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EVALUATION OF SHEAR WALL AS LATERAL LOAD RESISTING SYSTEM FOR A 12 STOREY RC BUILDING FRAME

Vidyashree D[1], Akash V [2], Kiran Kumar K S [3], Abhisheka.T [4], Yamanappa[5]

[1]*Assistant Professor, Dept. of Civil Engineering, Global Academy of Technology, Karnataka, India.*
[2,3,4,5] *U G student, Dept. of Civil Engineering, Global Academy of Technology, Karnataka, India.*

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Abstract - *A sudden tremor or movement of the earth's crust, which originates naturally at or below the surface of earth, causes an earthquake. This sudden movement of earth causes damage to or collapse of buildings and other manmade structures. Hence seismic (Earthquake) analysis is necessary for a structure so as to withstand minor earthquakes elastically without any damage, and major earthquake with acceptable level of dam\age, thus ensuring safety of people and contents. Therefore, it is important to know the behavior of building frame with different Lateral (earthquake) Load Resisting Structural Systems (LLRS). In the present study, an attempt is made to study the difference in structural behavior of 3-dimensional 2 X 4 bays, 12 storey basic moment resisting Reinforced Concrete (RC) frame provided with external shear wall as LLRS. The detailed investigations are carried out for zone V of seismic zone of India as per IS 1893 (part-1):2016, considering primary loads (dead, live and seismic loads) and their combinations. Six models are analyzed which consists of basic moment resisting frame with square column and frames with external shear wall at corners as LLRS. The results obtained from the Equivalent static lateral load method (ESLM) are thoroughly investigated for maximum values of joint displacements, support reactions, storey drift, and principal stress. The results indicate better resistance to lateral loads in the presence of shear wall provided at corners of the building.*

Key Words: External Shear Wall, Staad Pro, ESLM, LLRS.

INTRODUCTION

A natural hazard like Earthquake causes damage to or collapse of buildings and other man-made structures. Seismic analysis and design is necessary for a structure to withstand minor earthquakes elastically without any structural damage, and major earthquake with acceptable level of damage depending on the importance of the building ensuring safety of people and contents, and thereby a disaster is avoided. Many existing buildings lack the seismic strength and detailing requirements as per Indian standard codes of practice at present. An existing structure may need upgrading if the structure was initially not designed and constructed to resist an earthquake i.e. designed only for gravity loads but still has not undergone failure. For structures, which have undergone failure due to earthquake, it is essential to retrofit for future use. There are several techniques which can be thought off for upgrading or retrofitting, but the one which is suitable structurally and economically for the existing condition of the building, requires a thorough investigation, so a research is very much essential in this regard.

PRESENT INVESTIGATION

The study on External Shear walls for 12 storey frames are limited. Most of the studies are confined to 10 storey building, where as in reality structures have varying no. of stories and such studies are limited [2-4]. Thus, the present investigation is concerned with detailed 3D study of results of analysis of a twelve storey moment Resisting Frame having two bays along X and four bays along Z provided with external shear wall at corner, as Lateral load resisting systems (LLRS), in comparison with identical Moment Resisting Bare Frame (without any special LLRS feature) subjected to gravity load, seismic load and their combinations. External shear wall is considered in the present investigation. The study is hoped to be helpful during retrofitting of such structures which are initially designed only for gravity loads and found unsafe for seismic loads and any combination of loads.

METHOD OF ANALYSIS

The present study undertaken deals with Linear Static Analysis i.e., Equivalent Static Linear Load Method.

Modelling of the structures

For the present 3D study STAAD.Pro software package is used.

DETAILS OF THE PROBLEM CHOSEN

Plan and height of the bare frame

The plan (Figure1) consists of two bays of span 5.0m each along X direction, four bays of span 5.0m each along Z direction. The typical Twelve–storey building has each storey height of 3.0m along Y direction.
Beam Cross–Sections Size
Along X and Z directions (for all frames considered):

230mm X 500mm
Plinth Beam Size
P1 along X and Z directions (for all frames considered): 230mm X 300mm
Column Size Square column (for all frames considered): 750mm X 750mm.
Shear Wall Thickness (for all frames considered): 100mm

Frame with special features of LLRS:

Frames with External Shear Wall at Corners provided at end along X and Z directions (ESXZ2C)(Figure 2).

Seismic zone

Zone V of Seismic zones of India, as per IS:1893(part-1)-2016 code for which zone factor(Z) is 0.36.

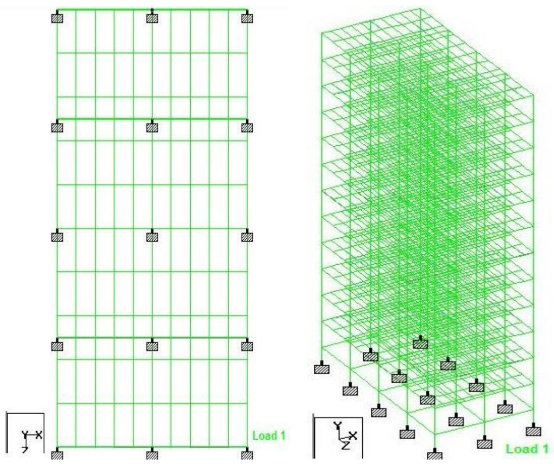

Figure 1. Typical Plan and 3D view of Bare Frame

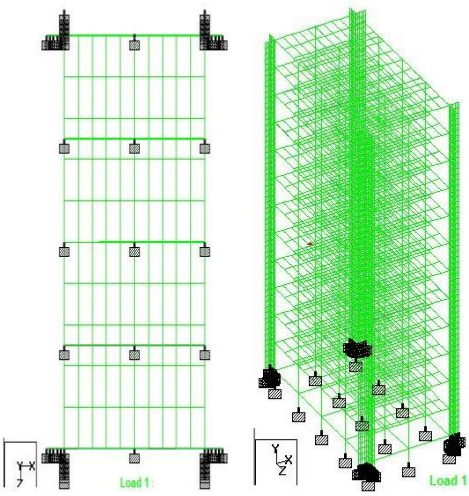

Figure 2. Typical Plan and 3D view of External Shear Wall at Corners (ESXZ2C)

Types of primary loads and load combinations

The structural systems are subjected to three types of Primary Load Cases as per IS: 875-1987 code [8], they are

1. Dead Load case (Gravity load), "DL"
2. Live Load case (Gravity load), "LL"
3. Seismic Load in X-direction (Lateral), "ELx"
4. Seismic Load in Z-direction (Lateral), "ELz"

In addition, the structural systems are subjected to 13 different Load Combinations, they are:

5. 1.5(DL+LL)
6. 1.2(DL+LL+ELx)
7. 1.2(DL+LL-ELx)
8. 1.2(DL+LL+ELz)
9. 1.2(DL+LL-ELz)
10. 1.5(DL+ELx)
11. 1.5(DL-ELx)
12. 1.5(DL+ELz)
13. 1.5(DL-ELz)
14. (0.9DL+1.5ELx)
15. (0.9DL-1.5ELx)
16. (0.9DL+1.5ELz)
17. (0.9DL-1.5ELz)

The dead load consists of self-weight of structural elements and masonry wall load of thickness 230mm.The live load considered is as adopted for medium office, hospital or hostel building i.e., 4kN/m^2 as per IS code IS:875-1987. Equivalent Static Linear Method is adopted for the calculation of the lateral load at each floor level as per IS: 1893 (part-1)-2016 code. The lateral loads applied are given in Table 1.

Physical properties considered for present study.

Density of brick wall = 18.85 kN/m^3
Poisson's Ratio of concrete = 0.17
Density of R.C.C = 25 kN/m^3
E of concrete = 2.17185x 10^7 kN/m^2

RESULTS AND DISCUSSIONS

The results obtained by "Equivalent Static Lateral Force Method" of analysis, are presented in Table 2, along with the corresponding load cases. The table indicates the results of frame with all types of LLRS considered (i.e. ESXZ2C) and for the moment resisting Bare frame (BF). The discussion focus on the comparison between frame with LLRS considered and the basic Bare frame with respect to the maximum joint displacements (X, Y and Z directions), Maximum support reaction, Storey drift and Maximum Principal stresses.

Table 1 represents the details of lateral load for each storey level and also for bare frame and external shear wall.

Table 1. Lateral Load at each Storey calculated by ESLM for zone V

SL NO	BARE FRAME			
	END FRAMI	MID FRAME	Z AXIS END	Z AXIS MID
1	0.55	0.84	1.02	1.56
2	2.20	3.35	4.10	6.26
3	4.96	7.54	9.22	14.08
4	8.82	13.40	16.40	25.03
5	13.78	20.93	25.62	39.11
6	19.84	30.14	36.89	56.32
7	27.00	41.03	50.21	76.66
8	35.27	53.59	65.59	100.13
9	44.63	67.82	83.01	126.72
10	55.10	83.73	102.48	156.45
11	66.68	101.31	124.00	189.30
12	59.55	92.25	111.56	172.72

SL NO	ESXZ4C			
	END FRAME	MID FRAME	Z AXIS END	Z AXIS MID
1	0.59	0.84	1.06	1.56
2	2.36	3.35	4.25	6.26
3	5.30	7.54	9.57	14.08
4	9.43	13.40	17.00	25.03
5	14.73	20.93	26.57	39.11
6	21.21	30.14	38.26	56.32
7	28.87	41.03	52.08	76.66
8	37.70	53.59	68.02	100.13
9	47.72	67.82	86.09	126.72
10	58.91	83.73	106.28	156.45
11	71.28	101.31	128.60	189.30
12	62.34	92.25	114.36	172.72

Maximum Joint Displacements

For all structural systems considered, the maximum joint displacement is observed at the top storey level, the bare frame (without any LLRS) undergoes the maximum joint displacement namely Max X and Max Z. (table 4).

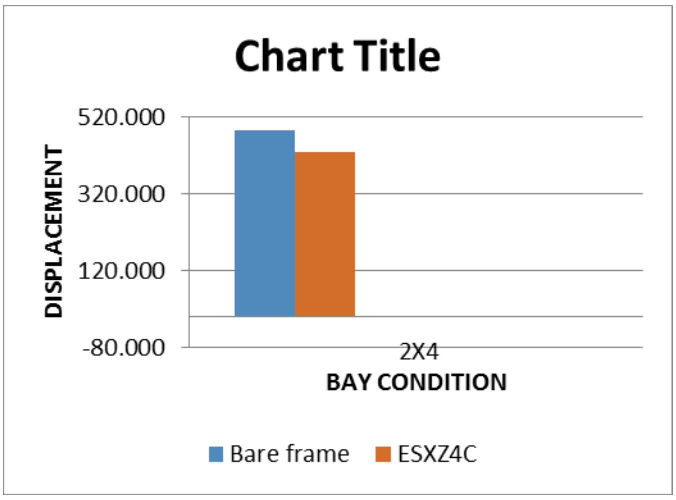

Figure 3. Graph showing variations in displacement of bare frame and external shear wall at corner.

Maximum Support reactions

For all structural systems considered, the support reactions is observed as shown in table 2 and table 3. Graph represents the variations in support reactions of bare frame and external shear wall.

Table 2 - MAXIMUM SUPPORT REACTION 12 STOREY BUILDING ZONE II column 0.75 x 0.75m

Frame	Type of frame	Max Fx			Max Fz		
		L/C	Max FxkN	Node No.	L/C	Max FzkN	Node No.
2x4	Bare frame	5	**25.696**	13	5	**26.148**	2
	ESXZ2C	5	**50.425**	1921	5	**-48.467**	388 0

Table 3 - MAXIMUM SUPPORT REACTION 12 STOREY BUILDING ZONE II column 0.75 x 0.75m

Frame	Type of frame	Max Fx			Max Fz		
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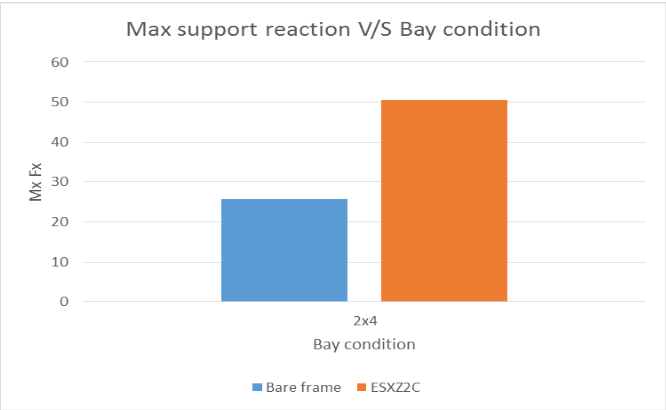

Figure 4. Graph showing variations in maximum support reaction along X direction of bare frame and external shear wall at corner.

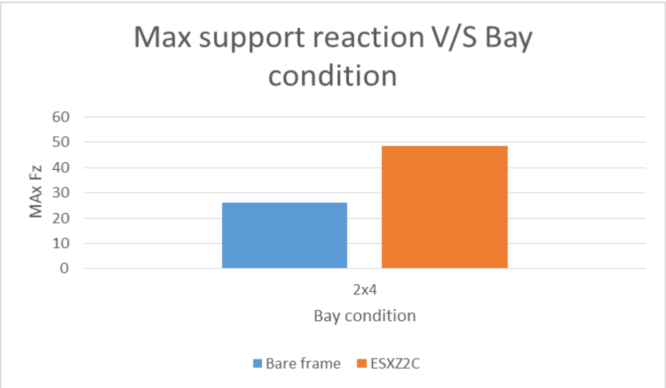

Figure 5. Graph showing variations in maximum support reaction along Z direction of bare frame and external shear wall at corner.

Storey Drift

For the structural system considered storey drift were obtained as shown the figure 6 and figure 7.

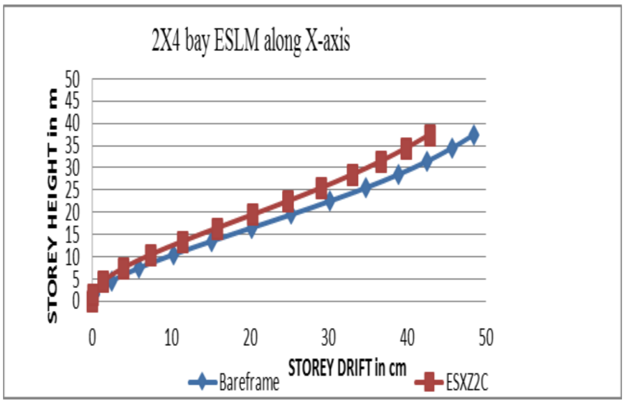

Figure 6. Storey drift of Bare frame and External shear wall along X -axis.

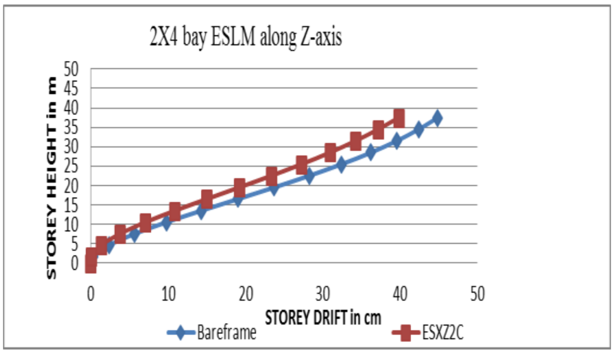

Figure 7. Storey drift of Bare frame and External shear wall along Z- axis.

Maximum Principal Stresses

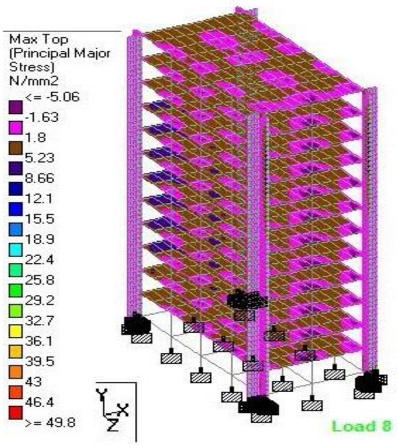

Figure 8. 2x4 Bays ESXZ2C Max Top Principal Stress

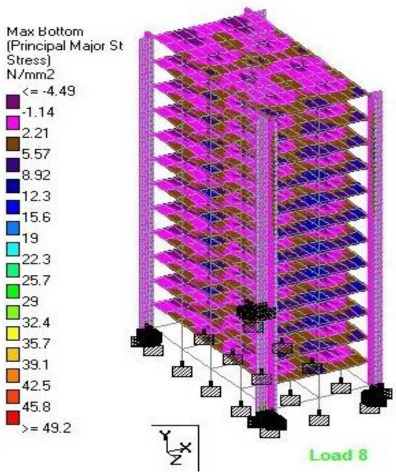

Figure 9.2x4 Bays ESXZ2C Max Bottom Principal Stress

Table 5 MAXIMUM PRINCIPAL STRESS,12 STOREY BUILDING, ZONE V, column 0.75x0.75m													
		Max Smax, N/mm^2				Max Smin, N/mm^2				Max Tmax, N/mm^2			
Frame	Type of frame	L/C	Position	Max Smax	Plate Number	L/C	Position	Max Smin	Plate Number	L/C	Position	Max Tmax	Plate Number
2x4	ESXZ2C	15	Top	67.38	2601	13	Top	-72.93	3253	10	Bottom	35.46	3597

Table 4. MAXIMUM JOINT DISPLACEMENT, 2(5m)x4(5m each) bays frame, 12 STOREY BUILDING, ZONE V Column 0.75mx0.75m											
Frame	Type of frame	Max X			Max Z			Max ABSL			δ_e=
		L/C	X-Trans	Position	L/C	Z-Trans	Position	L/C	ABL Trans	Position	$1/((1/\delta_x)+(1/\delta z))$
2X4	Bare frame	11	485.2	J-IV-9	13	368.53	I-III-8	10	485.3	DM-I-II-14	209.46
	ESXZ2C	11	428.7	Q-VI-17	13	398.67	S-VII-19	10	428.9	S-VIII-19	206.59

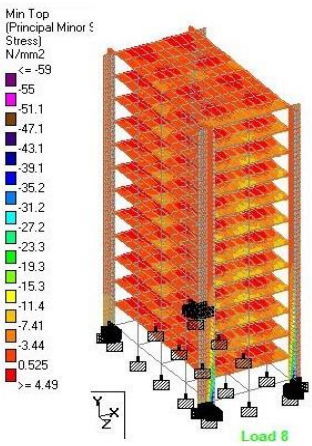

Figure 10. 2x4 Bays ESXZ2C Min Top Principal Stress

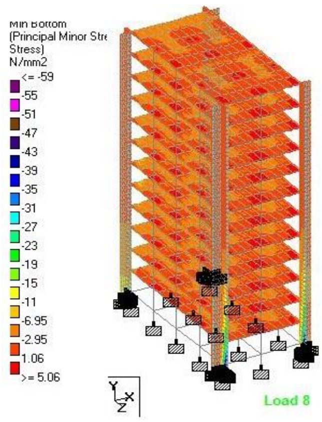

Figure 11.2x4 Bays ESXZ2C Min Bottom Principal Stress

The principal stresses are as shown in the above figure 8. To figure 11. Clearly represents the stress at top position of the structural system considered.

Conclusions

- All the LLRS considered are effective in resisting lateral loads due to earthquake.
- Provision of External shear wall as LLRS is one of the possible option for retrofitting.
- When different LLRS considered in the study are employed in field for upgrading or retrofitting a structure, it is necessary to ensure proper connections between existing structure and LLRS provided.

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BIOGRAPHIES

Assistant Professor, Dept. of Civil Engineering, Global Academy of Technology, Karnataka, India

U G student, Dept. of Civil Engineering, Global Academy of Technology, Karnataka, India.

U G student, Dept. of Civil Engineering, Global Academy of Technology, Karnataka, India.

U G student, Dept. of Civil Engineering, Global Academy of Technology, Karnataka, India.

U G student, Dept. of Civil Engineering, Global Academy of Technology, Karnataka, India.