International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-5, August 2015
ISSN: 2395-3470
www.ijseas.com

Force and Deformation Response of U-Shaped Multi-storeyed 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 U-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 of U-shaped reinforced concrete buildings 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. 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- and y-directions 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 Srinivasa 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 modeled 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

U-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, U-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 U-shaped buildings

Member	Size
Regular Columns	a) footing top to first floor slab1200 x 1200 mm b) first floor slab to 15th floor slab1100 x 1100 mm c) 15th floor slab to roof slab350 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

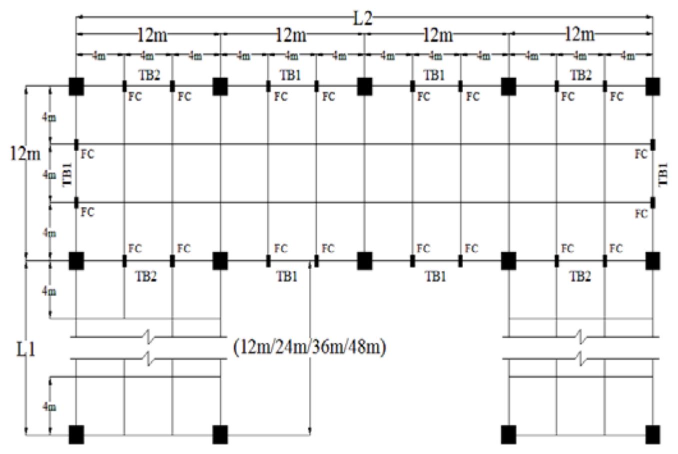

Fig.1: Plan of U-shaped building at 15th floor level

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 -	34	0.9 DL + 1.5

	WL_X)		$SPEC_X$
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)		

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 - $SPEC_X$
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 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 design storey drifts in x-direction for U-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

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	0.00017	0.00018	0.00019	0.00019	0.00027	0.00029	0.00030	0.00030
19	0.00031	0.00033	0.00035	0.00036	0.00050	0.00053	0.00056	0.00058
18	0.00046	0.00049	0.00051	0.00053	0.00073	0.00078	0.00081	0.00084
17	0.00057	0.00061	0.00063	0.00066	0.00091	0.00097	0.00101	0.00105
16	0.00048	0.00052	0.00054	0.00056	0.00077	0.00069	0.00087	0.00089
15	0.00013	0.00014	0.00014	0.00014	0.00021	0.00022	0.00022	0.00023

14	0.00017	0.00017	0.00018	0.00019	0.00027	0.00028	0.00029	0.00032
13	0.00019	0.0002	0.00021	0.00021	0.00030	0.00032	0.00033	0.00034
12	0.00021	0.00022	0.00023	0.00025	0.00033	0.00035	0.00037	0.00038
11	0.00022	0.00025	0.00027	0.00029	0.00036	0.00038	0.0004	0.00041
10	0.00024	0.00028	0.00031	0.00034	0.00037	0.0004	0.00042	0.00043
9	0.00026	0.00031	0.00035	0.00038	0.00039	0.00042	0.00044	0.00045
8	0.00028	0.00034	0.00038	0.00041	0.0004	0.00043	0.00045	0.00047
7	0.00030	0.00037	0.00042	0.00045	0.00041	0.00044	0.00046	0.00048
6	0.00033	0.00039	0.00045	0.00049	0.00041	0.00045	0.00047	0.00049
5	0.00034	0.00042	0.00047	0.00051	0.00042	0.00045	0.00047	0.00051
4	0.00036	0.00044	0.00049	0.00054	0.00042	0.00045	0.00049	0.00054
3	0.00037	0.00044	0.00050	0.00054	0.00041	0.00044	0.0005	0.00054
2	0.00036	0.00043	0.00048	0.00052	0.00039	0.00043	0.00048	0.00052
1	0.00032	0.00037	0.00041	0.00044	0.00034	0.00037	0.00041	0.00044
PLINTH	0.00017	0.00019	0.0002	0.00021	0.00017	0.00019	0.00020	0.00021
BASE	0	0	0	0	0	0	0	0

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

- For all the 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 increases. When L_1/L_2ratio =1.0, the value is 0.66m.

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

- For all the 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 increases. When L_1/L_2 ratio =1.0, the value is 1.05 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	0.00041	0.00043	0.00045	0.00046	0.00061	0.00065	0.00067	0.00068
19	0.00075	0.0008	0.00084	0.00086	0.00113	0.0012	0.00125	0.0013
18	0.00109	0.00117	0.00122	0.00126	0.00164	0.00175	0.00183	0.00189
17	0.00136	0.00145	0.00152	0.00157	0.00204	0.00218	0.00228	0.00236
16	0.00116	0.00124	0.0013	0.00134	0.00174	0.00186	0.00195	0.00201
15	0.00031	0.00032	0.00034	0.00034	0.00046	0.00048	0.0005	0.00052

International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-5, August 2015
ISSN: 2395-3470
www.ijseas.com

14	0.0004	0.00042	0.00043	0.00044	0.0006	0.00062	0.00065	0.00067
13	0.00046	0.00048	0.0005	0.00051	0.00068	0.00072	0.00075	0.00077
12	0.0005	0.00053	0.00055	0.00057	0.00075	0.00079	0.00083	0.00085
11	0.00053	0.00057	0.00059	0.00061	0.0008	0.00085	0.00089	0.00092
10	0.00056	0.0006	0.00063	0.00065	0.00084	0.0009	0.00094	0.00098
9	0.00058	0.00063	0.00066	0.00068	0.00088	0.00094	0.00098	0.00102
8	0.0006	0.00064	0.00068	0.00070	0.0009	0.00097	0.00102	0.00105
7	0.00061	0.00066	0.00069	0.00072	0.00092	0.00099	0.00104	0.00108
6	0.00062	0.00067	0.0007	0.00073	0.00093	0.0010	0.00106	0.00110
5	0.00063	0.00067	0.00071	0.00074	0.00094	0.00101	0.00106	0.00110
4	0.00062	0.00067	0.00071	0.00073	0.00094	0.00101	0.00106	0.00110
3	0.00061	0.00066	0.00069	0.00072	0.00092	0.00099	0.00104	0.00108
2	0.00058	0.00062	0.00065	0.00068	0.00087	0.00093	0.00098	0.00101
1	0.00051	0.00054	0.00056	0.00058	0.00075	0.00080	0.00084	0.00087
PLINTH	0.00025	0.00026	0.00027	0.00028	0.00036	0.00038	0.0004	0.00041
BASE	0	0	0	0	0	0	0	0

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

- For all the 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 increases. When L_1/L_2 ratio =1.0, the value is 1.57 mm.

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

- For all the 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 increases. When L_1/L_2 ratio =1.0, the value is 2.36 mm.

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

The design storey drifts in y-direction for U-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	0.00046	0.00046	0.00046	0.00046	0.00046	0.00046	0.00046	0.00046
19	0.00062	0.00062	0.00062	0.00062	0.00062	0.00062	0.00062	0.00062

18	0.00079	0.00079	0.00078	0.00078	0.00079	0.00079	0.00078	0.00078
17	0.00089	0.00087	0.00086	0.00085	0.00089	0.00087	0.00086	0.00085
16	0.00076	0.00069	0.00066	0.00065	0.00076	0.00083	0.00066	0.00065
15	0.00078	0.00049	0.00035	0.00028	0.00078	0.00049	0.00035	0.00028
14	0.00087	0.00054	0.00039	0.00030	0.00087	0.00054	0.00039	0.0003
13	0.00094	0.00058	0.00041	0.00032	0.00094	0.00058	0.00041	0.00036
12	0.001	0.00062	0.00044	0.00034	0.001	0.00062	0.00044	0.00039
11	0.00106	0.00065	0.00047	0.00036	0.00106	0.00065	0.00047	0.00041
10	0.00111	0.00068	0.00049	0.00038	0.00111	0.00068	0.00049	0.00043
9	0.00116	0.00071	0.00051	0.00040	0.00116	0.00071	0.00051	0.00045
8	0.0012	0.00074	0.00054	0.00042	0.0012	0.00074	0.00054	0.00046
7	0.00124	0.00077	0.00056	0.00044	0.00124	0.00077	0.00056	0.00047
6	0.00127	0.00079	0.00057	0.00045	0.00127	0.00079	0.00057	0.00047
5	0.00129	0.00081	0.00059	0.00046	0.00129	0.00081	0.00059	0.00047
4	0.00129	0.00082	0.00060	0.00047	0.00129	0.00082	0.00060	0.00047
3	0.00126	0.00081	0.0006	0.00047	0.00126	0.00081	0.00060	0.00047
2	0.00115	0.00076	0.00057	0.00045	0.00115	0.00076	0.00057	0.00045
1	0.00092	0.00063	0.00049	0.00040	0.00092	0.00063	0.00049	0.0004
PLINTH	0.00041	0.00029	0.00023	0.00019	0.00041	0.00029	0.00023	0.00019
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 6 for U-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.18.
- As L_1/L_2 ratio increases the maximum design storey drift decreases. When L_1/L_2 ratio = 0.25, the value is 1.29 mm.

The following observations are made from Table 6 for U-Shaped Buildings in Zone III (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.18.
- As L_1/L_2 ratio increases the maximum design storey drift decreases. When L_1/L_2 ratio =0.25, the value is 1.29 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	0.00043	0.00050	0.00054	0.00057	0.00059	0.00068	0.00073	0.00078
19	0.00057	0.00067	0.00073	0.00078	0.0008	0.00093	0.00102	0.00109
18	0.00071	0.00083	0.00091	0.00097	0.00099	0.00117	0.00129	0.00139
17	0.00079	0.00090	0.00099	0.00106	0.0011	0.00129	0.00143	0.00153
16	0.00067	0.00071	0.00077	0.00081	0.00094	0.00104	0.00113	0.00119
15	0.00071	0.00052	0.00044	0.00038	0.00093	0.00072	0.0006	0.00053
14	0.0008	0.00059	0.00049	0.00044	0.00104	0.00081	0.00069	0.00061
13	0.00086	0.00064	0.00055	0.00049	0.00112	0.00089	0.00077	0.00069
12	0.00091	0.00068	0.00059	0.00054	0.00118	0.00095	0.00084	0.00077
11	0.00096	0.00072	0.00063	0.00058	0.00124	0.00101	0.0009	0.00083
10	0.001	0.00075	0.00066	0.00061	0.0013	0.00105	0.00095	0.00088
9	0.00104	0.00076	0.00069	0.00064	0.00136	0.00109	0.00099	0.00093
8	0.00108	0.00078	0.0007	0.00066	0.00142	0.00111	0.00101	0.00096

International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-5, August 2015
ISSN: 2395-3470
www.ijseas.com

7	0.00111	0.00078	0.00071	0.00067	0.00147	0.00112	0.00103	0.00098
6	0.00114	0.00078	0.00072	0.00068	0.00151	0.00113	0.00104	0.00099
5	0.00115	0.00077	0.00071	0.00068	0.00154	0.00112	0.00104	0.00100
4	0.00115	0.00075	0.0007	0.00067	0.00155	0.0011	0.00103	0.00099
3	0.00112	0.00072	0.00068	0.00066	0.00151	0.00106	0.00100	0.00097
2	0.00102	0.00067	0.00063	0.00061	0.00138	0.00096	0.00093	0.00091
1	0.00081	0.00056	0.00053	0.00052	0.0011	0.00079	0.00078	0.00078
PLINTH	0.00037	0.00026	0.00024	0.00024	0.0005	0.00036	0.00036	0.00036
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 7 for U-Shaped Buildings in Zone IV (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.18.
- As L_1/L_2 ratio increases, the maximum design storey drift decreases from a maximum at L_1/L_2 ratio = 0.25 to a minimum at L_1/L_2 ratio = 0.50 and later increases. When L_1/L_2 ratio =0.25, the storey drift is 1.15 mm.

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

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.5.
- For other values of L_1/L_2ratio, maximum design storey drift occurs at floor no.18.
- As L_1/L_2 ratio increases, the maximum design storey drift decreases from a maximum at L_1/L_2 ratio = 0.25 to a minimum at L_1/L_2 ratio = 0.50 and later increases. When L_1/L_2 ratio =0.25, the storey drift is 1.55 mm.

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	0.00057	0.00061	0.00063	0.00066	0.00129	0.00087	0.00086	0.00085
III	0.00091	0.00097	0.00101	0.00105	0.00129	0.00087	0.00086	0.00085
IV	0.00136	0.00145	0.00152	0.00157	0.00115	0.00090	0.00099	0.00106
V	0.00204	0.00218	0.00228	0.00236	0.00155	0.00129	0.00143	0.00153

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 zones II and III, decreases with L_1/L_2 ratio. For the other zones, the maximum design storey drift decreases from a maximum value at L_1/L_2 ratio =0.25 to a minimum value at L_1/L_2 ratio=0.5 and later increases.
- The absolute maximum 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 zone II. The maximum design storey drift in y-direction is smaller than that in x-direction for zones IV and V. The variation in zone III is as defined in Table 8.

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

The design storey drifts in x-direction for U-shaped buildings with infill are given in Table 9 for various values of L_1/L_2 ratio 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	0.00012	0.00012	0.00013	0.00013	0.00018	0.00019	0.00019	0.0002
19	0.00020	0.00022	0.00022	0.00023	0.00032	0.00033	0.00033	0.00035
18	0.00029	0.00030	0.00031	0.00031	0.00044	0.00046	0.00046	0.00049
17	0.00036	0.00038	0.00039	0.00040	0.00056	0.00058	0.00058	0.00061
16	0.00034	0.00036	0.00037	0.00038	0.00053	0.00055	0.00056	0.00058
15	0.00012	0.00013	0.00013	0.00013	0.00019	0.0002	0.00021	0.00021
14	0.00016	0.00017	0.00017	0.00017	0.00025	0.00026	0.00027	0.00028
13	0.00019	0.00019	0.00020	0.00021	0.0003	0.00031	0.00032	0.00033
12	0.00021	0.00022	0.00023	0.00024	0.00033	0.00034	0.00035	0.00037
11	0.00022	0.00024	0.00026	0.00029	0.00035	0.00037	0.00038	0.0004
10	0.00023	0.00027	0.00030	0.00033	0.00037	0.00039	0.00041	0.00042
9	0.00025	0.0003	0.00033	0.00036	0.00039	0.00041	0.00043	0.00044
8	0.00027	0.00032	0.00037	0.0004	0.00040	0.00043	0.00044	0.00046
7	0.00029	0.00035	0.0004	0.00044	0.00041	0.00044	0.00045	0.00047
6	0.00031	0.00038	0.00043	0.00047	0.00042	0.00044	0.00046	0.00048
5	0.00033	0.0004	0.00046	0.00050	0.00042	0.00045	0.00046	0.00050
4	0.00034	0.00042	0.00048	0.00052	0.00042	0.00045	0.00046	0.00052
3	0.00035	0.00043	0.00049	0.00053	0.00042	0.00044	0.00047	0.00053
2	0.00035	0.00042	0.00047	0.00051	0.00040	0.00042	0.00046	0.00051
1	0.00032	0.00037	0.0004	0.00043	0.00036	0.00038	0.0004	0.00043
PLINTH	0.00017	0.00019	0.0002	0.00021	0.00018	0.00019	0.0002	0.00021
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 9 for U-Shaped Buildings in Zone II (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 increases. When L_1/L_2 ratio =1.0, the value is 0.53 mm.

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

- For all the 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 increases. When L_1/L_2 ratio =1.0, the value is 0.61 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	0.00027	0.00028	0.00028	0.00029	0.00039	0.00041	0.00043	0.00044
19	0.00046	0.00049	0.00049	0.00052	0.00069	0.00072	0.00075	0.00077
18	0.00065	0.00068	0.00068	0.00072	0.00096	0.00100	0.00104	0.00106
17	0.00081	0.00085	0.00085	0.00090	0.00120	0.00126	0.00130	0.00133
16	0.00078	0.00081	0.00082	0.00086	0.00115	0.0012	0.00124	0.00127
15	0.00029	0.0003	0.00031	0.00032	0.00043	0.00045	0.00046	0.00048
14	0.00038	0.00039	0.0004	0.00042	0.00057	0.00059	0.00061	0.00062
13	0.00044	0.00046	0.00047	0.00049	0.00066	0.00069	0.00071	0.00073
12	0.00049	0.00051	0.00053	0.00055	0.00073	0.00077	0.0008	0.00082
11	0.00052	0.00055	0.00057	0.00059	0.00078	0.00083	0.00086	0.00089
10	0.00055	0.00059	0.00061	0.00063	0.00083	0.00088	0.00092	0.00095
9	0.00058	0.00062	0.00064	0.00066	0.00086	0.00092	0.00096	0.00099
8	0.0006	0.00064	0.00066	0.00069	0.00089	0.00095	0.00100	0.00103
7	0.00061	0.00065	0.00068	0.00071	0.00091	0.00098	0.00102	0.00106
6	0.00062	0.00066	0.00069	0.00072	0.00093	0.00099	0.00104	0.00107
5	0.00063	0.00067	0.00069	0.00072	0.00093	0.00100	0.00105	0.00108
4	0.00063	0.00067	0.00069	0.00072	0.00094	0.00100	0.00105	0.00108
3	0.00062	0.00066	0.00068	0.00071	0.00093	0.00099	0.00103	0.00107
2	0.0006	0.00063	0.00065	0.00068	0.00089	0.00094	0.00099	0.00102
1	0.00053	0.00056	0.00058	0.00059	0.00079	0.00083	0.00086	0.00088
PLINTH	0.00026	0.00027	0.00028	0.00029	0.00038	0.0004	0.00041	0.00042
BASE	0	0	0	0	0	0	0	0

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

- For all the 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 increases. When L_1/L_2 ratio =1.0, the value is 0.90 mm.

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

- For all the 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 increases. When L_1/L_2 ratio =1.0, the value is 1.33 mm.

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

The design storey drifts in y-direction for U-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	0.00044	0.00044	0.00045	0.00044	0.00044	0.00044	0.00045	0.00044
19	0.00059	0.00059	0.00059	0.00058	0.00059	0.00059	0.00059	0.00058
18	0.00074	0.00074	0.00074	0.00073	0.00074	0.00074	0.00074	0.00073
17	0.00083	0.00082	0.00082	0.00081	0.00083	0.00082	0.00082	0.00080
16	0.00071	0.00066	0.00065	0.00063	0.00071	0.00066	0.00065	0.00062
15	0.00072	0.00045	0.0003	0.00033	0.00072	0.00045	0.0003	0.00026
14	0.0008	0.00049	0.00033	0.00035	0.0008	0.00049	0.00033	0.0003
13	0.00087	0.00053	0.00036	0.00038	0.00087	0.00053	0.00036	0.00033
12	0.00092	0.00056	0.00038	0.0004	0.00092	0.00056	0.00039	0.00036
11	0.00097	0.00059	0.0004	0.00042	0.00097	0.00059	0.00041	0.00039
10	0.00102	0.00062	0.00042	0.00044	0.00102	0.00062	0.00043	0.00041
9	0.00106	0.00065	0.00044	0.00047	0.00106	0.00065	0.00044	0.00042
8	0.0011	0.00068	0.00046	0.00048	0.0011	0.00068	0.00046	0.00043
7	0.00114	0.0007	0.00048	0.0005	0.00114	0.0007	0.00048	0.00044
6	0.00117	0.00072	0.00049	0.00052	0.00117	0.00072	0.00049	0.00044
5	0.00119	0.00074	0.0005	0.00053	0.00119	0.00074	0.0005	0.00044
4	0.00119	0.00075	0.00051	0.00054	0.00119	0.00075	0.00051	0.00044
3	0.00117	0.00074	0.00052	0.00054	0.00117	0.00074	0.00052	0.00043
2	0.00108	0.0007	0.0005	0.00052	0.00108	0.0007	0.0005	0.00041
1	0.00088	0.00061	0.00046	0.00046	0.00088	0.00061	0.00046	0.00038
PLINTH	0.0004	0.00028	0.00022	0.00022	0.0004	0.00028	0.00022	0.00018
BASE	0	0	0	0	0	0	0	0

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

- For L_1/L_2 ratio = 0.25, maximum drift occurs at floor no.5 and 6.
- For other values of L_1/L_2 ratio, maximum drift occurs at floor no.18.
- As L_1/L_2 ratio increases the maximum design storey drift decreases upto L_1/L_2 ratio

=0.50 and remains almost constant thereafter. The maximum value of drift is 1.19 mm.

The following observations are made from Table 11 for U-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.18.
- As L_1/L_2 ratio increases the maximum design storey drift decreases upto L_1/L_2 ratio =0.50 and remains almost constant thereafter. The maximum value of drift is 1.19 mm.

Table 12: Values of design storey drift in m

STOREY NO.	WL/EL in Y-direction; Infill							
	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	0.00042	0.00049	0.00054	0.00054	0.00056	0.00065	0.0007	0.00074
19	0.00054	0.00063	0.0007	0.00072	0.00075	0.00087	0.00094	0.001
18	0.00067	0.00076	0.00086	0.00088	0.00092	0.00107	0.00117	0.00125
17	0.00075	0.00083	0.00093	0.00095	0.00101	0.00118	0.00129	0.00137
16	0.00063	0.00066	0.00073	0.00074	0.00086	0.00096	0.00102	0.00107
15	0.00066	0.00049	0.00038	0.00035	0.00086	0.00066	0.00056	0.00049
14	0.00073	0.00055	0.00044	0.0004	0.00097	0.00075	0.00064	0.00057
13	0.00079	0.0006	0.00049	0.00046	0.00105	0.00083	0.00072	0.00065
12	0.00084	0.00064	0.00054	0.00051	0.00112	0.0009	0.00079	0.00072
11	0.00088	0.00068	0.00058	0.00055	0.00117	0.00096	0.00085	0.00079
10	0.00092	0.00071	0.00061	0.00058	0.00121	0.00100	0.0009	0.00084
9	0.00096	0.00073	0.00063	0.00061	0.00125	0.00104	0.00094	0.00088
8	0.00099	0.00074	0.00065	0.00063	0.0013	0.00106	0.00097	0.00092
7	0.00102	0.00075	0.00066	0.00064	0.00135	0.00108	0.00099	0.00094
6	0.00104	0.00075	0.00066	0.00065	0.00139	0.00108	0.001	0.00095
5	0.00106	0.00074	0.00066	0.00065	0.00142	0.00108	0.001	0.00096
4	0.00106	0.00072	0.00065	0.00065	0.00143	0.00106	0.001	0.00096
3	0.00104	0.0007	0.00064	0.00063	0.0014	0.00103	0.00097	0.00094
2	0.00095	0.00064	0.0006	0.0006	0.00129	0.00095	0.00091	0.00089
1	0.00078	0.00054	0.00054	0.00053	0.00106	0.0008	0.00079	0.00079
PLINTH	0.00036	0.00025	0.00025	0.00025	0.00048	0.00037	0.00037	0.00038
BASE	0	0	0	0	0	0	0	0

The following observations are made from Table 12 for U-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.18.
- The maximum design storey drift occurs when L_1/L_2 ratio = 0.25 and the value is 1.06 mm.

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

- For L_1/L_2 ratio = 0.25, maximum design storey drift occurs at floor no.5.
- For other values of L_1/L_2 ratio, maximum design storey drift occurs at floor no.18.
- The maximum design storey drift occurs when L_1/L_2 ratio = 0.25 and the value is 1.43 mm.

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	0.00035	0.00043	0.00049	0.00053	0.00119	0.00082	0.00082	0.00081
III	0.00056	0.00058	0.00058	0.00061	0.00119	0.00082	0.00082	0.00080
IV	0.00081	0.00085	0.00085	0.00090	0.00106	0.00083	0.00093	0.00095
V	0.00120	0.00126	0.00130	0.00133	0.00143	0.00118	0.00129	0.00137

From Table 13, 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 zones II and III, decreases with L_1/L_2 ratio.
- The maximum design storey drift in y-direction decreases from a maximum value to a minimum value at L_1/L_2 ratio = 0.5 and later increases in the cases of zones IV and V.
- The absolute maximum 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 zones II and III.

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 U-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	3315.92	3211.171	3321.2045	3320.9262	5554.4633	5580.9987	5577.271	5574.2551
TB2	4380.75	4384.891	4386.7992	4387.8982	5584.2446	5595.5987	5604.195	5609.2516

Table 15: Maximum moments in Transfer Girders of U-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	2807.66	2812.661	2674.1934	2812.473	4722.1114	4750.9302	4529.304	4744.4007
TB2	3671.86	3675.299	3407.8623	3677.9247	4632.0536	4643.5267	4227.163	4657.4696

From the results obtained, the following are observed in regard to transfer girders:

- The variation of design moments with L_1/L_2 ratio is insignificant.
- The variation of design moments with zone is also insignificant.
- The influence of infill wall on the moments is not insignificant. 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 U-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	664.833	694.5527	717.0256	733.5771	1235.474	1315.253	1375.827	1420.44
III	664.833	694.5527	717.0256	733.5771	1235.474	1315.253	1375.827	1420.44
IV	739.9536	732.4219	736.0961	742.7527	1438.023	1415.628	1425.542	1443.512
V	861.8816	850.6869	856.3136	866.2555	1766.763	1734.945	1750.129	1776.969

Table 17: Maximum moments in Main Beams of U-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	590.2441	621.8906	644.24	660.8244	1091.547	1176.738	1236.98	1281.682
III	599.3059	621.8906	547.1529	660.8244	1114.3	1176.738	1039.81	1281.682
IV	684.6294	685.8186	612.9714	693.7782	1344.62	1347.779	1227.424	13692686
V	812.5846	814.1504	819.7764	826.6564	1690.018	1694.273	1709.463	1728.039

From the results obtained, the following are observed in regard to main beams:

- The variation of design moments with L_1/L_2 ratio is not significant.
- The variation of design moments with zone is also not significant.
- The influence of infill wall on the design moments is not insignificant. 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	0.000567	0.000504	0.000360	0.000331
0.5	0.000606	0.000534	0.000376	0.000351
0.75	0.000634	0.000551	0.000387	0.000364
1.0	0.000655	0.000563	0.000395	0.000371

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	0.000907	0.000807	0.000555	0.000508
0.5	0.000969	0.000854	0.000580	0.000540
0.75	0.001014	0.000882	0.000577	0.000543
1.0	0.001049	0.000901	0.000611	0.000572

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	0.001361	0.001210	0.000814	0.000745
0.5	0.001454	0.001281	0.000852	0.000792
0.75	0.001521	0.001323	0.000848	0.000798
1.0	0.001573	0.001352	0.000898	0.000841

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	0.002041	0.001815	0.001204	0.001099
0.5	0.002180	0.001921	0.001260	0.001170
0.75	0.002282	0.001984	0.001300	0.001217
1.0	0.002359	0.002028	0.001329	0.001243

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.
- Absolute maximum value of storey drift in x-direction occurs when L_1/L_2 ratio is unity for all zones and both cases of infill and no fill according to ESLFM and RSM.
- The maximum 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 the 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	0.000500	0.000456	0.000466	0.000423
0.5	0.000440	0.000415	0.000416	0.000396
0.75	0.000482	0.000445	0.000450	0.000422
1.0	0.000512	0.000466	0.000474	0.000440

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	0.000676	0.000586	0.000639	0.000553
0.5	0.000637	0.000593	0.000591	0.000557
0.75	0.000699	0.000641	0.000668	0.000619
1.0	0.000745	0.000673	0.000680	0.000625

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	0.000926	0.000802	0.000884	0.000768
0.5	0.000899	0.000834	0.000825	0.000775
0.75	0.000989	0.000902	0.000928	0.000855
1.0	0.001057	0.000948	0.000954	0.000873

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	0.001308	0.001142	0.001259	0.001104
0.5	0.001292	0.001194	0.001175	0.001101
0.75	0.001425	0.001294	0.001285	0.001187
1.0	0.001525	0.001361	0.001365	0.001244

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 for all the cases.
- Absolute maximum value of storey drift in y-direction occurs when L_1/L_2 ratio is 1.0 for all zones and both cases of infill and no fill according to ESLFM and RSM.
- The maximum storey drift in y-direction in any case is smaller when infill is considered in the analysis.
- The response spectrum method predicts lower 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.
- For all the L_1/L_2 ratios and zones, maximum design storey drift in x-direction occurs at floor no.18.
- The maximum design storey drift in y-direction occurs either at floor no.5 or 6 or 18.
- 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, increases with L_1/L_2 ratio.
- The maximum design storey drift in y-direction, for zones II and III, decreases with L_1/L_2 ratio. For the other zones, the maximum design storey drift decreases from a maximum value at L_1/L_2 ratio =0.25 to a minimum value at L_1/L_2 ratio=0.5 and later increases.
- The absolute maximum 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 zone II. The maximum design storey drift in y-direction is smaller than that in x-direction for zones IV and V. The variation in zone III is as defined in relevant Table.

(ii) With 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 zone II, maximum design storey drift in x-direction occurs at either floor no.18 or 4. In the other zones it occurs at floor no.18.
- 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 or 18.
- 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 zones II and III, decreases with L_1/L_2 ratio.
- The maximum design storey drift in y-direction decreases from a maximum value to a minimum value at L_1/L_2 ratio = 0.5 and later increases in the cases of zones IV and V.
- The absolute maximum 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 zones II and III.

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 design moments is not insignificant. 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

- The maximum storey drift in x- and y-directions increases monotonically with the severity of the zone.
- Absolute maximum value of storey drift in x- and y-directions occurs when L_1/L_2 ratio is unity for all zones and both cases of infill and no fill according to ESLFM and RSM.
- The maximum storey drift in x- and y-directions in any case is smaller when infill is considered in the analysis.
- The response spectrum method predicts lower maximum storey drift in x- and y-directions compared to the equivalent static lateral force method in all the cases.

ACKNOWLEDGMENT

The authors gratefully acknowledge the encouragement and support provided by the Management, Principal and Head of the Department of Civil Engineering **Dr. Y. Ramalinga Reddy**, Reva Institute of Technology and Management, Bengaluru 560064.

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