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Effects of Plan Dimensions, Seismic Zone, Infill on Storey Drifts and Force Response of L-Shaped Reinforced Concrete Buildings

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***Abstract*— Recently it has become mandatory to design all the civil engineering structures including building frames for the earthquake effects in addition to dead load, live load and wind load effects. The present work deals with the determination of storey drifts and force response of 20-storeyed reinforced concrete L-shaped buildings located in different seismic zones using ETABS 2013 Ultimate 13.2.2. The effects of plan dimensions, severity of seismic zone, infill walls on the storey drifts and force response have been evaluated. It is observed that the absolute maximum storey drift occurs in Zone V and that the effect of presence of infill walls in the analysis is to reduce the storey drifts. The influence of infill wall on the moments in transfer girders and main beams is not insignificant. Both the design ultimate positive and negative moments in transfer girders and main beams decrease in magnitude when the effect of infill wall is considered in the analysis. The response spectrum method predicts lower maximum storey drift in x-direction compared to the equivalent static lateral force method in all the cases. The response spectrum method predicts higher maximum storey drift in y-direction compared to the equivalent static lateral force method in all the cases.**

Keywords—Reinforced Concrete Buildings; Storey Drift; Force Response; Infill Wall; Seismic Zone

1. INTRODUCTION

Building Codes specify that the effects due to earthquake load be considered in addition to those due to dead, live load and wind loads. A vast literature on dynamic analysis exists and a few of them are briefly mentioned here. Wakchaure M R and Ped S P [1] studied the effects of infill in high rise buildings. The infill walls were modeled as equivalent single strut by using the FEMA-356 approach. Mohammed Yousuf and P M Shimpale [2] carried out dynamic analysis for G+5 storied buildings located in seismic zone IV. They considered a rectangular symmetrical, C-shape, L-shape and irregular L unsymmetrical buildings for the analysis. The analysis was carried out by using the ETABS 9.5 software. Amin Alavi and P Srivinivasa Rao [3] studied the behavior of the 5-storied buildings located in seismic zone V. The buildings consisted of eight different configurations with re-entrant corners. Himanshu Gaur et al. [4] analyzed the horizontally irregular buildings for their stability using STAAD Pro software. They considered the 20-storeyed buildings of different shapes like L, U and H-shape for the analysis, each shape having different lateral length ratios. M G Shaikh and Hashmi S Shakeeb [5] investigated the seismic performance of L-shaped building with varying bay length and storey height. The buildings were modelled using STAAD Pro V8i software. The results obtained for infill and without infill building models were compared. Ravikumar C M et al. [6] studied the seismic performance of the buildings which are having irregularities in plan with geometric and diaphragm continuity, re-entrant corners, vertical irregularity with setback and also buildings resting on sloping ground. S Mahesh and Dr P B Panduranga Rao [7] studied the behavior of the G+11 storied building of regular and irregular configurations subjected to earthquake and wind load using ETABS and STAAD Pro V8i software. B Srikanth and V Ramesh [8] studied the earthquake response of a 20-storeyed building by seismic coefficient and Response spectrum methods. Pravin Ashok Shirule and Bharti V Mahajan [9] conducted the parametric studies on G+13 storeyed RC frame building with asymmetric column distribution with and without shear wall by using response spectrum method of analysis. A E Hassaballa et al. [10] carried out the seismic analysis of a multi-storied RC frame building situated in Khartoum city using STAAD Pro software. Critical damping of 5% was considered in response spectrum method of analysis. Ramesh Konakalla et al. [11] studied the response of the 20-storeyed building by linear static analysis using STAAD Pro software. One regular symmetric model and three vertical irregular models were considered in the analysis. S.S. Patil et al. [12] carried out the response spectrum analysis for G+14 storeyed building situated in the seismic zone IV using STAAD Pro software. The buildings were modeled as RC bare frame, bare frame with bracing and bare frame with shear wall in the analysis. Bracing and shear walls were located at different locations and directions in the building. Haroon Rasheed Tamboli and

Umesh.N.karadi [13] performed the seismic analysis on ten storey buildings considering three cases i) bare frame ii) infill frame iii) infill with ground soft storey and using ETABS software. Seismic zone III and 5% damping was considered in the analysis. Infill was modeled as an equivalent diagonal strut in the analysis. Mohit Sharma and Savitha Maru [14] carried out static and dynamic analyses on G+30 storeyed regular building using STAAD Pro software. Seismic zones II and III and medium soil type were considered in the analysis. P.B Prajapathi and Prof.Mayur G. Vanza [15] analysed 10 storeyed RCC residential buildings with different plan configurations and studied the influence of plan irregularity on the building. Static and dynamic analyses were carried out using SAP software. For dynamic analysis, response spectrum method and time history methods were used. Md Irfanullah and Vishwanath. B. Patil [16] studied the behavior of the building when subjected to seismic loading with various arrangements of infill. The building was having five bays in both X and Y directions and situated in seismic zone IV. Models considered for the analysis were i) Bare frame ii) full infill frame iii) infill in all floor except below plinth iv) infill with first floor as soft storey v) Infill with soft storey at first floor and basement vi) Infill with soft storey at first and basement and infill provided in swastika pattern in ground floor. Equivalent static analysis was carried out by using ETABS 9.6 software.

2. PRESENT WORK

2.1 Details of Buildings, Loads and Load Combinations Considered

L-shaped Reinforced Concrete Buildings of 20 storeys having soft storey, floating columns and transfer girders with and without infill are analyzed for all loading combinations specified by IS Codes using ETABS software. The effects of the following parameters: 1) L_1/L_2 ratio (L_1 and L_2 are defined later), 2) Location of building and the corresponding seismic zone, 3) Infill walls or No infill walls on (a) storey drifts and (b) maximum ultimate forces and moments in the main beams and transfer girders are evaluated by performing the stiffness analysis using ETABS Version 2013 Ultimate 13.2.2 software. In the present work, L-shaped reinforced concrete buildings having a foundation depth of 2.0 m below existing ground level, plinth height = 0.5 m and 20 storeys each of 3 m height located in seismic zones II, III, IV and V (Infill and No infill) are considered. In all the cases the first storey (ground floor) is a soft storey. The floating columns start from the top of the 15th floor and extend up to the roof. These are marked as FC in Fig. 1. The other columns shown in Fig. 1 extend up to the roof starting from footing top (regular columns). The floating columns are supported by transfer girders (marked as TB1 and TB2) spanning between regular columns. The dimensions L_1 and L_2 are as defined in Fig. 1. The sizes of the beams and columns are given in Table 1. All the slabs including the roof are of 150 mm thickness. M50 grade concrete is used for all slabs, beams and columns.

Table 1: Sizes of beams and columns in L-shaped buildings

Member	Size
Regular Columns	a) footing top to first floor slab 1200 x 1200 mm b) first floor slab to 15th floor slab 1100 x 1100 mm c) 15th floor slab to roof slab 300 x 750 mm
Floating Columns	300 x 750 mm
Stub Columns up to plinth level	300 x 300 mm
Plinth Beams connecting stub and other columns	300 x 450 mm
Main Beam (a) 12 m span (up to 15th floor) (b) 4 m span (16th floor to roof)	 450 x 1200 mm 300 x 450 mm
Secondary Beam (a) 12 m span (b) 4 m span	 300 x 750 mm 300 x 450 mm
Transfer Girder TB1 TB2	 1000 x 1000 mm 1100 x 1100 mm

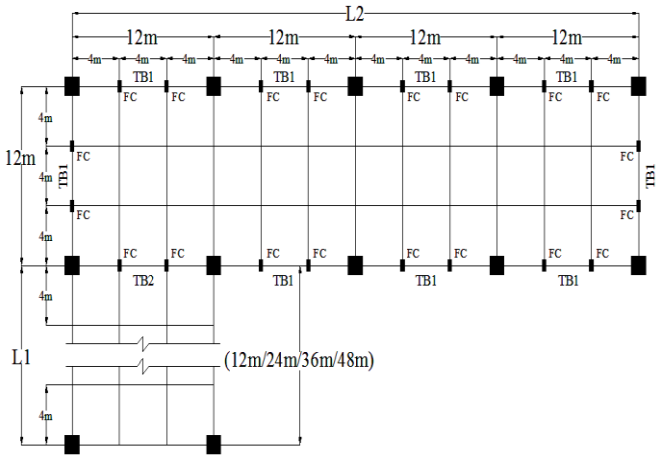

Fig.1: Plan of L-shaped building at 15th floor level

The live loads considered are 3.5 kN/m^2 for floors and 1.5 kN/m^2 for roof. The floor finish is assumed as 1.0 kN/m^2. The roof finish is taken as 2.0kN/m^2. 300 mm thick masonry walls are provided on the beams at all floor levels along the periphery of the building. 150 mm thick parapet walls are provided along the periphery of the building at the roof level. In addition to the dead and live loads, wind and seismic loads corresponding to the chosen four locations Vishakhapatnam, Vijayawada, Delhi and Darbhanga are considered. Load combinations are made in accordance with IS: 456, IS: 875 and IS: 1893. Stiffness analysis of frames is performed using ETABS Version 2013 Ultimate 13.2.2. The load combinations used for the limit state of collapse are shown in Table 2.

Table 2: Load combinations for the limit state of collapse

Sl.No.	Load combination	Sl.No.	Load combination
1	1.5 (DL + LL)	20	1.5 (DL + WL_Y)
2	1.2 (DL + LL + EQ_X)	21	1.5 (DL - WL_Y)
3	1.2 (DL + LL - EQ_X)	22	0.9 DL + 1.5 WL_X
4	1.2 (DL + LL + EQ_Y)	23	0.9 DL - 1.5 WL_X
5	1.2 (DL + LL - EQ_Y)	24	0.9 DL + 1.5 WL_Y
6	1.5 (DL + EQ_X)	25	0.9 DL - 1.5 WL_Y
7	1.5 (DL - EQ_X)	26	1.2 (DL + LL + $SPEC_X$)
8	1.5(DL + EQ_Y)	27	1.2 (DL + LL - $SPEC_X$)
9	1.5 (DL - EQ_Y)	28	1.2 (DL + LL + $SPEC_Y$)
10	0.9 DL + 1.5 EQ_X	29	1.2 (DL + LL - $SPEC_Y$)
11	0.9 DL - 1.5 EQ_X	30	1.5 (DL + $SPEC_X$)
12	0.9 DL + 1.5 EQ_Y	31	1.5 (DL - $SPEC_X$)
13	0.9 DL - 1.5 EQ_Y	32	1.5 (DL + $SPEC_Y$)
14	1.2 (DL + LL + WL_X)	33	1.5 (DL - $SPEC_Y$)
15	1.2 (DL + LL - WL_X)	34	0.9 DL + 1.5 $SPEC_X$
16	1.2 (DL + LL + WL_Y)	35	0.9 DL - 1.5 $SPEC_X$
17	1.2 (DL + LL - WL_Y)	36	0.9 DL + 1.5 $SPEC_Y$
18	1.5 (DL + WL_X)	37	0.9 DL - 1.5 $SPEC_Y$
19	1.5 (DL - WL_X)		
7	DL + 0.8 LL - 0.8 EQ_X	20	DL + $SPEC_Y$
8	DL + 0.8 LL + 0.8 EQ_Y	21	DL - $SPEC_Y$
9	DL + 0.8 LL - 0.8 EQ_Y	22	DL + 0.8 LL + 0.8 $SPEC_X$
10	DL + WL_X	23	DL + 0.8 LL - 0.8 $SPEC_X$
11	DL - WL_X	24	DL + 0.8 LL + 0.8 $SPEC_Y$
12	DL + WL_Y	25	DL + 0.8 LL - 0.8 $SPEC_Y$
13	DL - WL_Y		

The load combinations used for the serviceability limit state are shown in Table 3.

Table 3: Load combinations for the limit state of serviceability

Sl.No.	Load combination	Sl.No.	Load combination
1	DL + LL	14	DL + 0.8 LL + 0.8 WL_X
2	DL + EQ_X	15	DL + 0.8 LL - 0.8 WL_X
3	DL - EQ_X	16	DL + 0.8 LL + 0.8 WL_Y
4	DL + EQ_Y	17	DL + 0.8 LL - 0.8 WL_Y
5	DL - EQ_Y	18	DL + $SPEC_X$
6	DL + 0.8 LL + 0.8 EQ_X	19	DL - $SPEC_X$

The effect due to seismic loading is evaluated using (i) Equivalent Static Lateral Force Method and (ii) Response Spectrum Method separately. The more critical value obtained from these two methods is considered in the design. The effect of the infill wall is accounted in the analysis by treating it as a diagonal strut in accordance with the recommendations of FEMA 356.

2.2 Storey Drifts

(a) Design Storey Drifts in X-Direction (No Infill)

The storey drifts in x-direction for L-shaped buildings with no infill are given in Table 4 for various values of L_1/L_2 ratio and zones II and III and in Table 5 for various values of L_1/L_2 ratio and zones IV and V. Each storey drift entry in the table represents the maximum value obtained by considering all load combinations specified by the relevant IS Codes (called design storey drift).

Table 4: Values of design storey drift in m

L-shaped building; WL/EL in X-direction; No infill								
STOREY NO.	ZONE II				ZONE III			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
20	0.00021	0.00022	0.00022	0.00023	0.0003	0.00031	0.00032	0.00033
19	0.00034	0.00036	0.00037	0.00039	0.00052	0.00055	0.00057	0.00059
18	0.00048	0.00051	0.00052	0.00054	0.00074	0.00078	0.00081	0.00083
17	0.00059	0.00062	0.00064	0.00066	0.00091	0.00096	0.00099	0.00102
16	0.0005	0.00053	0.00055	0.00056	0.00078	0.00082	0.00085	0.00088
15	0.00024	0.00036	0.00038	0.00036	0.00025	0.00036	0.00038	0.00036
14	0.00027	0.00041	0.00043	0.0004	0.0003	0.00041	0.00043	0.0004
13	0.0003	0.00044	0.00047	0.00043	0.00034	0.00044	0.00047	0.00043
12	0.00032	0.00048	0.00051	0.0005	0.00036	0.00048	0.00051	0.0005
11	0.00034	0.00051	0.00054	0.00058	0.00038	0.00051	0.00054	0.00058
10	0.00036	0.00054	0.00058	0.00067	0.00039	0.00054	0.00058	0.00067
9	0.00038	0.00057	0.00064	0.00075	0.0004	0.00057	0.00064	0.00075
8	0.0004	0.0006	0.0007	0.00082	0.00041	0.0006	0.0007	0.00082
7	0.00041	0.00062	0.00076	0.0009	0.00041	0.00062	0.00076	0.0009
6	0.00043	0.00064	0.00081	0.00097	0.00043	0.00064	0.00081	0.00097
5	0.00045	0.00066	0.00086	0.00102	0.00045	0.00066	0.00086	0.00102
4	0.00047	0.00069	0.00090	0.00107	0.00047	0.00069	0.0009	0.00107
3	0.00047	0.00070	0.00091	0.00108	0.00047	0.0007	0.00091	0.00108
2	0.00045	0.00067	0.00086	0.00102	0.00045	0.00067	0.00086	0.00102
1	0.0004	0.00057	0.00072	0.00085	0.0004	0.00057	0.00072	0.00085
PLINTH	0.0002	0.00027	0.00034	0.00039	0.0002	0.00027	0.00034	0.00039
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 4 for L-Shaped Buildings in Zone II (No Infill)

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.18.
- For other values of L_1/L_2 ratio, maximum design storey drift occurs at floor no.4.
- As L_1/L_2 ratio increases the maximum design storey drift also increases. When L_1/L_2 ratio =1.0, the value is 1.08 mm.

The following observations are made from Table 4 for L-Shaped Buildings in Zone III (No Infill):

- For L_1/L_2 ratio = 0.25, 0.50 and 0.75, maximum design storey drift occurs at floor no.18.
- For L_1/L_2 ratio = 1.0, maximum design storey drift occurs at floor no. 4.
- As L_1/L_2 ratio increases the maximum design storey drift also increases. When L_1/L_2ratio =1.0, the value is 1.08 mm.

Table 5: Values of design storey drift in m

WL/EL in X-direction; No infill								
STOREY NO.	ZONE IV				ZONE V			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
20	0.00043	0.00045	0.00046	0.00048	0.00062	0.00065	0.00067	0.00069
19	0.00076	0.0008	0.00083	0.00086	0.00112	0.00118	0.00122	0.00126
18	0.00109	0.00114	0.00119	0.00122	0.00161	0.00169	0.00176	0.00181
17	0.00135	0.00141	0.00147	0.00151	0.00200	0.00210	0.00218	0.00225
16	0.00115	0.00121	0.00126	0.0013	0.00171	0.0018	0.00187	0.00192
15	0.00035	0.00034	0.00036	0.00037	0.0005	0.0005	0.00053	0.00055
14	0.00043	0.00042	0.00045	0.00046	0.00061	0.00063	0.00066	0.00069
13	0.00048	0.00048	0.00051	0.00053	0.00068	0.00072	0.00075	0.00078
12	0.00051	0.00052	0.00055	0.00057	0.00074	0.00078	0.00082	0.00085
11	0.00054	0.00056	0.00059	0.00061	0.00078	0.00083	0.00087	0.00091
10	0.00056	0.00058	0.00061	0.00064	0.00082	0.00087	0.00091	0.00095
9	0.00058	0.0006	0.00064	0.00067	0.00085	0.0009	0.00095	0.00100
8	0.00059	0.00062	0.00065	0.00073	0.00087	0.00092	0.00097	0.00106
7	0.00059	0.00063	0.00067	0.00079	0.00088	0.00094	0.00099	0.00111
6	0.0006	0.00064	0.00072	0.00085	0.0009	0.00095	0.00101	0.00117
5	0.0006	0.00064	0.00076	0.00091	0.0009	0.00096	0.00104	0.00124
4	0.0006	0.00064	0.00079	0.00094	0.0009	0.00095	0.00108	0.00129
3	0.00059	0.00063	0.0008	0.00095	0.00088	0.00094	0.0011	0.0013
2	0.00056	0.00059	0.00076	0.0009	0.00084	0.00088	0.00104	0.00124
1	0.00049	0.00052	0.00064	0.00075	0.00073	0.00077	0.00087	0.00102
PLINTH	0.00024	0.00025	0.0003	0.00035	0.00035	0.00037	0.00041	0.00047
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 5 for L-Shaped Buildings in Zone IV (No Infill):

- For all L_1/L_2 ratios, maximum design storey drift occurs at floor no.18.
- As L_1/L_2 ratio increases the maximum design storey drift also increases. When L_1/L_2 ratio =1.0, the value is 1.51 mm.

The following observations are made from Table 5 for L-Shaped Buildings in Zone V (No Infill):

- For all L_1/L_2 ratios, maximum design storey drift occurs at floor no.18.
- As L_1/L_2 ratio increases the maximum design storey drift also increases. When L_1/L_2 ratio =1.0, the value is 2.25 mm.

(b) Design Storey Drifts in Y-Direction (No Infill)

The storey drifts in y-direction for L-shaped buildings with no infill are given in Table 6 for various values of L_1/L_2 ratio and zones II and III and in Table 7 for various values of L_1/L_2 ratio and zones IV and V. Each storey drift entry in the table represents the maximum value obtained by considering all load combinations specified by the relevant IS Codes.

Table 6: Values of design storey drift in m

WL/EL in Y-direction; No infill								
STOREY NO.	ZONE II				ZONE III			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
20	0.00055	0.00051	0.00047	0.00045	0.00055	0.00051	0.00047	0.00045
19	0.00072	0.00068	0.00064	0.00061	0.00072	0.00068	0.00064	0.00061
18	0.0009	0.00086	0.00082	0.00078	0.0009	0.00086	0.00082	0.00078
17	0.00108	0.00101	0.00096	0.00091	0.00108	0.00101	0.00096	0.00091
16	0.00117	0.00106	0.00096	0.00088	0.00117	0.00106	0.00096	0.00088
15	0.00127	0.00107	0.00088	0.00071	0.00127	0.00107	0.00088	0.00071
14	0.00146	0.00121	0.00099	0.0008	0.00146	0.00121	0.00099	0.0008
13	0.00162	0.00135	0.00109	0.00087	0.00162	0.00135	0.00109	0.00087

12	0.00177	0.00147	0.00118	0.00095	0.00177	0.00147	0.00118	0.00095
11	0.00191	0.00158	0.00127	0.00102	0.00191	0.00158	0.00127	0.00102
10	0.00205	0.00169	0.00136	0.00109	0.00205	0.00169	0.00136	0.00109
9	0.00217	0.0018	0.00144	0.00115	0.00217	0.0018	0.00144	0.00115
8	0.00228	0.00189	0.00152	0.00121	0.00228	0.00189	0.00152	0.00121
7	0.00238	0.00198	0.00159	0.00127	0.00238	0.00198	0.00159	0.00127
6	0.00246	0.00205	0.00165	0.00132	0.00246	0.00205	0.00165	0.00132
5	0.00252	0.00210	0.00169	0.00136	0.00252	0.00210	0.00169	0.00136
4	0.00251	0.00211	0.00171	0.00137	0.00251	0.00211	0.00171	0.00137
3	0.00241	0.00204	0.00167	0.00135	0.00241	0.00204	0.00167	0.00135
2	0.00212	0.00182	0.00151	0.00124	0.00212	0.00182	0.00151	0.00124
1	0.00156	0.00137	0.00116	0.00097	0.00156	0.00137	0.00116	0.00097
PLINTH	0.00068	0.0006	0.00052	0.00044	0.00068	0.0006	0.00052	0.00044
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 6 for L-Shaped Buildings in Zone II (No Infill):

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.6.
- For other values of L_1/L_2 ratio, maximum design storey drift occurs at floor no. 5.
- As L_1/L_2 ratio increases the maximum design storey drift decreases. When L_1/L_2 ratio =0.25, the value is 2.52 mm.

The following observations are made from Table 6 for L-Shaped Buildings in Zone III (No Infill):

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.6.
- For other values of L_1/L_2 ratio, maximum design storey drift occurs at floor no. 5.
- As L_1/L_2 ratio increases the maximum design storey drift decreases. When L_1/L_2 ratio = 0.25, the value is 2.52 mm.

Table 7: Values of design storey drift in m

WL/EL in Y-direction; No infill								
STOREY NO.	ZONE IV				ZONE V			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
20	0.00049	0.00047	0.00049	0.0005	0.00066	0.00069	0.00073	0.00074
19	0.00064	0.00066	0.0007	0.00071	0.00086	0.00097	0.00103	0.00105
18	0.0008	0.00082	0.00088	0.0009	0.00109	0.00122	0.0013	0.00133
17	0.00095	0.00091	0.00096	0.00098	0.00129	0.00135	0.00143	0.00146
16	0.00104	0.00094	0.00086	0.00085	0.00141	0.00127	0.00126	0.00125
15	0.00113	0.00095	0.00078	0.00065	0.00152	0.00128	0.00105	0.00094
14	0.0013	0.00108	0.00088	0.00072	0.00175	0.00145	0.00118	0.00105
13	0.00144	0.0012	0.00097	0.00079	0.00194	0.00161	0.0013	0.00114
12	0.00158	0.00131	0.00105	0.00085	0.00213	0.00176	0.00141	0.00123
11	0.0017	0.00141	0.00113	0.00091	0.0023	0.0019	0.00153	0.00129
10	0.00182	0.0015	0.00121	0.00097	0.00246	0.00203	0.00163	0.00135
9	0.00192	0.00159	0.00128	0.00103	0.00261	0.00216	0.00173	0.0014
8	0.00202	0.00168	0.00135	0.00108	0.00275	0.00227	0.00183	0.00146
7	0.00211	0.00175	0.00141	0.00113	0.00287	0.00238	0.00191	0.00153
6	0.00218	0.00182	0.00146	0.00117	0.00297	0.00247	0.00199	0.00159
5	0.00223	0.00186	0.00150	0.00120	0.00303	0.00253	0.00204	0.00164
4	0.00222	0.00187	0.00151	0.00122	0.00303	0.00254	0.00206	0.00166
3	0.00213	0.00181	0.00148	0.00119	0.00291	0.00246	0.00201	0.00163
2	0.00188	0.00161	0.00134	0.00109	0.00256	0.0022	0.00182	0.00149
1	0.00138	0.00121	0.00103	0.00086	0.00188	0.00165	0.0014	0.00117
PLINTH	0.0006	0.00053	0.00046	0.00039	0.00082	0.00073	0.00062	0.00053
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 7 for L-Shaped Buildings in Zone IV (No Infill):

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.6.
- For other values of L_1/L_2 ratio, maximum design storey drift occurs at floor no.5.
- As L_1/L_2 ratio increases the maximum design storey drift decreases. When L_1/L_2 ratio =0.25, the value is 2.23 mm.

The following observations are made from Table 7 for L-Shaped Buildings in Zone V (No Infill):

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.5 and 6.
- For other values of L_1/L_2 ratio, maximum design storey drift occurs at floor no.5
- As L_1/L_2ratio increases the maximum design storey drift decreases. When L_1/L_2 ratio =0.25, the value is 3.03 mm.

The values of maximum design storey drifts for all L_1/L_2 ratios and zones are listed separately for X-direction and Y-direction in Table 8.

Table 8: Values of maximum design storey drift in m (No infill)

Zone No.	EL / WL in X- Direction				EL / WL in Y- Direction			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
II	0.00059	0.00070	0.00091	0.00108	0.00252	0.00211	0.00171	0.00137
III	0.00091	0.00096	0.00099	0.00108	0.00252	0.00211	0.00171	0.00137
IV	0.00135	0.00141	0.00147	0.00151	0.00223	0.00187	0.00151	0.00122
V	0.00200	0.00210	0.00218	0.00225	0.00303	0.00254	0.00206	0.00166

From Table 8, it can be observed that:

- The maximum design storey drift in x-direction, for any given zone, increases with L_1/L_2 ratio.
- The maximum design storey drift in y-direction, for any given zone, decreases with L_1/L_2 ratio.
- The absolute maximum (maximum of maximums) design storey drift in x- or y-direction occurs in zone V.
- The maximum design storey drift in y-direction is greater than that in x-direction for the same zone and L_1/L_2 ratio in majority of cases.

(c) Design Storey Drifts in X-Direction (Infill)

The storey drifts in x-direction for L-shaped buildings with infill are given in Table 9 for various values of L_1/L_2ratio and zones II and III and in Table 10 for various values of L_1/L_2 ratio and zones IV and V. Each storey drift entry in the table represents the maximum value obtained by considering all load combinations specified by the relevant IS Codes.

Table 9: Values of design storey drift in m

WL/EL in X-direction; Infill								
STOREY NO.	ZONE II				ZONE III			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
20	0.00016	0.00017	0.00017	0.00016	0.00022	0.00023	0.00024	0.000238
19	0.00024	0.00025	0.00026	0.00025	0.00035	0.00036	0.00037	0.000378
18	0.00032	0.00033	0.00034	0.00032	0.00047	0.00049	0.0005	0.00051
17	0.00039	0.00041	0.00042	0.00039	0.00058	0.0006	0.00062	0.000628
16	0.00037	0.00038	0.00039	0.00037	0.00055	0.00057	0.00059	0.000597
15	0.00022	0.00034	0.00037	0.00034	0.00024	0.00034	0.00037	0.00035
14	0.00026	0.00039	0.00041	0.00038	0.0003	0.00039	0.00041	0.000386
13	0.00029	0.00042	0.00045	0.00041	0.00033	0.00042	0.00045	0.000425
12	0.00031	0.00046	0.00048	0.00047	0.00036	0.00046	0.00048	0.000506
11	0.00033	0.00049	0.00052	0.00055	0.00038	0.00049	0.00052	0.000587
10	0.00035	0.00052	0.00055	0.00063	0.00039	0.00052	0.00055	0.000666
9	0.00036	0.00055	0.00061	0.00071	0.0004	0.00055	0.00061	0.000743
8	0.00038	0.00057	0.00067	0.00079	0.00041	0.00057	0.00067	0.000817
7	0.00039	0.00059	0.00072	0.00086	0.00042	0.00059	0.00072	0.000887
6	0.00041	0.00061	0.00078	0.00092	0.00042	0.00061	0.00078	0.000951
5	0.00042	0.00063	0.00082	0.00098	0.00042	0.00063	0.00082	0.001006
4	0.00044	0.00065	0.00086	0.00102	0.00044	0.00065	0.00086	0.001048
3	0.00045	0.00066	0.00087	0.00104	0.00045	0.00066	0.00087	0.001061
2	0.00044	0.00064	0.00084	0.00099	0.00044	0.00064	0.00084	0.001012
1	0.00039	0.00056	0.00071	0.00083	0.00039	0.00056	0.00071	0.000845
PLINTH	0.00019	0.00027	0.00033	0.00039	0.00019	0.00027	0.00033	0.000393
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 9 for L-Shaped Buildings in Zone II (Infill):

- For all the L_1/L_2 ratios, maximum design storey drift occurs at floor no.4.
- As L_1/L_2 ratio increases the maximum design storey drift increases. When L_1/L_2 ratio =1.0, the value is 1.04 mm.

The following observations are made from Table 9 for L-Shaped Buildings in Zone III (Infill):

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.18
- For L_1/L_2 ratio =0.50, 0.75 and 1.0, maximum design storey drift occurs at floor no.4.
- As L_1/L_2 ratio increases the maximum design storey drift also increases. When L_1/L_2 ratio =1.0, the value is 1.06 mm.

Table 10: Values of design storey drift in m

WL/EL in X-direction; Infill								
STOREY NO.	ZONE IV				ZONE V			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
20	0.00030	0.00032	0.00032	0.0003	0.00043	0.00044	0.00045	0.00043
19	0.00049	0.00051	0.00052	0.00049	0.00071	0.00074	0.00075	0.0007
18	0.00067	0.0007	0.00072	0.00067	0.00097	0.00101	0.00104	0.00096
17	0.00083	0.00086	0.00088	0.00082	0.00121	0.00125	0.00129	0.00120
16	0.00079	0.00082	0.00084	0.00078	0.00115	0.0012	0.00123	0.00114
15	0.00033	0.00031	0.00034	0.0003	0.00047	0.00047	0.0005	0.00045
14	0.00042	0.0004	0.00042	0.00039	0.00059	0.0006	0.00062	0.00058
13	0.00047	0.00046	0.00048	0.00045	0.00067	0.00069	0.00072	0.00067
12	0.00051	0.00051	0.00053	0.00049	0.00073	0.00075	0.00079	0.00073
11	0.00054	0.00054	0.00057	0.00053	0.00078	0.00081	0.00084	0.00078
10	0.00056	0.00057	0.0006	0.00056	0.00082	0.00085	0.00089	0.00083
9	0.00058	0.0006	0.00062	0.00063	0.00085	0.00088	0.00092	0.00086
8	0.00059	0.00061	0.00064	0.0007	0.00087	0.00091	0.00095	0.00095
7	0.0006	0.00063	0.00065	0.00076	0.00088	0.00093	0.00097	0.00104
6	0.00061	0.00063	0.00069	0.00082	0.00089	0.00094	0.001	0.00111
5	0.0006	0.00064	0.00073	0.00087	0.0009	0.00095	0.00103	0.00118
4	0.0006	0.00064	0.00076	0.0009	0.0009	0.00095	0.00103	0.00124
3	0.0006	0.00063	0.00077	0.00092	0.00089	0.00094	0.00105	0.00125
2	0.00058	0.0006	0.00074	0.00088	0.00086	0.0009	0.00101	0.0012
1	0.00052	0.00054	0.00063	0.00073	0.00077	0.0008	0.00086	0.001
PLINTH	0.00026	0.00026	0.0003	0.00034	0.00037	0.00038	0.0004	0.00047
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 10 for L-Shaped Buildings in Zone IV (Infill):

- For L_1/L_2 ratio = 0.25, 0.50 and 0.75, maximum design storey drift occurs at floor no.18.
- For L_1/L_2 ratio = 1.0, maximum design storey drift occurs at floor no.4.
- As L_1/L_2 ratio increases the maximum design storey drift also increases. When L_1/L_2 ratio =1.0, the value is 0.92mm.

The following observations are made from Table 10 for L-Shaped Buildings in Zone V (Infill):

- For L_1/L_2 ratio = 0.25, 0.50 and 0.75, maximum design storey drift occurs at floor no.18.
- For L_1/L_2 ratio = 1.0, maximum design storey drift occurs at floor no.4.
- As L_1/L_2 ratio increases the maximum design storey drift also increases. When L_1/L_2 ratio =1.0, the value is 1.25mm.

(d) Design Storey Drifts in Y-Direction (Infill)

The storey drifts in y-direction for L-shaped buildings with infill are given in Table 11 for various values of L_1/L_2 ratio and zones II and III and in Table 12 for various values of L_1/L_2 ratio and zones IV and V. Each storey drift entry in the table represents the maximum value obtained by considering all load combinations specified by the relevant IS Codes.

Table 11: Values of design storey drift in m

WL/EL in Y-direction; Infill								
STOREY NO.	ZONE II				ZONE III			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
20	0.00050	0.00046	0.00043	0.00044	0.0005	0.00046	0.00043	0.000426
19	0.00065	0.00061	0.00058	0.00059	0.00065	0.00061	0.00058	0.000573
18	0.00082	0.00078	0.00074	0.00074	0.00082	0.00078	0.00074	0.000725
17	0.00098	0.00092	0.00087	0.00083	0.00098	0.00092	0.00087	0.000827
16	0.00109	0.00098	0.00089	0.00081	0.00109	0.00098	0.00089	0.00081
15	0.00119	0.00100	0.00082	0.00067	0.00119	0.00100	0.00082	0.000665
14	0.00137	0.00114	0.00092	0.00074	0.00137	0.00114	0.00092	0.000738
13	0.00152	0.00126	0.00101	0.00081	0.00152	0.00126	0.00101	0.000809
12	0.00166	0.00137	0.0011	0.00088	0.00166	0.00137	0.0011	0.000877
11	0.00179	0.00147	0.00119	0.00095	0.00179	0.00147	0.00119	0.000943
10	0.00191	0.00157	0.00126	0.00101	0.00191	0.00157	0.00126	0.001006
9	0.00202	0.00167	0.00134	0.00107	0.00202	0.00167	0.00134	0.001066
8	0.00213	0.00176	0.00141	0.00112	0.00213	0.00176	0.00141	0.001122
7	0.00222	0.00184	0.00148	0.00117	0.00222	0.00184	0.00148	0.001174
6	0.0023	0.00191	0.00153	0.00122	0.0023	0.00191	0.00153	0.00122
5	0.00235	0.00195	0.00158	0.00126	0.00235	0.00195	0.00158	0.001256
4	0.00235	0.00197	0.00159	0.00127	0.00235	0.00197	0.00159	0.001275
3	0.00227	0.00192	0.00156	0.00126	0.00227	0.00192	0.00156	0.001258
2	0.00202	0.00173	0.00143	0.00117	0.00202	0.00173	0.00143	0.001166
1	0.00151	0.00132	0.00112	0.00093	0.00151	0.00132	0.00112	0.000933
PLINTH	0.00066	0.00059	0.0005	0.00042	0.00066	0.00059	0.0005	0.000424
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 11 for L-Shaped Buildings in Zone II (No Infill):

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.5 and 6.
- For other values of L_1/L_2 ratio, maximum design storey drift occurs at floor no.5
- As L_1/L_2 ratio increases the maximum design storey drift decreases. When L_1/L_2 ratio =0.25, the value is 2.35mm.

The following observations are made from Table 11 for L-Shaped Buildings in Zone III (Infill):

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.5 and 6.
- For other values of L_1/L_2 ratio, maximum design storey drift occurs at floor no.5
- As L_1/L_2 ratio increases the maximum design storey drift decreases. When L_1/L_2 ratio =0.25, the value is 2.35 mm.

Table 12: Values of design storey drift in m

WL/EL in Y-direction; Infill								
STOREY NO.	ZONE IV				ZONE V			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
20	0.00045	0.00042	0.00044	0.00045	0.00061	0.00062	0.00065	0.0006
19	0.00058	0.00057	0.0006	0.00058	0.00079	0.00085	0.0009	0.0008
18	0.00073	0.00071	0.00075	0.00071	0.00099	0.00106	0.00113	0.00099
17	0.00087	0.00082	0.00083	0.00077	0.00118	0.00117	0.00124	0.00111
16	0.00097	0.00087	0.00079	0.00072	0.0013	0.00117	0.00113	0.00106
15	0.00106	0.00089	0.00073	0.00061	0.00143	0.0012	0.00098	0.00088
14	0.00122	0.00101	0.00082	0.00068	0.00164	0.00136	0.0011	0.00098
13	0.00135	0.00112	0.0009	0.00074	0.00182	0.0015	0.00121	0.00108
12	0.00147	0.00122	0.00098	0.0008	0.00199	0.00164	0.00132	0.00116
11	0.00159	0.00131	0.00106	0.00084	0.00215	0.00177	0.00142	0.00123
10	0.00169	0.0014	0.00113	0.0009	0.00229	0.00189	0.00152	0.00129
9	0.00179	0.00148	0.00119	0.00095	0.00243	0.00201	0.00161	0.00133
8	0.00189	0.00156	0.00125	0.00100	0.00256	0.00211	0.0017	0.00139
7	0.00197	0.00163	0.00131	0.00104	0.00268	0.00221	0.00178	0.00144
6	0.00204	0.00169	0.00136	0.00108	0.00277	0.0023	0.00185	0.00149
5	0.00208	0.00173	0.00140	0.00111	0.00283	0.00236	0.0019	0.00151
4	0.00208	0.00174	0.00141	0.00113	0.00284	0.00238	0.00192	0.00154
3	0.00201	0.0017	0.00138	0.00111	0.00274	0.00232	0.00189	0.00152
2	0.00179	0.00153	0.00127	0.00103	0.00244	0.00209	0.00173	0.00141
1	0.00133	0.00117	0.00099	0.00083	0.00182	0.0016	0.00135	0.00113
PLINTH	0.00058	0.00052	0.00045	0.00038	0.0008	0.00071	0.00061	0.00051
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 12 for L-Shaped Buildings in Zone IV (Infill):

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.5 and 6.
- For other values of L_1/L_2 ratio, maximum design storey drift occurs at floor no.5
- As L_1/L_2ratio increases the maximum design storey drift decreases. When L_1/L_2 ratio =0.25, the value is 2.08 mm.

The following observations are made from Table 12 for L-Shaped Buildings in Zone V (Infill):

- For all L_1/L_2 ratios, maximum design storey drift occurs at floor no.5.
- As L_1/L_2 ratio increases the maximum design storey drift also decreases. When L_1/L_2 ratio =0.25, the value is 2.84 mm.

The values of maximum design storey drifts for all L_1/L_2 ratios and zones are listed separately for X-direction and Y-direction in Table 13.

Table 13: Values of maximum design storey drift in m (Infill)

Zone	EL / WL in X- Direction				EL / WL in Y- Direction			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
II	0.00045	0.00066	0.00087	0.00104	0.00235	0.00197	0.00159	0.00127
III	0.00058	0.00066	0.00087	0.00208	0.00235	0.00197	0.00159	0.00256
IV	0.00083	0.00086	0.00088	0.00092	0.00208	0.00174	0.00141	0.00113
V	0.00121	0.00125	0.00129	0.00125	0.00284	0.00238	0.00192	0.00154

From Table 13, it can be observed that:

- The maximum design storey drift in x-direction, for any given zone except zone V, increases with L_1/L_2 ratio. In the case of zone V, the maximum design storey drift increases initially, becomes maximum at L_1/L_2 ratio = 0.75 and later decreases.
- The maximum design storey drift in y-direction, for any given zone except zone III, decreases with L_1/L_2 ratio. In the case of zone III, the maximum design

storey drift decreases initially, becomes minimum at L_1/L_2 ratio = 0.75 and later increases.
- The absolute maximum (maximum of maximums) design storey drift in x- or y-direction occurs in zone III at L_1/L_2 ratio = 1.0.
- The maximum design storey drift in y-direction is greater than that in x-direction for the same zone and L_1/L_2 ratio.

2.3 Variation of Design Ultimate Positive Moment and Design Ultimate Negative Moment in Transfer Girders TB1 and TB2

The design ultimate positive and negative moments in transfer girders are given in Tables 14 and 15.

Table 14: Maximum moments in Transfer Girders of L-Shaped Buildings (No Infill)

Transfer Girder	Design Ultimate Positive Moment				Design Ultimate Negative Moment			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
TB1	3296.79	3304.995	3306.1228	3306.2118	5457.6456	5498.407	5503.014	5502.9021
TB2	4389.75	4397.624	4401.2401	4402.6311	5554.4309	5575.5512	5589.089	5594.9293

Table 15: Maximum moments in Transfer Girders of L-Shaped Buildings (Infill)

Transfer Girder	Design Ultimate Positive Moment				Design Ultimate Negative Moment			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
TB1	2792.41	2799.193	2800.2848	2811.9492	4626.1677	4667.7212	4672.834	4733.2077
TB2	3666.39	3672.078	3675.2209	3669.5182	4658.2851	4631.7489	4620.424	4675.7406

From the results obtained, the following are observed in regard to transfer girders:
- The variation with L_1/L_2 ratio is insignificant.
- The variation with zone is also insignificant.
- The influence of infill wall on the moments is significant. Both the design ultimate positive and negative moments decrease in magnitude when the effect of infill wall is considered in the analysis as indicated by Tables 14 and 15.

2.4 Variation of Design Ultimate Positive Moment and Design Ultimate Negative Moment in Main Beams

The design ultimate positive and negative moments in main beams are given in Tables 16 and 17.

Table 16: Maximum moments in Main Beams of L-Shaped Buildings (No Infill)

Zone	Design Ultimate Positive Moment				Design Ultimate Negative Moment			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
II	652.0576	691.916	713.1223	723.9056	1307.968	1422.911	1484.044	1515.157
III	652.0576	691.916	713.1223	723.9056	1307.968	1422.911	1484.044	1515.157
IV	706.5589	714.0471	723.5481	733.2348	1465.918	1487.61	1515.096	1543.103
V	822.0541	833.0336	847.1936	861.7119	1799.893	1831.696	1872.662	1914.637

Table 17: Maximum moments in Main Beams of L-Shaped Buildings (Infill)

Zone	Design Ultimate Positive Moment				Design Ultimate Negative Moment			
	L_1/L_2 Ratio				L_1/L_2 Ratio			
	0.25	0.5	0.75	1.0	0.25	0.5	0.75	1.0
II	597.1986	646.5993	633.8827	645.3786	1140.628	918.5251	1316.965	1350.169
III	597.1986	612.4028	633.8827	645.0452	1140.628	1255.047	1316.965	1349.1265
IV	643.6309	651.1873	659.5208	643.6725	1346.018	1367.866	1391.954	1346.137
V	763.6075	774.5538	786.8924	762.9033	1693.04	1724.686	1760.35	1690.978

From the results obtained, the following are observed in regard to main beams:
- The variation with L_1/L_2 ratio is not significant.
- The variation with zone is also not significant.

- The influence of infill wall on the moments is significant. Both the design ultimate positive and negative moments decrease in magnitude when the effect of infill wall is considered in the analysis as indicated by Tables 16 and 17.

2.5 Comparative Study of Equivalent Static Lateral Force Method and Response Spectrum Method

2.5.1 Loading Combinations Considered

For the purpose of comparing the two methods, the load combinations shown in Table 18 are considered.

Table 18: Load combinations for the limit state of serviceability

Load combination			
Sl.No.	Equivalent Static Lateral Force Method	Sl.No.	Response Spectrum Method
1	DL + EQ_X	1	DL + $SPEC_X$
2	DL - EQ_X	2	DL - $SPEC_X$
3	DL + EQ_Y	3	DL + $SPEC_Y$
4	DL - EQ_Y	4	DL - $SPEC_Y$
5	DL + 0.8 LL + 0.8 EQ_X	5	DL + 0.8 LL + 0.8 $SPEC_X$
6	DL + 0.8 LL - 0.8 EQ_X	6	DL + 0.8 LL - 0.8 $SPEC_X$
7	DL + 0.8 LL + 0.8 EQ_Y	7	DL + 0.8 LL + 0.8 $SPEC_Y$
8	DL + 0.8 LL - 0.8 EQ_Y	8	DL + 0.8 LL - 0.8 $SPEC_Y$

2.5.2 Maximum Storey Drifts in X-Direction

The maximum values of storey drift in x-direction for various values of L_1/L_2 ratio and seismic zone are given in Tables 19 through 22 for both infill and no infill.

Table 19: Maximum values of storey drift in x-direction for Zone II

L_1/L_2 RATIO	ZONE II , X -DIRECTION			
	NO INFILL		INFILL	
	ESLFM	RSM	ESLFM	RSM
0.25	0.000582	0.000520	0.000392	0.000353
0.5	0.000617	0.000542	0.000407	0.000362
0.75	0.000639	0.000549	0.000416	0.000365
1.0	0.000658	0.000552	0.000392	0.000268

Table 20: Maximum values of storey drift in x-direction for Zone III

L_1/L_2 RATIO	ZONE III , X -DIRECTION			
	NO INFILL		INFILL	
	ESLFM	RSM	ESLFM	RSM
0.25	0.000912	0.000811	0.000581	0.000518
0.5	0.000958	0.000838	0.000603	0.000530
0.75	0.000994	0.000850	0.000617	0.000535
1.0	0.001024	0.000854	0.000628	0.000537

Table 21: Maximum values of storey drift in x-direction for Zone IV

L_1/L_2 RATIO	ZONE IV , X -DIRECTION			
	NO INFILL		INFILL	
	ESLFM	RSM	ESLFM	RSM
0.25	0.001346	0.001195	0.000832	0.000738
0.5	0.001414	0.001234	0.000863	0.000756
0.75	0.001467	0.001252	0.000884	0.000773
1.0	0.001513	0.001265	0.000824	0.000638

Table 22: Maximum values of storey drift in x-direction for Zone V

L_1/L_2 RATIO	ZONE V , X -DIRECTION			
	NO INFILL		INFILL	
	ESLFM	RSM	ESLFM	RSM
0.25	0.001998	0.001771	0.001209	0.001068
0.5	0.002097	0.001829	0.001254	0.00111
0.75	0.002177	0.001873	0.001286	0.001137
1.0	0.002245	0.001893	0.001195	0.000955

From Tables 19 through 22, the following observations are made:

- The maximum storey drift in x-direction increases monotonically with the severity of the zone.
- Maximum value of storey drift in x-direction in any zone occurs when L_1/L_2 ratio is unity.
- The storey drift in x-direction in any case is smaller when infill is considered in the analysis.
- The response spectrum method predicts lower maximum storey drift in x-direction compared to the equivalent static lateral force method in all cases.

2.5.3 Maximum Storey Drifts in Y-Direction

The maximum values of storey drift in y-direction for various values of L1/L2 ratio and seismic zone are given in Tables 23 through 26 for both infill and no infill.

Table 23: Maximum values of storey drift in y-direction for Zone II

L_1/L_2 RATIO	ZONE II , Y -DIRECTION			
	NO INFILL		INFILL	
	ESLFM	RSM	ESLFM	RSM
0.25	0.000525	0.000508	0.000510	0.000500
0.5	0.000514	0.000529	0.000492	0.000516
0.75	0.000475	0.000502	0.000455	0.000489
1.0	0.000434	0.000459	0.000418	0.000443

Table 24: Maximum values of storey drift in y-direction for Zone III

L_1/L_2 RATIO	ZONE III , Y -DIRECTION			
	NO INFILL		INFILL	
	ESLFM	RSM	ESLFM	RSM
0.25	0.000812	0.00080	0.000784	0.000777
0.5	0.000785	0.00082	0.000756	0.000804
0.75	0.000728	0.00078	0.000699	0.000762
1.0	0.000664	0.000713	0.000637	0.000683

Table 25: Maximum values of storey drift in y-direction for Zone IV

L_1/L_2 RATIO	ZONE IV , Y -DIRECTION			
	NO INFILL		INFILL	
	ESLFM	RSM	ESLFM	RSM
0.25	0.001188	0.001177	0.001150	0.001148
0.5	0.001149	0.001209	0.001109	0.001187
0.75	0.001065	0.00115	0.001025	0.001127
1.0	0.000973	0.001052	0.000939	0.001017

Table 26: Maximum values of storey drift in y-direction for Zone V

L_1/L_2 RATIO	ZONE V , Y -DIRECTION			
	NO INFILL		INFILL	
	ESLFM	RSM	ESLFM	RSM
0.25	0.001753	0.001744	0.001668	0.001703
0.5	0.001695	0.001793	0.001638	0.001762
0.75	0.001571	0.001705	0.001436	0.001676
1.0	0.001438	0.001563	0.001388	0.001508

From Tables 23 through 26, the following observations are made:

- The maximum storey drift in y-direction increases monotonically with the severity of the zone.
- Maximum value of storey drift in y-direction in any zone occurs when L_1/L_2 ratio is 0.25 as per ESLFM and 0.5 as per RSM.
- The storey drift in y-direction in any case is smaller when infill is considered in the analysis.
- The response spectrum method predicts higher maximum storey drift in y-direction compared to the equivalent static lateral force method in all cases.

3. CONCLUSIONS

3.1 Design Storey Drifts

- The absolute maximum design storey drift in x- or y-direction occurs in Zone V.
- The maximum design storey drift in x- or y-direction for any zone and any value of L_1/L_2 ratio is smaller when infill wall is considered in the analysis. Thus the effect of infill walls is to reduce the storey drifts.

(i) No Infill

- As L_1/L_2 ratio increases the maximum design storey drift in x-direction also increases in all zones. The maximum design storey drift in x-direction increases monotonically with the seismic severity of the zone.
- In zones II and III, the maximum design storey drift in x-direction occurs either at floor no.4 or 18. In zones IV and V, the maximum design storey drift in x-direction occurs at floor no.18.
- As L_1/L_2 ratio increases the maximum design storey drift in y-direction decreases monotonically with increase in L_1/L_2 ratio in all the zones.
- As seismic severity of the zone increases, the maximum design storey drift in y-direction varies and is maximum for zone V.
- In all the zones, the maximum design storey drift in y-direction occurs either at floor no.5 or 6
- The maximum design storey drift in x-direction, for any given zone, increases with L_1/L_2 ratio.
- The maximum design storey drift in y-direction, for any given zone, decreases with L_1/L_2 ratio.
- The absolute maximum (maximum of maximums) design storey drift in x- or y-direction occurs in zone V.
- The maximum design storey drift in y-direction is greater than that in x-direction for the same zone and L_1/L_2 ratio in majority of cases.

(ii) With Infill

- In zone II, the maximum design storey drift in x-direction occurs at floor no.4. In zones III, IV and V, the maximum drift in x-direction occurs at either floor no.4 or 18.
- As L_1/L_2 ratio increases the maximum design storey drift in x-direction also increases in all zones.
- As L_1/L_2 ratio increases the maximum design storey drift in y-direction decreases monotonically with increase in L_1/L_2 ratio in all the zones.
- In zones II, III and IV, the maximum design storey drift in y-direction occurs either at floor no.5 or 6. In zone V the maximum design storey drift in y-direction occurs at floor no.5.
- As seismic severity of the zone increases, the maximum design storey drift in y-direction varies and is maximum for zone V.

- The maximum design storey drift in x-direction, for any given zone except zone V, increases with L_1/L_2 ratio. In the case of zone V, the maximum design storey drift increases initially, becomes maximum at L_1/L_2 ratio = 0.75 and later decreases.
- The maximum design storey drift in y-direction, for any given zone except zone III, decreases with L_1/L_2 ratio. In the case of zone III, the maximum design storey drift decreases initially, becomes minimum at L_1/L_2 ratio = 0.75 and later increases.
- The absolute maximum (maximum of maximums) design storey drift in x- or y-direction occurs in zone III at L_1/L_2 ratio = 1.0.
- The maximum design storey drift in y-direction is greater than that in x-direction for the same zone and L_1/L_2 ratio.

3.2 Design Ultimate Moments in Transfer Girders and Main Beams

- The variation with L_1/L_2 ratio and severity of seismic zone is not significant.
- The influence of infill wall on the moments is significant. Both the design ultimate positive and negative moments decrease in magnitude when the effect of infill wall is considered in the analysis.

3.3 Equivalent Static Lateral Force Method Versus Response Spectrum Method (L-Shaped Buildings)

- The response spectrum method predicts lower maximum storey drift in x-direction compared to the equivalent static lateral force method in all the cases. The response spectrum method predicts higher maximum storey drift in y-direction compared to the equivalent static lateral force method in all the cases.

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