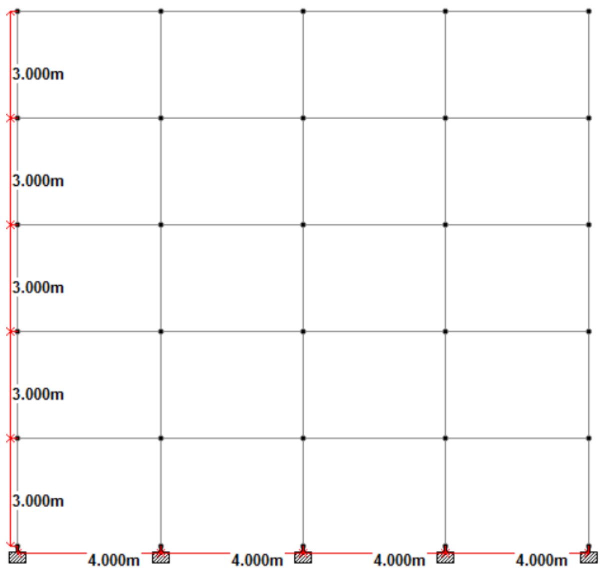


Frame with slab

Fig 1 Isometric view of L shaped building



Plan



Elevation

Fig 2 Plan and elevation of L shaped building

Following two cases are analysed and compared using STAAD Pro software to evaluate the effect of stiffness of slab for gravity and seismic loads.

Case I : L shaped building frame without consideration of slab stiffness

Case II : L shaped building frame with consideration of slab stiffness.

Geometric and material properties of the frame have been tabulated in table 1 and 2.

Table 1: Geometric properties

S.No.	Description	Values
1	Number of storey	Four
2	Number of bays	Four
3	Storey height	3 m
4	Bay width	4 m
5	Size of beam	200 x 500 mm
6	Size of column	450 x 450 mm
7	Thickness of R.C.C. slab	150 mm
8	Thickness of brick wall	230 mm

Table 2 : Material properties

S.No.	Material property	Values
1	Grade of concrete	M-25
2	Young's modulus of concrete, E_c	2.17×10^4 N/mm^2
3	Poisson ratio,	0.17

Live load of 3kN/m^2 is considered on each floor. The seismic parameters are shown in table 3.

Table 3: Seismic parameters

S.No.	Parameter	Value

1	Zone (V)	0.36
2	Damping ratio	0.05
3	Importance factor	1
4	Response Reduction Factor	5
5	Soil site factor	Medium

III. RESULTS AND DISCUSSIONS

In the present study, L shaped building frame is analysed with and without consideration of slab stiffness. Structural behaviour of the building frames have been compared under gravity and seismic loads in terms of displacement of roof nodes, support reactions, beam forces, column forces and reinforcement required.

3.1 Effect of slab stiffness on displacement of roof nodes

Plan of building frame with numbering of roof nodes is shown in the figure 3

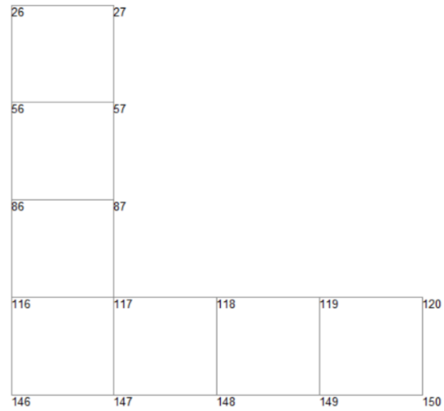


Fig 3 Numbering of roof nodes

3.1.1 Displacement of roof nodes for gravity load combination 1.5DL+1.5LL

Effect of slab stiffness on lateral Displacement and rotation of roof nodes for gravity load combination 1.5DL+1.5LL is depicted in table 4. The displacement and rotation of roof nodes are found to be negligible in both the cases.

Table 4 Comparison of displacement of roof nodes for gravity load combination 1.5DL+1.5LL

Node number	Without slab stiffness			With slab stiffness			Ratio		
	Ux_1 mm	Ry_1 rad	Rz_1 rad	Ux_2 mm	Ry_2 rad	Rz_2 rad	Ux_2/Ux_1	Ry_2/Ry_1	Rz_2/Rz_1
26	0.05	0	0	-0.09	0	0	-1.63	**	**
27	0.02	0	0	-0.09	0	0	-5.63	**	**
56	0.02	0	0	-0.09	0	0	-4.43	**	**
57	-0.03	0	0	-0.10	0	0	3.39	**	**
86	-0.02	0	0	-0.10	0	0	4.50	**	**
87	-0.07	0	0	-0.10	0	0	1.42	**	**
116	-0.14	0	0	-0.10	0	0	0.71	**	**
117	-0.20	0	0	-0.11	0	0	0.54	**	**
118	-0.24	0	0	-0.12	0	0	0.50	**	**
119	-0.27	0	0	-0.13	0	0	0.47	**	**
120	-0.31	0	0	-0.14	0	0	0.44	**	**
146	-0.01	0	0	-0.10	0	0	7.07	**	**
147	-0.05	0	0	-0.11	0	0	2.00	**	**
148	-0.09	0	0	-0.11	0	0	1.22	**	**
149	-0.13	0	0	-0.12	0	0	0.91	**	**
150	-0.17	0	0	-0.13	0	0	0.76	**	**

Note:

** indicates insignificant values

Ux indicates lateral displacement in x direction.

Ry and Rz indicates rotation about y and z direction respectively.

3.1.2 Displacement of roof nodes for seismic load combination 0.9DL+1.5EQ(+X).

Effect of slab stiffness on lateral Displacement and rotation of roof nodes, for seismic load combination 0.9DL+1.5EQ(+X) is depicted in table 5. Frame with consideration of slab stiffness provides a variation of 0.68 to 0.84 times in the Lateral displacement as compared to frame without consideration of slab stiffness. There is a considerable reduction in lateral displacement of roof nodes whereas rotation of the roof nodes either nullifies or reduces in most of the cases due to introduction of slab stiffness.

Table 5 Comparison of displacement of roof nodes for seismic load combination 0.9DL+1.5EQ(+X)

Node	Without slab stiffness			With slab stiffness			Ratio		
	Ux_1 mm	Ry_1 rad	Rz_1 rad	Ux_2 mm	Ry_2 rad	Rz_2 rad	Ux_2/Ux_1	Ry_2/Ry_1	Rz_2/Rz_1
26	39.59	0.001	-0.001	31.21	0	-0.001	0.79	0	1.00
27	39.58	0.001	-0.001	31.21	0	-0.001	0.79	0	1.00
56	44.32	0	-0.002	30.32	0	-0.001	0.68	**	0.50
57	44.30	0	-0.001	30.32	0	-0.001	0.68	**	1.00
86	43.32	-0.001	-0.002	29.41	0	-0.001	0.68	0	0.50
87	43.30	-0.001	-0.001	29.42	0	-0.001	0.68	0	1.00
116	36.14	-0.001	-0.001	28.52	0	-0.001	0.79	0	1.00
117	36.08	-0.001	-0.001	28.50	0	0	0.79	0	0
118	36.01	0	-0.001	28.46	0	0	0.79	**	0
119	35.97	0	-0.001	28.44	0	0	0.79	**	0
120	35.95	0	-0.001	28.44	0	-0.001	0.79	**	1.00
146	33.07	0	-0.001	27.65	0	-0.001	0.84	**	1.00
147	33.05	0	-0.001	27.65	0	0	0.84	**	0
148	33.02	0	-0.001	27.66	0	0	0.84	**	0
149	33.01	0	-0.001	27.67	0	0	0.84	**	0
150	33.00	0	-0.001	27.67	0	-0.001	0.84	**	1.00

3.1.3 Displacement of roof nodes for seismic load combination 1.5DL+1.5EQ(+X)

Effect of slab stiffness on lateral Displacement and rotation of roof nodes for seismic load combination 1.5DL+1.5EQ(+X) is depicted in table 6. Frame with consideration of slab stiffness provides a variation of 0.68 to 0.84 times in the Lateral displacement as compared to frame without consideration of slab stiffness. There is a considerable reduction in lateral displacement of roof nodes whereas rotation of the roof nodes either nullifies or reduces in most of the cases due to introduction of slab stiffness.

Table 6 Comparison of displacement of roof nodes for seismic load combination 1.5DL+1.5EQ(+X)

Node	Without slab stiffness			With slab stiffness			Ratio		
	Ux_1 mm	Ry_1 rad	Rz_1 rad	Ux_2 mm	Ry_2 rad	Rz_2 rad	Ux_2/Ux_1	Ry_2/Ry_1	Rz_2/Rz_1
26	39.61	0.001	-0.001	31.18	0	-0.001	0.79	0	1.00
27	39.58	0.001	-0.001	31.18	0	-0.001	0.79	0	1.00

56	44.32	0	-0.002	30.29	0	-0.001	0.68	**	0.50
57	44.29	0	-0.001	30.29	0	-0.001	0.68	**	1.00
86	43.31	-0.001	-0.002	29.38	0	-0.001	0.68	0	0.50
87	43.28	-0.001	-0.001	29.38	0	-0.001	0.68	0	1.00
116	36.09	-0.001	-0.001	28.48	0	-0.001	0.79	0	1.00
117	36.01	-0.001	-0.001	28.46	0	0	0.79	0	0
118	35.93	0	-0.001	28.42	0	0	0.79	**	0
119	35.88	0	-0.001	28.40	0	0	0.79	**	0
120	35.85	0	-0.001	28.40	0	0	0.79	**	0
146	33.07	0	-0.001	27.61	0	-0.001	0.84	**	1.00
147	33.03	0	-0.001	27.61	0	0	0.84	**	0
148	32.99	0	-0.001	27.62	0	0	0.84	**	0
149	32.96	0	-0.001	27.62	0	0	0.84	**	0
150	32.94	0	-0.001	27.62	0	0	0.84	**	0

3.1.4 Displacement of roof nodes for seismic load combination 1.2DL+1.2LL+1.2EQ(+X)

Effect of slab stiffness on lateral Displacement and rotation of roof nodes for seismic load combination 1.2DL+1.2LL+1.2EQ(+X) is depicted in table 7. Frame with consideration of slab stiffness provides a variation of 0.68 to 0.84 times in the Lateral displacement as compared to frame without consideration of slab stiffness. There is a considerable reduction in lateral displacement of roof nodes whereas rotation of the roof nodes either nullifies or reduces in most of the cases due to introduction of slab stiffness.

Table 7 Comparison of displacement of roof nodes for seismic load combination 1.2DL+1.2LL+1.2EQ(+X)

Node	Without slab stiffness			With slab stiffness			Ratio		
	Ux_1 mm	Ry_1 rad	Rz_1 rad	Ux_2 mm	Ry_2 rad	Rz_2 rad	Ux_2/Ux_1	Ry_2/Ry_1	$Rz_2/Rz1$
26	31.70	0	-0.001	24.93	0	-0.001	0.79	**	1.00
27	31.67	0	-0.001	24.93	0	-0.001	0.79	**	1.00
56	35.46	0	-0.001	24.22	0	-0.001	0.68	**	1.00
57	35.43	0	-0.001	24.22	0	0	0.68	**	0
86	34.65	-0.001	-0.001	23.49	0	-0.001	0.68	0	1.00
87	34.61	-0.001	-0.001	23.49	0	0	0.68	0	0
116	28.85	-0.001	-0.001	22.77	0	-0.001	0.79	0	1.00
117	28.78	-0.001	0	22.76	0	0	0.79	0	**
118	28.71	0.	-0.001	22.72	0	0	0.79	**	0
119	28.66	0	-0.001	22.70	0	0	0.79	**	0
120	28.63	0	0	22.70	0	0	0.79	**	**
146	26.45	0	-0.001	22.08	0	-0.001	0.83	**	1.00
147	26.42	0	-0.001	22.08	0	0	0.84	**	0
148	26.38	0	0	22.08	0	0	0.84	**	**
149	26.35	0	0	22.08	0	0	0.84	**	**
150	26.33	0	0	22.08	0	0	0.84	**	**

3.2 Effect of slab stiffness on support reactions

Supports of the building frame with numbering of supports is shown in the figure 4

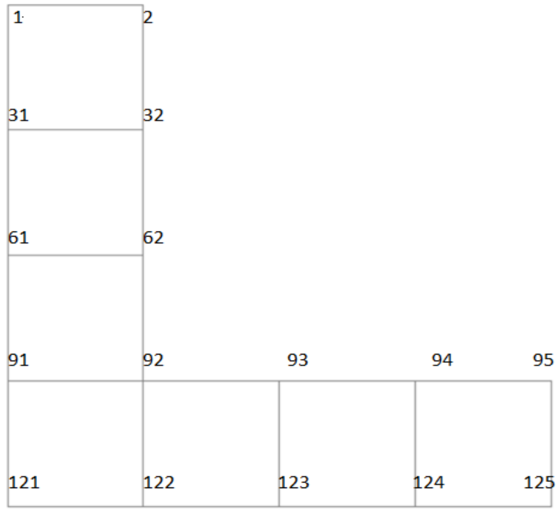


Fig 4 Node numbering at supports

3.2.1 Support reactions for gravity load combination 1.5DL+1.5LL

Effect of slab stiffness on vertical Support reactions, torsional moment and bending moment at supports for gravity load combination 1.5DL+1.5LL is depicted in table 8. Frame with consideration of slab stiffness provides a variation of 0.98 to 1.02 times in vertical support reactions as compared to frame without consideration of slab stiffness however Effect of slab stiffness on vertical support reactions is found to be insignificant.

Change in torsional moment and bending moment at support due to introduction of slab is found to be insignificant for given load case.

Table 8 Comparison of Support reactions for gravity load combination 1.5DL+1.5LL

Node	Without slab stiffness			With slab stiffness			Ratio		
	Fy_1 kN	My_1 kNm	Mz_1 kNm	Fy_2 kN	My_2 kNm	Mz_2 kNm	Fy_2/Fy_1	My_2/My_1	Mz_2/Mz_1
1	688.61	0.01	-7.79	694.69	0.00	-6.16	1.01	0.07	0.79
2	688.02	0.01	8.06	692.82	-0.02	5.62	1.01	-1.50	0.70
31	1065.15	0.02	-10.99	1060.46	0.00	-7.31	1.00	-0.13	0.67
32	1064.41	0.02	10.92	1057.60	-0.01	6.80	0.99	-0.58	0.62
61	1074.13	0.02	-11.33	1077.39	-0.01	-7.30	1.00	-0.40	0.64
62	1085.03	0.02	10.57	1088.29	-0.01	6.78	1.00	-0.32	0.64
91	1071.75	0.00	-11.51	1071.37	-0.01	-7.37	1.00	-2.25	0.64
92	1421.84	0.00	2.78	1399.03	0.00	1.22	0.98	**	0.44
93	1085.03	-0.02	0.44	1088.29	0.01	0.31	1.00	-0.32	0.71
94	1064.41	-0.02	0.60	1057.60	0.01	0.20	0.99	-0.58	0.34
95	688.02	-0.01	8.66	692.82	0.02	6.14	1.01	-1.50	0.71
121	696.45	0.00	-8.87	708.23	0.00	-6.26	1.02	**	0.71
122	1071.75	0.00	-0.78	1071.37	0.01	-0.34	1.00	-2.25	0.44
123	1074.13	-0.02	-0.31	1077.39	0.01	-0.09	1.00	-0.40	0.29
124	1065.15	-0.02	0.17	1060.46	0.00	0.18	1.00	-0.13	1.00
125	688.61	-0.01	8.28	694.69	0.00	6.13	1.01	0.07	0.74

Note:
** indicates insignificant values
Fy indicates force in y direction.
My and Mz indicates torsional and bending moment respectively.

3.2.2 Support reactions for seismic load combination 0.9DL+1.5EQ(+X)

Effect of slab stiffness on vertical Support reactions, torsional moment and bending moment at supports for seismic load combination 0.9DL+1.5EQ(+X) is depicted in table 9. Frame with consideration of slab stiffness provides a variation of 0.81 to 1.42 times in vertical support reactions as compared to frame without consideration of slab stiffness. Effect of slab stiffness on vertical support reactions is found to be insignificant.

A variation of -0.27 to 0.65 times in torsional moment and a variation of 0.86 to 0.95 times in bending moment is found at supports due to introduction of slab. Torsional and bending moments are reduced significantly although in some cases reversal of sign can be observed.

Table 9 Comparison of Support reactions for seismic load combination 0.9DL+1.5EQ(+X)

Node	Without slab stiffness			With slab stiffness			Ratio		
	Fy_1 kN	My_1 kNm	Mz_1 kNm	Fy_2 kN	My_2 kNm	Mz_2 kNm	Fy_2/Fy_1	My_2/My_1	Mz_2/Mz_1
1	40.75	-1.59	154.09	57.70	0.27	141.57	1.42	-0.17	0.92
2	682.15	-1.58	161.88	676.91	0.25	147.10	0.99	-0.16	0.91
31	175.54	-1.05	169.01	163.31	0.29	148.47	0.93	-0.27	0.88
32	888.94	-1.09	178.77	895.11	0.28	153.80	1.01	-0.25	0.86
61	188.37	1.62	166.95	189.24	0.31	148.72	1.00	0.19	0.89
62	878.13	1.76	176.89	885.76	0.34	154.18	1.01	0.19	0.87
91	257.95	2.31	159.14	210.00	0.40	147.19	0.81	0.17	0.92
92	723.70	1.56	187.72	764.97	0.44	169.75	1.06	0.28	0.90
93	541.37	0.78	186.45	534.24	0.50	164.65	0.99	0.65	0.88
94	513.37	1.09	187.27	494.38	0.55	166.31	0.96	0.50	0.89
95	620.52	1.69	168.59	608.35	0.40	147.53	0.98	0.24	0.88
121	104.96	1.20	147.43	96.82	0.56	140.01	0.92	0.47	0.95
122	545.28	0.84	172.37	546.15	0.41	163.47	1.00	0.49	0.95
123	537.59	1.01	171.83	543.96	0.47	161.95	1.01	0.47	0.94
124	523.33	1.04	172.79	530.40	0.48	163.32	1.01	0.46	0.95
125	621.53	1.70	155.81	646.21	0.64	145.24	1.04	0.37	0.93

3.2.3 Support reactions for seismic load combination 1.5DL+1.5EQ(+X)

Effect of slab stiffness on vertical Support reactions, torsional moment and bending moment at supports for seismic load combination 1.5DL+1.5EQ(+X) is depicted in table 10. Frame with consideration of slab stiffness provides a variation of 0.92 to 1.07 times in vertical support reactions as compared to frame without consideration of slab stiffness. Effect of slab stiffness on vertical support reactions is found to be insignificant.

A variation of -0.28 to 0.66 times in torsional moment and a variation of 0.85 to 0.96 times in bending moment is found at supports due to introduction of slab. Torsional and bending moments at supports are reduced significantly although in some cases reversal of sign can be observed.

Table 10 Comparison of Support reactions for seismic load combination 1.5DL+1.5EQ(+X)

Node	Without slab stiffness			With slab stiffness			Ratio		
	Fy_1 kN	My_1 kNm	Mz_1 kNm	Fy_2 kN	My_2 kNm	Mz_2 kNm	Fy_2/Fy_1	My_2/My_1	Mz_2/Mz_1
1	279.55	-1.58	151.54	298.52	0.27	139.66	1.07	-0.17	0.92
2	920.76	-1.58	164.52	917.08	0.25	148.82	1.00	-0.16	0.90
31	530.41	-1.04	165.75	516.64	0.29	146.61	0.97	-0.28	0.88
32	1243.57	-1.08	182.01	1247.47	0.27	155.49	1.00	-0.25	0.85
61	545.76	1.63	163.57	547.79	0.31	146.85	1.00	0.19	0.90
62	1239.17	1.77	180.01	1247.96	0.34	155.86	1.01	0.19	0.87
91	614.68	2.31	155.71	566.60	0.39	145.31	0.92	0.17	0.93
92	1187.51	1.56	188.33	1220.88	0.44	169.78	1.03	0.28	0.90
93	902.41	0.77	186.59	896.43	0.51	164.76	0.99	0.66	0.88
94	868.00	1.09	187.44	846.75	0.56	166.36	0.98	0.51	0.89
95	859.13	1.68	171.40	848.53	0.41	149.40	0.99	0.24	0.87
121	346.00	1.20	144.53	341.80	0.56	138.08	0.99	0.47	0.96
122	902.01	0.84	172.12	902.76	0.42	163.36	1.00	0.50	0.95
123	894.99	1.00	171.73	902.51	0.47	161.91	1.01	0.47	0.94
124	878.19	1.03	172.83	883.74	0.48	163.36	1.01	0.46	0.95
125	860.34	1.70	158.51	887.03	0.64	147.11	1.03	0.37	0.93

3.2.4 Support reactions for seismic load combination 1.2DL+1.2LL+1.2EQ(+X)

Effect of slab stiffness on vertical Support reactions, torsional moment and bending moment at supports for seismic load combination 1.2DL+1.2LL+1.2EQ(+X) is depicted in table 11. Frame with consideration of slab stiffness provides a variation of 0.94 to 1.05 times in vertical support reactions as compared to frame without consideration of slab stiffness. Effect of slab stiffness on vertical support reactions is found to be insignificant.

A variation of -0.28 to 0.66 times in torsional moment and a variation of 0.86 to 0.96 times in bending moment is found at supports due to introduction of slab. Torsional and bending moments at supports are reduced significantly although in some cases reversal of sign can be observed.

Table 11 Comparison of support reactions for seismic load combination 1.2DL+1.2LL+1.2EQ(+X)

Node	Without slab stiffness			With slab stiffness			Ratio		
	Fy_1 kN	My_1 kNm	Mz_1 kNm	Fy_2 kN	My_2 kNm	Mz_2 kNm	Fy_2/Fy_1	My_2/My_1	Mz_2/Mz_1
1	296.92	-1.27	120.10	312.92	0.21	110.61	1.05	-0.17	0.92
2	809.81	-1.26	132.78	807.57	0.20	120.11	1.00	-0.16	0.90
31	566.72	-0.83	130.33	555.01	0.23	115.17	0.98	-0.28	0.88
32	1137.13	-0.86	147.86	1139.32	0.22	126.45	1.00	-0.25	0.86
61	581.12	1.30	128.55	583.05	0.25	115.37	1.00	0.19	0.90
62	1137.28	1.42	146.22	1144.61	0.27	126.76	1.01	0.19	0.87
91	635.69	1.85	122.22	597.16	0.31	114.11	0.94	0.17	0.93
92	1159.85	1.25	151.66	1184.11	0.35	136.74	1.02	0.28	0.90
93	867.88	0.61	149.35	863.39	0.41	131.84	0.99	0.66	0.88
94	836.67	0.87	150.10	818.74	0.45	133.16	0.98	0.51	0.89

95	760.50	1.35	138.42	752.72	0.33	120.68	0.99	0.24	0.87
121	351.88	0.96	114.32	350.07	0.45	109.32	0.99	0.47	0.96
122	865.55	0.67	137.57	866.09	0.33	130.64	1.00	0.50	0.95
123	860.50	0.80	137.35	866.83	0.38	129.53	1.01	0.48	0.94
124	844.94	0.82	138.33	848.68	0.38	130.76	1.00	0.47	0.95
125	761.55	1.36	128.03	783.73	0.51	118.84	1.03	0.37	0.93

3.3 Beam forces in the section

Building frames with and without consideration of slab stiffness has been analyzed for beam forces at section X-X. Section X-X and numbering of beam and columns are shown in the figure 5.

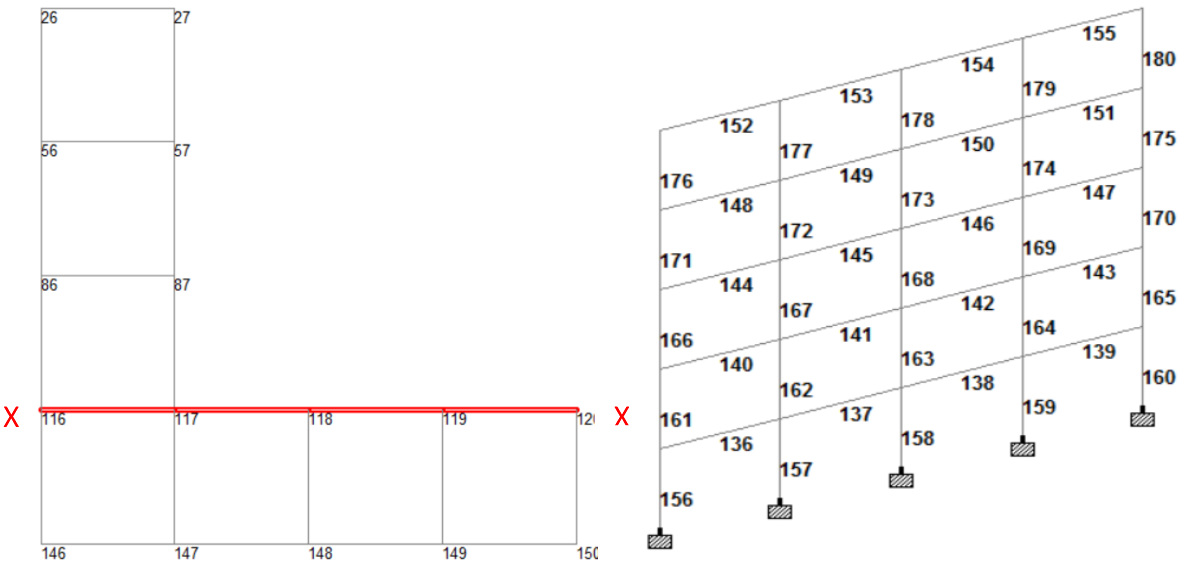


Fig 5 Beams and column numbering at section X-X

3.3.1 Beam forces in the section for gravity load combination 1.5DL+1.5LL

Effect of slab stiffness on shear force and bending moment for gravity load combination 1.5DL+1.5LL is depicted in table 12. Frame with consideration of slab stiffness provides a variation of 0.71 to 0.84 times in shear force as compared to frame without consideration of slab stiffness whereas a variation of 0.67 to 0.86 times is observed in bending moment due to introduction of slab element in the frame. Reduction in shear force and bending moment in the beams due to introduction of slab can be clearly observed.

Table 12 Comparison of beam forces for gravity load combination 1.5DL+1.5LL

Beam	Node	Without slab stiffness		With slab stiffness		Ratio	
		Fy_1 kN	Mz_1 kNm	Fy_2 kN	Mz_2 kNm	Fy_2/Fy_1	Mz_2/Mz_1
136	96	76.67	53.43	55.96	37.98	0.73	0.71
136	97	77.97	-56.03	56.28	-38.61	0.72	0.69
137	97	57.14	41.32	46.11	31.18	0.81	0.75
137	98	58.30	-43.64	48.13	-35.20	0.83	0.81
138	98	57.77	41.95	47.20	33.15	0.82	0.79
138	99	57.67	-41.74	47.04	-32.82	0.82	0.79
139	99	58.43	41.29	47.36	31.95	0.81	0.77
139	100	57.01	-38.46	46.88	-30.98	0.82	0.81
140	101	78.63	57.92	57.49	41.39	0.73	0.71

140	102	76.02	-52.71	54.75	-35.92	0.72	0.68
141	102	55.76	38.24	44.80	28.28	0.80	0.74
141	103	59.68	-46.08	49.44	-37.56	0.83	0.82
142	103	58.27	42.88	47.51	33.70	0.82	0.79
142	104	57.18	-40.70	46.73	-32.14	0.82	0.79
143	104	56.96	38.71	45.94	29.38	0.81	0.76
143	105	58.48	-41.74	48.30	-34.10	0.83	0.82
144	106	79.88	60.15	58.30	42.79	0.73	0.71
144	107	74.77	-49.94	53.94	-34.07	0.72	0.68
145	107	55.14	37.04	44.03	26.69	0.80	0.72
145	108	60.31	-47.39	50.21	-39.06	0.83	0.82
146	108	58.45	43.29	47.62	33.92	0.81	0.78
146	109	56.99	-40.39	46.62	-31.93	0.82	0.79
147	109	56.12	36.89	45.18	27.72	0.81	0.75
147	110	59.33	-43.30	49.06	-35.48	0.83	0.82
148	111	80.99	63.14	59.27	45.24	0.73	0.72
148	112	73.65	-48.46	52.96	-32.62	0.72	0.67
149	112	54.21	34.84	43.26	24.95	0.80	0.72
149	113	61.23	-48.88	50.98	-40.39	0.83	0.83
150	113	58.89	44.02	47.81	34.21	0.81	0.78
150	114	56.56	-39.37	46.43	-31.45	0.82	0.80
151	114	55.38	35.84	44.28	26.30	0.80	0.73
151	115	60.07	-45.22	49.95	-37.64	0.83	0.83
152	116	77.45	51.42	57.17	38.38	0.74	0.75
152	117	77.19	-50.90	55.07	-34.17	0.71	0.67
153	117	55.38	38.00	43.88	26.47	0.79	0.70
153	118	60.06	-47.37	50.35	-39.41	0.84	0.83
154	118	58.91	44.29	48.02	34.86	0.82	0.79
154	119	56.53	-39.54	46.22	-31.26	0.82	0.79
155	119	58.60	39.56	46.57	28.94	0.79	0.73
155	120	56.84	-36.03	47.67	-31.13	0.84	0.86

Note:

** indicates insignificant values

Fy and Mz indicates shear force and bending moment in the beam respectively.

3.3.2 Beam forces in the section for seismic load combination 0.9DL+1.5EQ(+X)

Effect of slab stiffness on shear force and bending moment for seismic load combination 0.9DL+1.5EQ(+X) is depicted in table 13. Frame with consideration of slab stiffness provides a variation of 0.54 to 1.14 times in shear force as compared to frame without consideration of slab stiffness. There is a significant reduction in shear forces due to introduction of slab although in some cases this ratio is greater than 1 due to comparatively insignificant values of shear force in beams 153,154 and 155.

The variation of 0.52 to 0.74 times is found in the bending moment due to frame with consideration of slab stiffness compared to frame without consideration of slab stiffness. Bending moment in the beams are reduced significantly due to introduction of slab.

Table 13 Comparison of beam forces for seismic load combination 0.9DL+1.5EQ(+X)

Beam	Node	Without slab stiffness		With slab stiffness		Ratio	
		Fy_1 kN	Mz_1 kNm	Fy_2 kN	Mz_2 kNm	Fy_2/Fy_1	Mz_2/Mz_1
136	96	-31.89	-115.92	-21.38	-78.82	0.67	0.68
136	97	103.07	-154.00	67.12	-98.19	0.65	0.64
137	97	-32.67	-102.80	-19.77	-68.62	0.61	0.67
137	98	91.13	-144.81	65.51	-101.94	0.72	0.70
138	98	-32.11	-102.37	-20.21	-71.28	0.63	0.70
138	99	90.57	-143.00	65.95	-101.03	0.73	0.71
139	99	-37.45	-108.33	-25.46	-76.79	0.68	0.71
139	100	95.91	-158.39	71.20	-116.52	0.74	0.74
140	101	-37.43	-126.64	-23.77	-83.31	0.63	0.66
140	102	108.62	-165.47	69.51	-103.23	0.64	0.62
141	102	-41.01	-119.83	-25.19	-79.89	0.61	0.67
141	103	99.48	-161.15	70.94	-112.36	0.71	0.70
142	103	-39.51	-117.03	-24.55	-79.75	0.62	0.68
142	104	97.98	-157.95	70.29	-109.92	0.72	0.70
143	104	-44.55	-122.53	-29.25	-84.55	0.66	0.69
143	105	103.02	-172.61	74.99	-123.92	0.73	0.72
144	106	-28.01	-107.43	-17.31	-70.15	0.62	0.65
144	107	99.20	-146.98	63.06	-90.60	0.64	0.62
145	107	-33.97	-105.77	-20.92	-71.60	0.62	0.68
145	108	92.44	-147.04	66.66	-103.56	0.72	0.70
146	108	-32.04	-102.02	-19.50	-69.58	0.61	0.68
146	109	90.51	-143.07	65.25	-99.92	0.72	0.70
147	109	-36.12	-106.21	-23.37	-73.25	0.65	0.69
147	110	94.58	-155.19	69.11	-111.70	0.73	0.72
148	111	-8.92	-67.36	-4.77	-43.61	0.54	0.65
148	112	80.11	-110.69	50.52	-66.96	0.63	0.60
149	112	-18.32	-74.77	-10.91	-52.11	0.60	0.70
149	113	76.79	-115.45	56.65	-83.00	0.74	0.72
150	113	-15.75	-69.38	-8.59	-47.63	0.55	0.69
150	114	74.22	-110.57	54.33	-78.22	0.73	0.71
151	114	-17.92	-71.19	-10.75	-49.27	0.60	0.69
151	115	76.39	-117.42	56.49	-85.21	0.74	0.73
152	116	12.22	-27.13	10.37	-14.02	0.85	0.52
152	117	58.97	-66.35	35.38	-36.01	0.60	0.54
153	117	5.00	-27.96	5.46	-19.91	1.09	0.71
153	118	53.47	-68.98	40.29	-49.75	0.75	0.72
154	118	7.16	-23.31	8.17	-13.75	1.14	0.59

154	119	51.30	-64.97	37.57	-45.05	0.73	0.69
155	119	6.48	-23.68	7.20	-14.58	1.11	0.62
155	120	51.98	-67.31	38.54	-48.10	0.74	0.71

3.3.3 Beam forces in the section for seismic load combination 1.5DL+1.5EQ(+X)

Effect of slab stiffness on shear force and bending moment for seismic load combination 1.5DL+1.5EQ(+X) is depicted in table 14. Frame with consideration of slab stiffness provides a variation of 0.33 to 1.67 times in shear force as compared to frame without consideration of slab stiffness. There is a significant reduction in shear force due to introduction of slab although in one case this ratio is greater than 1 due to insignificant value of shear force in beam number 150.

The variation of 0.34 to 0.77 times is found in the bending moment due to frame with consideration of slab stiffness compared to frame without consideration of slab stiffness. There is considerable reduction in bending moment values due to introduction of slab.

Table 14 Comparison of beam forces for seismic load combination 1.5DL+1.5EQ(+X)

Beam	Node	Without slab stiffness		With slab stiffness		Ratio	
		Fy_1 kN	Mz_1 kNm	Fy_2 kN	Mz_2 kNm	Fy_2/Fy_1	Mz_2/Mz_1
136	96	-8.39	-100.10	-6.17	-69.20	0.74	0.69
136	97	127.04	-170.75	82.40	-107.94	0.65	0.63
137	97	-13.42	-89.42	-4.93	-59.28	0.37	0.66
137	98	110.87	-159.15	81.17	-112.91	0.73	0.71
138	98	-12.60	-88.59	-4.93	-61.03	0.39	0.69
138	99	110.04	-156.69	81.16	-111.16	0.74	0.71
139	99	-17.69	-94.71	-10.13	-66.92	0.57	0.71
139	100	115.13	-170.93	86.37	-126.08	0.75	0.74
140	101	-13.33	-109.45	-8.09	-72.70	0.61	0.66
140	102	131.98	-181.18	84.33	-112.15	0.64	0.62
141	102	-22.17	-107.36	-10.73	-71.37	0.48	0.66
141	103	119.62	-176.23	86.97	-124.03	0.73	0.70
142	103	-19.85	-102.96	-9.17	-69.33	0.46	0.67
142	104	117.29	-171.32	85.41	-119.84	0.73	0.70
143	104	-25.25	-109.71	-14.36	-75.47	0.57	0.69
143	105	122.69	-186.18	90.60	-134.44	0.74	0.72
144	106	-3.52	-89.55	-1.39	-59.09	0.40	0.66
144	107	122.17	-161.84	77.63	-98.96	0.64	0.61
145	107	-15.33	-93.67	-6.69	-63.58	0.44	0.68
145	108	112.77	-162.52	82.93	-115.67	0.74	0.71
146	108	-12.32	-87.83	-4.10	-59.09	0.33	0.67
146	109	109.76	-156.34	80.34	-109.78	0.73	0.70
147	109	-17.08	-93.95	-8.71	-64.68	0.51	0.69
147	110	114.52	-169.24	84.95	-122.65	0.74	0.72
148	111	15.91	-48.57	11.44	-31.87	0.72	0.66

148	112	102.73	-125.07	64.80	-74.87	0.63	0.60
149	112	0.06	-63.30	3.10	-44.56	**	0.70
149	113	97.39	-131.37	73.13	-95.50	0.75	0.73
150	113	4.11	-54.96	6.87	-37.06	1.67	0.67
150	114	93.34	-123.51	69.37	-87.93	0.74	0.71
151	114	0.89	-59.24	3.64	-41.13	**	0.69
151	115	96.55	-132.07	72.60	-96.81	0.75	0.73
152	116	35.95	-11.89	25.97	-4.10	0.72	0.34
152	117	82.70	-81.61	50.26	-44.48	0.61	0.54
153	117	23.67	-15.70	19.58	-12.15	0.83	0.77
153	118	73.77	-84.49	56.66	-62.03	0.77	0.73
154	118	27.03	-8.79	23.71	-2.94	0.88	0.34
154	119	70.41	-77.98	52.53	-54.69	0.75	0.70
155	119	26.34	-10.55	22.28	-5.65	0.85	0.54
155	120	71.10	-78.98	53.96	-57.72	0.76	0.73

3.3.4 Beam forces in the section for seismic load combination 1.2DL+1.2LL+1.2EQ(+X)

Effect of slab stiffness on shear force and bending moment for seismic load combination 1.2DL+1.2LL+1.2EQ(+X) is depicted in table 15. Frame with consideration of slab stiffness provides a variation of -1.58 to 2.03 times in shear force as compared to frame without consideration of slab stiffness. In most of the cases there is a significant reduction in shear force due to introduction of slab.

The variation of 0.49 to 0.76 times is found in the bending moment due to frame with consideration of slab stiffness compared to frame without consideration of slab stiffness. There is considerable reduction in bending moment values due to introduction of slab.

Table 15 Comparison of beam forces for seismic load combination 1.2DL+1.2LL+1.2EQ(+X)

Beam	Node	Without slab stiffness		With slab stiffness		Ratio	
		Fy_1 kN	Mz_1 kNm	Fy_2 kN	Mz_2 kNm	Fy_2/Fy_1	Mz_2/Mz_1
136	96	7.64	-68.97	9.41	-44.22	1.23	0.64
136	97	116.08	-147.92	80.39	-97.74	0.69	0.66
137	97	-3.52	-65.24	3.27	-41.17	-0.93	0.63
137	98	95.87	-133.54	72.13	-96.55	0.75	0.72
138	98	-2.88	-64.87	3.26	-42.82	-1.13	0.66
138	99	95.24	-131.37	72.13	-94.93	0.76	0.72
139	99	-6.93	-69.98	-0.86	-47.71	0.12	0.68
139	100	99.28	-142.43	76.25	-106.52	0.77	0.75
140	101	4.03	-75.61	8.17	-46.28	2.03	0.61
140	102	119.69	-155.70	81.62	-100.63	0.68	0.65
141	102	-10.81	-80.24	-1.67	-51.52	0.15	0.64
141	103	103.16	-147.69	77.06	-105.95	0.75	0.72
142	103	-8.59	-76.20	-0.08	-49.34	0.01	0.65
142	104	100.95	-142.89	75.47	-101.74	0.75	0.71
143	104	-13.23	-82.45	-4.52	-55.04	0.34	0.67

143	105	105.59	-155.20	79.90	-113.80	0.76	0.73
144	106	12.11	-59.28	13.68	-35.16	1.13	0.59
144	107	111.60	-139.70	76.11	-89.70	0.68	0.64
145	107	-5.44	-69.51	1.42	-45.56	-0.26	0.66
145	108	97.80	-136.97	73.97	-99.55	0.76	0.73
146	108	-2.54	-64.02	4.01	-41.10	-1.58	0.64
146	109	94.89	-130.85	71.38	-93.65	0.75	0.72
147	109	-6.85	-70.17	-0.14	-46.70	0.02	0.67
147	110	99.20	-141.93	75.52	-104.62	0.76	0.74
148	111	27.87	-25.92	24.15	-12.80	0.87	0.49
148	112	95.85	-110.06	65.64	-70.18	0.68	0.64
149	112	6.66	-45.70	9.07	-30.79	1.36	0.67
149	113	85.69	-112.37	66.32	-83.71	0.77	0.74
150	113	10.67	-37.59	12.82	-23.41	1.20	0.62
150	114	81.68	-104.42	62.57	-76.09	0.77	0.73
151	114	7.39	-42.62	9.57	-28.15	1.29	0.66
151	115	84.97	-112.54	65.82	-84.36	0.77	0.75
152	116	43.27	1.14	35.30	7.59	0.82	**
152	117	80.45	-75.49	54.49	-45.98	0.68	0.61
153	117	25.89	-6.67	22.53	-4.07	0.87	0.61
153	118	66.46	-74.47	52.86	-56.59	0.80	0.76
154	118	29.02	-0.64	26.31	3.93	0.91	**
154	119	63.34	-67.99	49.08	-49.46	0.77	0.73
155	119	28.24	-3.07	24.93	0.78	0.88	**
155	120	64.11	-68.67	50.46	-51.84	0.79	0.75

3.4 Column forces in the section

Building frames with and without consideration of slab stiffness has been analyzed for column forces at section X-X. Section X-X and numbering of beam and columns are shown in the figure 5.

3.4.1 Column forces in the section for seismic load combination 1.5DL+1.5LL

Effect of slab stiffness on axial force, torsional and bending moment of column for gravity load combination 1.5DL+1.5LL is depicted in table 16. Frame with consideration of slab stiffness provides a variation of 0.98 to 1.01 times in axial forces of column compared to frame without consideration of slab stiffness. There is no significant change in axial force of columns for the given loading whereas Torsional and bending moment in columns are negligible and the change is insignificant due to introduction of slab.

Table 16 Comparison of column forces for gravity load combination 1.5DL+1.5LL

Column number	Node	Without slab stiffness			With slab stiffness			Ratio		
		Fx_1 kN	Mx_1 kNm	Mz_1 kNm	Fx_2 kN	Mx_2 kNm	Mz_2 kNm	Fx_2/Fx_1	Mx_2/Mx_1	Mz_2/Mz_1
156	91	1071.75	0.00	-11.51	1071.37	-0.01	-7.37	1.00	-2.25	0.64
156	96	-1050.28	0.00	-22.90	-1049.90	0.01	-15.05	1.00	-2.25	0.66

157	92	1421.84	0.00	2.78	1399.03	0.00	1.22	0.98	**	0.44
157	97	-1400.37	0.00	6.28	-1377.56	0.00	2.89	0.98	**	0.46
158	93	1085.03	-0.02	0.44	1088.29	0.01	0.31	1.00	-0.32	0.71
158	98	-1063.56	0.02	0.86	-1066.82	-0.01	0.83	1.00	-0.32	0.97
159	94	1064.41	-0.02	0.60	1057.60	0.01	0.20	0.99	-0.58	0.34
159	99	-1042.94	0.02	0.69	-1036.13	-0.01	0.46	0.99	-0.58	0.66
160	95	688.02	-0.01	8.66	692.82	0.02	6.14	1.01	-1.50	0.71
160	100	-666.55	0.01	17.07	-671.35	-0.02	12.78	1.01	-1.50	0.75
161	96	857.51	0.01	-30.39	857.13	0.00	-21.38	1.00	0.18	0.70
161	101	-836.04	-0.01	-28.44	-835.66	0.00	-20.41	1.00	0.18	0.72
162	97	1130.14	0.00	8.66	1109.24	0.00	3.55	0.98	**	0.41
162	102	-1108.67	0.00	8.05	-1087.77	0.00	2.96	0.98	**	0.37
163	98	870.32	-0.05	0.82	873.02	0.00	1.28	1.00	-0.02	1.56
163	103	-848.85	0.05	1.62	-851.54	0.00	1.86	1.00	-0.02	1.15
164	99	849.53	-0.04	-0.23	843.37	0.00	0.72	0.99	-0.02	-3.09
164	104	-828.06	0.04	0.82	-821.90	0.00	1.58	0.99	-0.02	1.93
165	100	551.75	-0.04	21.39	556.32	0.00	17.57	1.01	-0.07	0.82
165	105	-530.28	0.04	20.90	-534.85	0.00	17.22	1.01	-0.07	0.82
166	101	643.23	0.05	-29.34	642.87	0.00	-20.82	1.00	0.04	0.71
166	106	-621.76	-0.05	-29.74	-621.40	0.00	-21.64	1.00	0.04	0.73
167	102	845.11	0.00	6.56	828.00	0.00	2.07	0.98	**	0.31
167	107	-823.64	0.00	7.35	-806.53	0.00	2.24	0.98	**	0.30
168	103	653.81	-0.12	1.55	655.92	0.00	2.28	1.00	0.02	1.47
168	108	-632.34	0.12	2.09	-634.45	0.00	2.67	1.00	0.02	1.28
169	104	636.61	-0.06	1.17	631.59	0.00	2.29	0.99	0.06	1.97
169	109	-615.13	0.06	1.47	-610.12	0.00	2.64	0.99	0.06	1.80
170	105	414.00	-0.08	20.83	417.90	-0.01	17.45	1.01	0.08	0.84
170	110	-392.53	0.08	21.71	-396.43	0.01	18.40	1.01	0.08	0.85
171	106	428.75	0.08	-30.31	428.54	0.00	-21.50	1.00	0.00	0.71
171	111	-407.28	-0.08	-28.08	-407.07	0.00	-19.97	1.00	0.00	0.71
172	107	563.82	0.00	5.66	551.45	0.00	1.35	0.98	**	0.24
172	112	-542.35	0.00	4.56	-529.98	0.00	0.71	0.98	**	0.15
173	108	436.50	-0.18	1.94	437.98	-0.01	2.85	1.00	0.04	1.47
173	113	-415.03	0.18	2.38	-416.51	0.01	3.07	1.00	0.04	1.29
174	109	424.69	-0.07	2.01	421.10	-0.01	3.26	0.99	0.18	1.62
174	114	-403.22	0.07	3.10	-399.63	0.01	3.91	0.99	0.18	1.26
175	110	275.40	-0.11	21.57	278.44	-0.02	18.22	1.01	0.14	0.84
175	115	-253.93	0.11	20.74	-256.97	0.02	17.26	1.01	0.14	0.83
176	111	214.35	0.05	-34.98	214.23	0.04	-26.70	1.00	0.83	0.76
176	116	-192.88	-0.05	-51.13	-192.76	-0.04	-36.26	1.00	0.83	0.71
177	112	286.62	0.00	9.08	280.21	0.00	2.26	0.98	**	0.25
177	117	-265.15	0.00	13.24	-258.74	0.00	4.32	0.98	**	0.33
178	113	217.77	-0.12	2.40	218.92	-0.03	3.63	1.01	0.24	1.51
178	118	-196.30	0.12	2.96	-197.45	0.03	4.51	1.01	0.24	1.52
179	114	213.95	-0.07	0.39	212.08	-0.04	3.34	0.99	0.61	8.58
179	119	-192.48	0.07	-0.03	-190.61	0.04	3.21	0.99	0.61	-94.50
180	115	136.07	-0.10	24.44	137.70	-0.06	22.35	1.01	0.62	0.91
180	120	-114.60	0.10	35.99	-116.22	0.06	30.69	1.01	0.62	0.85

Note:
** indicates insignificant values
Fx indicates axial force in the column.
Mx and Mz indicates torsional and bending moment respectively.

3.4.2 Column forces in the section for seismic load combination 0.9DL+1.5EQ(+X)

Effect of slab stiffness on axial force, torsional and bending moment of column for seismic load combination 0.9DL+1.5EQ(+X) is depicted in table 17. Frame with consideration of slab stiffness provides a variation of 0.80 to 1.06 times in axial force of columns compared to frame without consideration of slab stiffness. The slab stiffness causes redistribution of axial force and bending moment in columns.

There is a variation of 0.17 to 1.02 times in torsional moment due to frame with consideration of slab stiffness compared to frame without consideration of slab stiffness. There is considerable reduction in torsional moment due to introduction of slab except in column number 173 where ratio appears to be greater than one.

Table 17 Comparison of column forces for seismic load combination 0.9DL+1.5EQ(+X)

Column number	Node	Without slab stiffness			With slab stiffness			Ratio		
		Fx_1 kN	Mx_1 kNm	Mz_1 kNm	Fx_2 kN	Mx_2 kNm	Mz_2 kNm	Fx_2/Fx_1	Mx_2/Mx_1	Mz_2/Mz_1
156	91	257.95	2.31	159.14	210.00	0.40	147.19	0.81	0.17	0.92
156	96	-245.07	-2.31	37.66	-197.11	-0.40	63.04	0.80	0.17	1.67
157	92	723.70	1.56	187.72	764.97	0.44	169.75	1.06	0.28	0.90
157	97	-710.82	-1.56	96.10	-752.09	-0.44	109.94	1.06	0.28	1.14
158	93	541.37	0.78	186.45	534.24	0.50	164.65	0.99	0.65	0.88
158	98	-528.49	-0.78	92.88	-521.36	-0.50	98.66	0.99	0.65	1.06
159	94	513.37	1.09	187.27	494.38	0.55	166.31	0.96	0.50	0.89
159	99	-500.49	-1.09	94.75	-481.50	-0.55	101.96	0.96	0.50	1.08
160	95	620.52	1.69	168.59	608.35	0.40	147.53	0.98	0.24	0.88
160	100	-607.64	-1.69	56.49	-595.47	-0.40	62.98	0.98	0.24	1.11
161	96	218.23	3.51	78.19	185.79	0.72	93.35	0.85	0.21	1.19
161	101	-205.35	-3.51	67.57	-172.90	-0.72	86.84	0.84	0.21	1.29
162	97	574.12	2.65	159.55	600.45	0.69	160.77	1.05	0.26	1.01
162	102	-561.23	-2.65	147.29	-587.57	-0.69	153.03	1.05	0.26	1.04
163	98	434.37	0.97	154.62	429.05	0.67	144.74	0.99	0.68	0.94
163	103	-421.49	-0.97	143.87	-416.16	-0.67	138.87	0.99	0.68	0.97
164	99	412.79	1.38	156.91	397.49	0.64	148.48	0.96	0.47	0.95
164	104	-399.90	-1.38	145.51	-384.61	-0.64	141.68	0.96	0.47	0.97
165	100	485.51	1.99	102.31	473.22	0.80	92.56	0.97	0.41	0.90
165	105	-472.62	-1.99	90.87	-460.34	-0.80	86.55	0.97	0.41	0.95
166	101	185.18	4.09	58.54	166.78	0.88	78.07	0.90	0.22	1.33
166	106	-172.29	-4.09	71.61	-153.90	-0.88	86.16	0.89	0.22	1.20
167	102	427.72	3.14	136.37	440.08	0.87	142.21	1.03	0.28	1.04
167	107	-414.84	-3.14	147.88	-427.20	-0.87	149.13	1.03	0.28	1.01
168	103	326.51	0.95	134.68	323.30	0.82	130.65	0.99	0.86	0.97
168	108	-313.63	-0.95	146.30	-310.42	-0.82	138.70	0.99	0.86	0.95
169	104	312.02	1.39	135.36	301.15	0.79	132.11	0.97	0.57	0.98

169	109	-299.13	-1.39	146.71	-288.27	-0.79	139.77	0.96	0.57	0.95
170	105	343.67	1.96	82.20	334.27	0.80	79.08	0.97	0.41	0.96
170	110	-330.79	-1.96	95.97	-321.39	-0.80	88.74	0.97	0.41	0.92
171	106	143.33	3.80	35.16	136.18	0.85	54.77	0.95	0.22	1.56
171	111	-130.45	-3.80	67.13	-123.29	-0.85	75.74	0.95	0.22	1.13
172	107	283.87	2.94	103.21	285.92	0.86	110.97	1.01	0.29	1.08
172	112	-270.99	-2.94	126.93	-273.04	-0.86	125.61	1.01	0.29	0.99
173	108	218.15	0.78	103.11	216.81	0.79	103.74	0.99	1.02	1.01
173	113	-205.27	-0.78	128.10	-203.93	-0.79	120.72	0.99	1.02	0.94
174	109	210.09	1.15	102.93	203.91	0.75	103.94	0.97	0.65	1.01
174	114	-197.21	-1.15	127.61	-191.03	-0.75	120.37	0.97	0.65	0.94
175	110	209.73	1.60	59.66	203.98	0.71	59.66	0.97	0.44	1.00
175	115	-196.85	-1.60	90.33	-191.10	-0.71	81.60	0.97	0.44	0.90
176	111	83.09	2.60	-0.48	82.78	0.68	16.97	1.00	0.26	**
176	116	-70.21	-2.60	26.66	-69.89	-0.68	38.02	1.00	0.26	1.43
177	112	143.95	2.09	57.09	141.44	0.64	63.29	0.98	0.31	1.11
177	117	-131.07	-2.09	93.22	-128.56	-0.64	87.29	0.98	0.31	0.94
178	113	108.99	0.49	56.98	109.06	0.48	61.63	1.00	0.98	1.08
178	118	-96.11	-0.49	92.37	-96.17	-0.48	87.93	1.00	0.98	0.95
179	114	105.94	0.69	54.42	103.68	0.42	58.97	0.98	0.61	1.08
179	119	-93.06	-0.69	88.79	-90.80	-0.42	83.74	0.98	0.61	0.94
180	115	93.11	0.94	27.43	90.44	0.48	30.08	0.97	0.52	1.10
180	120	-80.23	-0.94	67.50	-77.56	-0.48	60.13	0.97	0.52	0.89

3.4.3 Column forces in the section for seismic load combination 1.5DL+1.5EQ(+X)

Effect of slab stiffness on axial force, torsional and bending moment of column for seismic load combination 1.5DL+1.5EQ(+X) is depicted in table 18. Frame with consideration of slab stiffness provides a variation of 0.92 to 1.03 times in axial force of columns compared to frame without consideration of slab stiffness. The slab stiffness causes redistribution of axial force and bending moment in columns.

There is a variation of 0.17 to 1.10 times in torsional moment due to frame with consideration of slab stiffness compared to frame without consideration of slab stiffness. There is considerable reduction in torsional moment due to introduction of slab except in column number 173 and 178 where ratio appears to be greater than one.

Table 18 Comparison of column forces for seismic load combination 1.5DL+1.5EQ(+X)

Column number	Node	Without slab stiffness			With slab stiffness			Ratio		
		Fx_1 kN	Mx_1 (kNm)	Mz_1 kNm	Fx_2 kN	Mx_2 kNm	Mz_2 kNm	Fx_2/Fx_1	Mx_2/Mx_1	Mz_2/Mz_1
156	91	614.68	2.31	155.71	566.60	0.39	145.31	0.92	0.17	0.93
156	96	-593.21	-2.31	30.88	-545.13	-0.39	59.23	0.92	0.17	1.92
157	92	1187.51	1.56	188.33	1220.88	0.44	169.78	1.03	0.28	0.90
157	97	-1166.04	-1.56	97.55	-1199.41	-0.44	110.12	1.03	0.28	1.13
158	93	902.41	0.77	186.59	896.43	0.51	164.76	0.99	0.66	0.88
158	98	-880.94	-0.77	93.17	-874.96	-0.51	98.96	0.99	0.66	1.06
159	94	868.00	1.09	187.44	846.75	0.56	166.36	0.98	0.51	0.89
159	99	-846.53	-1.09	94.94	-825.28	-0.56	102.07	0.97	0.51	1.08

160	95	859.13	1.68	171.40	848.53	0.41	149.40	0.99	0.24	0.87
160	100	-837.66	-1.68	62.06	-827.06	-0.41	66.90	0.99	0.24	1.08
161	96	503.65	3.51	69.19	471.08	0.72	87.90	0.94	0.21	1.27
161	101	-482.18	-3.51	59.14	-449.61	-0.72	81.60	0.93	0.21	1.38
162	97	942.93	2.65	161.56	962.16	0.69	160.87	1.02	0.26	1.00
162	102	-921.46	-2.65	149.15	-940.69	-0.69	153.02	1.02	0.26	1.03
163	98	723.90	0.96	154.90	719.51	0.67	145.19	0.99	0.69	0.94
163	103	-702.43	-0.96	144.38	-698.04	-0.67	139.48	0.99	0.69	0.97
164	99	695.88	1.36	156.79	678.56	0.64	148.66	0.98	0.47	0.95
164	104	-674.41	-1.36	145.72	-657.08	-0.64	142.14	0.97	0.47	0.98
165	100	676.80	1.97	109.28	666.00	0.81	97.95	0.98	0.41	0.90
165	105	-655.33	-1.97	97.67	-644.52	-0.81	91.83	0.98	0.41	0.94
166	101	399.28	4.11	49.81	380.76	0.88	72.66	0.95	0.21	1.46
166	106	-377.81	-4.11	62.78	-359.29	-0.88	80.53	0.95	0.21	1.28
167	102	703.55	3.14	137.79	710.11	0.87	141.96	1.01	0.28	1.03
167	107	-682.08	-3.14	149.53	-688.64	-0.87	148.91	1.01	0.28	1.00
168	103	544.00	0.91	135.17	541.52	0.82	131.38	1.00	0.89	0.97
168	108	-522.53	-0.91	146.95	-520.05	-0.82	139.55	1.00	0.89	0.95
169	104	524.18	1.37	135.68	511.66	0.78	132.78	0.98	0.57	0.98
169	109	-502.71	-1.37	147.12	-490.19	-0.78	140.55	0.98	0.57	0.96
170	105	487.18	1.94	88.97	479.05	0.79	84.44	0.98	0.41	0.95
170	110	-465.71	-1.94	103.02	-457.58	-0.79	94.39	0.98	0.41	0.92
171	106	286.05	3.83	26.13	278.83	0.85	49.13	0.97	0.22	1.88
171	111	-264.58	-3.83	58.75	-257.36	-0.85	70.49	0.97	0.22	1.20
172	107	467.87	2.94	104.36	465.72	0.86	110.51	1.00	0.29	1.06
172	112	-446.40	-2.94	127.78	-444.25	-0.86	125.02	1.00	0.29	0.98
173	108	363.36	0.72	103.71	362.52	0.79	104.64	1.00	1.10	1.01
173	113	-341.89	-0.72	128.83	-341.05	-0.79	121.67	1.00	1.10	0.94
174	109	351.63	1.13	103.52	344.27	0.75	104.92	0.98	0.66	1.01
174	114	-330.16	-1.13	128.56	-322.80	-0.75	121.56	0.98	0.66	0.95
175	110	305.20	1.57	66.65	300.45	0.71	65.26	0.98	0.45	0.98
175	115	-283.73	-1.57	97.05	-278.98	-0.71	86.91	0.98	0.45	0.90
176	111	154.47	2.61	-10.88	154.12	0.70	9.97	1.00	0.27	-0.92
176	116	-133.00	-2.61	11.48	-132.65	-0.70	28.55	1.00	0.27	2.49
177	112	237.35	2.09	59.17	232.55	0.64	62.93	0.98	0.31	1.06
177	117	-215.88	-2.09	96.35	-211.08	-0.64	87.24	0.98	0.31	0.91
178	113	181.48	0.46	57.72	181.95	0.48	62.78	1.00	1.04	1.09
178	118	-160.01	-0.46	93.32	-160.48	-0.48	89.41	1.00	1.04	0.96
179	114	177.23	0.67	54.45	174.33	0.40	59.95	0.98	0.60	1.10
179	119	-155.76	-0.67	88.65	-152.86	-0.40	84.65	0.98	0.60	0.95
180	115	140.32	0.90	35.34	138.20	0.46	36.93	0.98	0.51	1.04
180	120	-118.85	-0.90	79.16	-116.73	-0.46	69.53	0.98	0.51	0.88

3.4.4 Column forces in the section for seismic load combination 1.2DL+1.2LL+1.2EQ(+X)

Effect of slab stiffness on axial force, torsional and bending moment of column for seismic load combination 1.2DL+1.2LL+1.2EQ(+X) is depicted in table 19. Frame with consideration of slab stiffness provides a variation of 0.94 to 1.02 times in axial force of columns compared to frame without consideration of slab stiffness. The slab stiffness causes redistribution of axial force and bending moment in columns.

There is a variation of 0.17 to 1.15 times in torsional moment due to frame with consideration of slab stiffness compared to frame without consideration of slab stiffness. There is considerable reduction in torsional moment due to introduction of slab except in column number 173 and 178 where ratio appears to be greater than one.

Table 19 Comparison of column forces for seismic load combination 1.2DL+1.2LL+1.2EQ(+X)

Column number	Node	Without slab stiffness			With slab stiffness			Ratio		
		Fx_1 kN	Mx_1 kNm	Mz_1 kNm	Fx_2 kN	Mx_2 kNm	Mz_2 kNm	Fx_2/Fx_1	Mx_2/Mx_1	Mz_2/Mz_1
156	91	635.69	1.85	122.22	597.16	0.31	114.11	0.94	0.17	0.93
156	96	-618.51	-1.85	19.95	-579.98	-0.31	42.96	0.94	0.17	2.15
157	92	1159.85	1.25	151.66	1184.11	0.35	136.74	1.02	0.28	0.90
157	97	-1142.68	-1.25	80.16	-1166.93	-0.35	90.05	1.02	0.28	1.12
158	93	867.88	0.61	149.35	863.39	0.41	131.84	0.99	0.66	0.88
158	98	-850.70	-0.61	74.64	-846.22	-0.41	79.23	0.99	0.66	1.06
159	94	836.67	0.87	150.10	818.74	0.45	133.16	0.98	0.51	0.89
159	99	-819.49	-0.87	76.13	-801.56	-0.45	81.79	0.98	0.51	1.07
160	95	760.50	1.35	138.42	752.72	0.33	120.68	0.99	0.24	0.87
160	100	-743.32	-1.35	52.17	-735.54	-0.33	55.89	0.99	0.24	1.07
161	96	518.09	2.81	49.05	491.98	0.58	64.13	0.95	0.21	1.31
161	101	-500.91	-2.81	41.43	-474.81	-0.58	59.43	0.95	0.21	1.43
162	97	920.83	2.12	132.16	933.71	0.55	131.33	1.01	0.26	0.99
162	102	-903.65	-2.12	122.03	-916.53	-0.55	124.81	1.01	0.26	1.02
163	98	696.31	0.76	124.02	693.09	0.53	116.29	1.00	0.70	0.94
163	103	-679.14	-0.76	115.77	-675.91	-0.53	111.86	1.00	0.70	0.97
164	99	670.14	1.09	125.49	655.41	0.52	119.14	0.98	0.48	0.95
164	104	-652.97	-1.09	116.81	-638.23	-0.52	114.06	0.98	0.48	0.98
165	100	600.25	1.57	90.59	592.30	0.65	81.64	0.99	0.41	0.90
165	105	-583.08	-1.57	81.27	-575.13	-0.65	76.67	0.99	0.41	0.94
166	101	405.81	3.29	33.83	390.94	0.71	52.30	0.96	0.21	1.55
166	106	-388.63	-3.29	44.10	-373.77	-0.71	58.37	0.96	0.21	1.32
167	102	687.26	2.51	112.64	690.42	0.70	115.71	1.00	0.28	1.03
167	107	-670.09	-2.51	122.19	-673.25	-0.70	121.35	1.00	0.28	0.99
168	103	523.27	0.71	108.40	521.51	0.65	105.47	1.00	0.91	0.97
168	108	-506.09	-0.71	117.92	-504.34	-0.65	112.06	1.00	0.91	0.95
169	104	504.30	1.09	108.83	493.57	0.63	106.70	0.98	0.58	0.98
169	109	-487.13	-1.09	118.05	-476.40	-0.63	112.99	0.98	0.58	0.96
170	105	433.92	1.54	74.30	428.00	0.63	70.79	0.99	0.41	0.95
170	110	-416.74	-1.54	85.69	-410.83	-0.63	78.93	0.99	0.41	0.92
171	106	286.40	3.07	14.71	280.59	0.68	33.37	0.98	0.22	2.27
171	111	-269.22	-3.07	41.29	-263.42	-0.68	50.92	0.98	0.22	1.23
172	107	457.35	2.35	85.71	454.14	0.69	90.40	0.99	0.29	1.05
172	112	-440.17	-2.35	104.16	-436.96	-0.69	101.76	0.99	0.29	0.98
173	108	349.48	0.55	83.32	348.98	0.63	84.19	1.00	1.15	1.01
173	113	-332.31	-0.55	103.50	-331.80	-0.63	97.88	1.00	1.15	0.95

174	109	337.97	0.89	83.25	331.58	0.60	84.58	0.98	0.67	1.02
174	114	-320.80	-0.89	103.44	-314.40	-0.60	97.99	0.98	0.67	0.95
175	110	273.53	1.24	56.59	270.17	0.56	55.59	0.99	0.45	0.98
175	115	-256.36	-1.24	80.79	-253.00	-0.56	72.72	0.99	0.45	0.90
176	111	152.30	2.10	-15.89	152.00	0.56	0.62	1.00	0.27	-0.04
176	116	-135.13	-2.10	-1.35	-134.82	-0.56	12.77	1.00	0.27	-9.46
177	112	232.37	1.67	50.44	227.99	0.52	52.87	0.98	0.31	1.05
177	117	-215.19	-1.67	81.41	-210.81	-0.52	73.35	0.98	0.31	0.90
178	113	174.43	0.35	46.62	174.91	0.38	50.83	1.00	1.08	1.09
178	118	-157.25	-0.35	75.12	-157.73	-0.38	72.18	1.00	1.08	0.96
179	114	170.36	0.52	43.80	167.83	0.32	48.67	0.99	0.61	1.11
179	119	-153.19	-0.52	71.16	-150.65	-0.32	68.46	0.98	0.61	0.96
180	115	126.69	0.70	32.00	125.19	0.36	33.72	0.99	0.51	1.05
180	120	-109.51	-0.70	68.80	-108.02	-0.36	61.38	0.99	0.51	0.89

3.5 Effect of slab stiffness on reinforcement requirement

The material quantities for buildings with and without slab stiffness are depicted in table 20. The quantity of concrete remains same since the column and beam sections are kept same in both the cases. Approximately 15% lesser steel is required when stiffness of slab is considered in the analysis resulting in an economical design.

Table 20 Material quantities for L shaped plan building with and without slab stiffness

S. No.	Frame type	Concrete (m^3)	Reinforcement (Kg)	Remark
1.	Without slab	92.6	9454	15% lesser steel is required when stiffness of slab is considered
2.	With slab	92.6	8062	

IV. CONCLUSION

The effect of slab stiffness on structural behaviour of L shaped building is studied in the present work and the following salient conclusions can be made from the above study.

1. There is a considerable reduction in lateral displacement of roof nodes whereas rotation of the roof nodes either nullifies or reduces in most of the cases due to introduction of slab stiffness under seismic loading.
2. The slab stiffness causes significant reduction in torsional and bending moments at supports. However its effect on vertical reaction is found to be insignificant.
3. Shear force and bending moment in the beams are significantly reduced by consideration of slab stiffness.
4. The slab stiffness causes redistribution of axial force and bending moment in columns. However a significant reduction is observed in torsional moment of columns.
5. In present work approximately 15% lesser steel is required when stiffness of slab is considered in the analysis resulting in an economical design.

V. REFERENCES

[1]. Large, G.E. (1950), "Basic Reinforced Concrete Design", The Ronald Press Company.
[2]. Danay A. (1976), "A general element for analysis of asymmetric multi-storey buildings with

varying cross-section, Building and Environment", 11 (1), pp. 57–67.

[3]. Nakashima M., Huang T., and Lu L.W. (1983), "Effect of diaphragm flexibility on seismic response of building structures", Proceedings of The Eight World Conference on Earthquake Engineering, pp. 735-742.

[4]. Jain S. K., and Jennings P. (1985), "Analytical models for low-rise buildings with flexible floor diaphragms", Earthquake Engineering Structural Dynamics, 13(2), pp. 225-241.

[5]. Jin C.S., Ti H., Wu L.L. (1988), "Diaphragm behavior of reinforced concrete floor slabs", Proceedings of Ninth World Conference on Earthquake Engineering, Tokyo Japan.

[6]. Kunnath S., Panahshahi N., and Reinhorn A. (1991), "Seismic response of RC buildings with inelastic floor diaphragms", Journal of Structural Engineering, 117(4), pp. 1218–1237.

[7]. Hawary M. M. (1994), "Effect of horizontal diaphragm flexibility on the P-delta analysis", Published by Elsevier Ltd, 53(6), pp. 1275–1280.

[8]. Dolce M., Lorusso V. D., Masi A. (1994), "Seismic response of building structures with flexible inelastic diaphragms", Structural Design of Tall Buildings, 3(2), pp. 87-106.

[9]. Chopra, A. K. (1995), "Dynamics of Structures: Theory and Applications to Earthquake Engineering", Prentice-Hall.Inc., Englewood Cliffs, New Jersey.

[10]. Lee D.G., Kim H.S., Chun M.H. (2002)," Efficient seismic analysis of high-rise building structures with the effects of floor slabs", Engineering Structures, 24(5), pp. 613-623.

[11]. IS 1893 : 2002, "Indian Standard criteria for earthquake resistant design of structures", Part 1 General provisions and buildings, Draft of Fifth Revision, Bureau of Indian Standards, New Delhi.

[12]. Bull D.K. (2003), "Understanding the Complexities of Designing Diaphragms in Buildings for Earthquakes", Bulletin of the New Zealand Society for the Earthquake Engineering 37(4).

[13]. Joel B.M. and Mary H.B.D. (2004), "Diaphragm Effects in Rectangular Reinforced Concrete Buildings", ACI Structural Journal, pp. 615-624.

[14]. Lee H.J., Aschheim M.A., Kuchma D. (2007)," Interstory drift estimates for low-rise flexible diaphragm structures", Engineering Structures, 29(7), pp. 1375-1397.

[15]. Gardiner D. R., Bull D.K., Carr A. J. (2008), "Internal forces of concrete floor diaphragms in multi-storey buildings", New Zealand Society Earthquake Engineering Conference, Paper No. 21.

[16]. Fouad K., Ali Z., Mustapha R. (2012), "Structural analyses with flexibility effect of the floor slabs", Proceedings of the Fifteenth World Conference on Earthquake Engineering, pp. 1223-1230.

[17]. Duggal S.K. (2015), "Earthquake Resistant Design of Structures", Oxford Publications.

[18]. Yadav P. and Khuswaha S.S. (2016), "Influence of floor diaphragm building while considering seismic forces", International Journal of Engineering Sciences and Research Technology, 5(6), pp. 178-191.

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