International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 07 | July 2024 www.irjet.net p-ISSN: 2395-0072

STUDY ON POSITIONING OF SHEAR WALL IN RC STRUCTURE FOR RESISTING SEISMIC LOADS

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Abstract - *Earthquakes can inflict damage not only through direct vibrations but also through secondary effects such as landslides, floods, and fires. The response of a building during an earthquake largely depends on its overall shape, size, geometry, and the impact of seismic forces on the ground. Reinforced concrete (RC) multi-story buildings are generally designed to withstand both vertical and horizontal loads. Shear walls, which are structural elements used to counteract horizontal forces, play a crucial role in this regard. With their high stiffness and strength, shear walls can resist significant horizontal loads while also supporting gravity loads, making them essential for both economic efficiency and controlling horizontal displacement. This study examines the effect of shear wall placement on seismic load resistance. Finite Element (FE) analysis is performed on a G+13 RC building to evaluate various shear wall configurations. Results from the Response Spectrum Analysis include natural time period, base shear, story displacement, and story drift.*

Key Words: **Earthquake, Geometry of the structure, Shear wall, Horizontal Displacement, FE analysis, Natural time period, Base shear, Storey displacement and Storey drift.**

1. INTRODUCTION

An earthquake is a sudden shaking of the ground caused by the passage of seismic waves. Earthquake Ground Motions (EQGMs) transfer significant energy to structures, making them highly vulnerable to sudden damage. Consequently, designing structures to minimize vibrations caused by earthquakes has been a longstanding concern for structural engineers. Reinforced Concrete (RC) buildings often incorporate vertical plate-like RC walls known as shear walls. These shear walls are specifically engineered to resist horizontal forces induced in the plane of the wall from wind, earthquakes, and other forces. Therefore, buildings When buildings are designed without shear walls, the sizes of beams and columns need to be significantly larger, which can lead to issues at the joints. These larger structural elements can cause congestion in certain areas, making it challenging to properly vibrate the concrete, and resulting in noticeable displacement. This increased displacement can, in turn, induce substantial forces within the building's members. In such cases, incorporating shear walls becomes crucial for both economic efficiency and effective control of horizontal displacement.

1.1 Shear Wall

In addition to beams and columns, Reinforced Concrete (RC) buildings commonly include vertical, plate-like RC walls known as shear walls. These shear walls typically extend from the foundation level to the top of the building. Their thickness can range from 150mm to 400mm in moderate to high-rise structures. Functioning like vertically oriented wide beams, shear walls are strategically placed along both the length and width of the building.

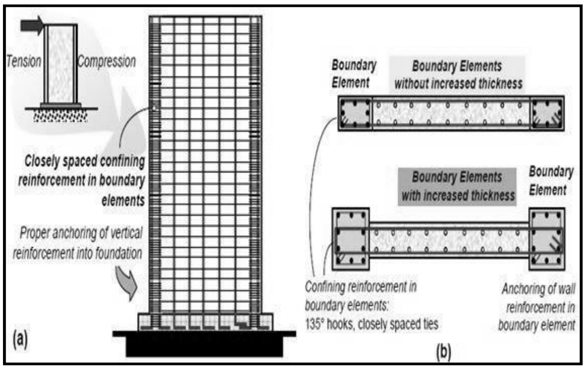

Fig-1: Layout of Main Reinforcement in Shear Wall as per IS: 13920:1993 (IITK: Earthquake Tips)

Shear walls are straightforward to construct due to their simple reinforcement detailing, which can be easily implemented on site. They are both cost-effective and efficient in reducing earthquake damage to structural and non-structural elements. Shear walls typically have an oblong cross-section, where one dimension is much larger than the other. While rectangular cross-sections are common, L- and U-shaped sections are also utilized. Thin-walled hollow RC shafts around elevator cores can also function as shear walls and should be utilized to resist earthquake forces. Steel reinforcing bars are arranged in regularly spaced vertical and horizontal grids within these walls, often organized into one or two parallel layers, known as curtains. Horizontal reinforcement must be anchored to the ends of the walls, and the minimum area of reinforcing steel should be 0.0025 times the cross-sectional area in both horizontal and vertical directions. This vertical reinforcement should be evenly distributed across the wall's cross-section.

1.2 Loading and Failure Mechanisms

A shear wall resists loads that are parallel to its plane. Collectors, also known as drag members, transfer the diaphragm shear to shear walls and other vertical elements of the seismic force-resisting system. Shear walls can be constructed from various materials, including light-framed or braced wooden walls with thin shear-resisting panels, reinforced concrete walls, reinforced masonry walls, or steel plates

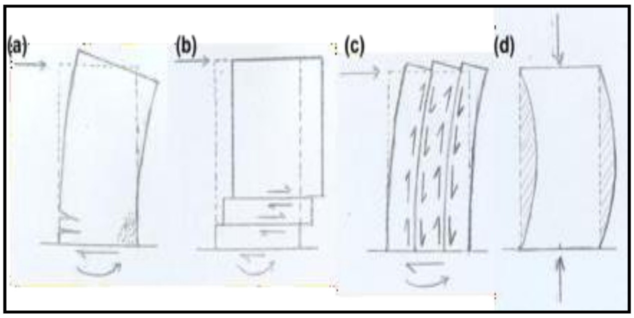

Fig-2: Failure mechanisms of shear walls.

(a) Flexural failure, (b) Horizontal shear, (c) Vertical shear, (d) buckling

A shear wall is stiffer along its principal axis compared to the other axis. It functions as a primary structural element, providing significant resistance to both vertical and horizontal forces acting within its plane. Under these combined loading conditions, a shear wall experiences complex internal stress distributions due to axial, shear, torsional, and flexural strains. This allows for the vertical transfer of loads to the building's foundation. Consequently, there are four critical failure mechanisms, as illustrated in Fig-2. Factors influencing these failure mechanisms include the wall's geometry, loading conditions, material properties, restraint, and construction techniques. Shear walls can also be constructed using light-gauge steel diagonal bracing members, which are connected to collectors and anchor points.

Various studies have been conducted by different authors, leading to various conclusions. These studies often involve creating 3D building models for both linear static and linear dynamic analyses, as well as examining the impact of incorporating a concrete core wall at the building's center. These analyses compare different models to assess performance under various conditions.

Placing a shear wall at the center of a building, along with four shear walls positioned at the outer edges parallel to the X and Y directions, results in maximum base shear, reduced displacement, and minimized inter-story drift in both equivalent static and response spectrum analyses, particularly in the longitudinal direction. The presence of shear walls enhances the strength and stiffness of the structure (Shahzad Jamil Sardar and Umesh N. Karadi). It is observed that base shear and displacement are greater along the slope compared to the transverse direction. Among various configurations, straight or rectangular shear wall arrangements are generally more effective in resisting lateral displacement. However, during seismic events, L-shaped configurations can be particularly advantageous (Pawar S.P.).

The earthquake-resistant performance of a building improves with the strategic placement of shear walls, particularly when they are centrally located and symmetrically arranged. Nevertheless, in some cases, lateral displacements may still be minimal. Additionally, plan irregularity plays a significant role in seismic evaluation (Tabarej Alam).

This chapter outlines the structural models used in this study, providing a comprehensive summary of the parameters considered for analyzing the positioning of shear walls in resisting seismic loads. It includes details on the plan for each respective model. The chapter also explains the methodology employed to compute these parameters and highlights key features of the current provisions for earthquake-resistant design in reinforced concrete lateral force-resisting systems.

2. METHODOLOGY

A comprehensive literature review is conducted to examine the positioning of shear walls in resisting seismic loads and to develop Response Spectra for all seismic zones according to IS: 1893 (Part-1): 2016. The study involves performing modal analysis on a G+13 RC structure with various shear wall configurations to determine the Time Period and mode shapes. Additionally, Equivalent Static and Response Spectrum Analyses are carried out to calculate Static Base Shear, Dynamic Base Shear, Scale Factor, Corrected Base Shear, Displacement, and Storey Drift. The results from the modal analysis are compared with the Time Period formulae provided in IS: 1893 (Part-1): 2016. All Finite Element (FE) analysis results are presented in tabulated form, discussed, and used to draw conclusions.

2.2 Material properties considered for analysis.

The present study adopts structural 3D models with different positioning of the shear wall placed in the RC structure is mentioned. The seismic response of these models with different shear wall position is compared with the regular frame system RC structure model. The base plan size has been kept as 25m x 25m. The structural configuration are shown in Table-1 and model nomenclature are shown in Table-2.

Table -1: Structural configuration

Description	Data
Type of structure	RC structure
Grade of Concrete (fck)	M30
Grade of Reinforcing Steel (fyr)	Fe 500
Number of storeys	G+13
Storey to storey Height	3.0m
Bay to Bay Distance	5m
Column Size used	600 x 600
Beam Size used	300 x 450
Thickness of slab	150mm
Live load	3kN/m^2
Floor Finish Load	1.5kN/m^2
Seismic Zone	V
Seismic Zone Factor (Z)	0.36
Importance Factor (I)	1.0
Response Reduction Factor (R)	5.0
Damping Ratio	0.05
Soil Type	Medium soil
Load Combination	1. 1.5(DL+LL) 2. 1.2(DL+LL±EQ) 3. 1.5(DL±EQ) 4. 0.9DL± EQ

Table -2: Building nomenclature

RCBF	RC structure without shear wall.
RCSW	RC structure with shear wall for all the floors.
RCSWUH	RC structure with shear wall for upper half of its height.
RCSWLH	RC structure with shear wall for lower half of its height
RCSWUL3	RC structure with shear wall at upper and lower h/3
RCSWM3	RC structure with shear wall at middle h/3.

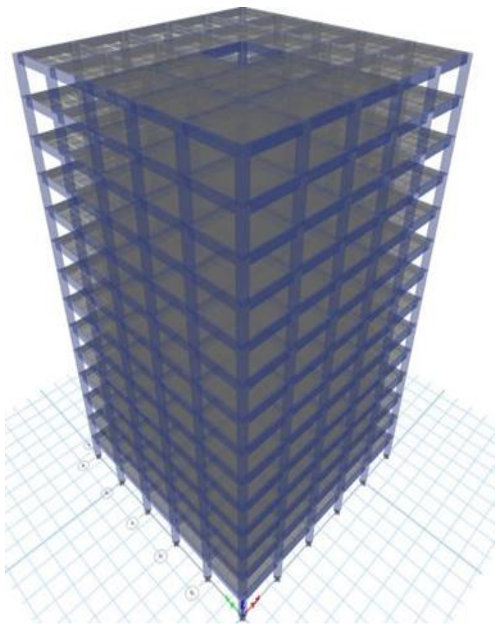

Fig 3: 3D view of RCBF

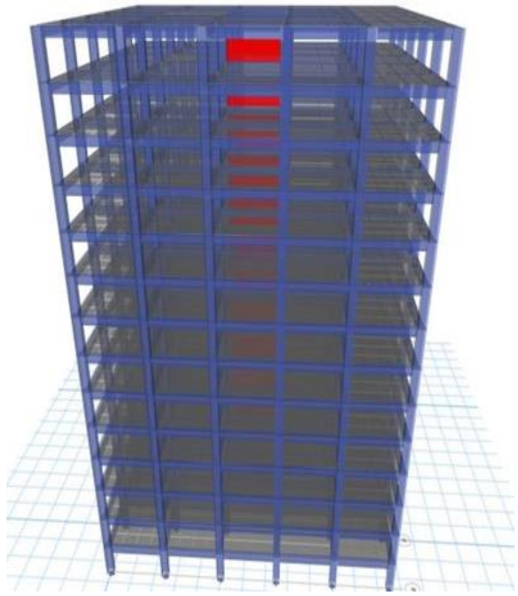

Fig 4: 3D view of RCSW

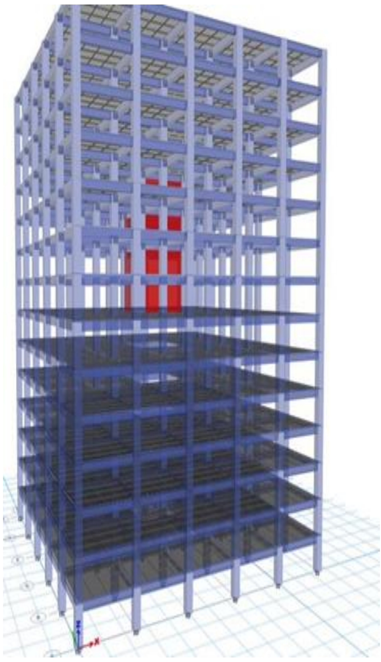

Fig 5: 3D view of RCSWUH

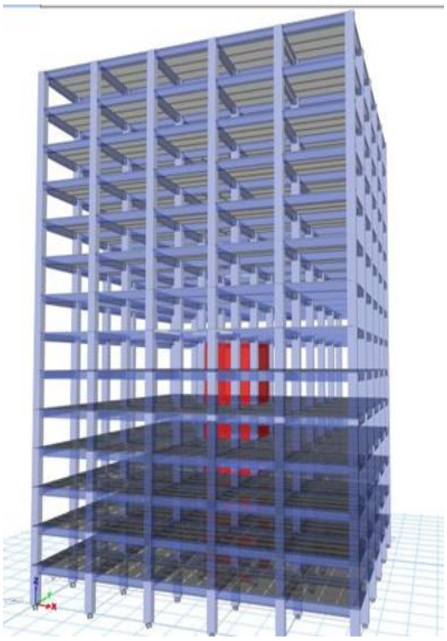

Fig 6: 3D view of RCSWLH

3. RESULTS

Table 3.1: Time Period (sec)

BUILDING MODELS	From IS 1893:2016 Time period(s)	Modal Analysis Time period(s)
RCBF	1.23	1.83
RCSW0	3.451	1.22
RCSWUH		1.74
RCSWLH		1.33
RCSWUL3		1.34
RCSWM3		1.65

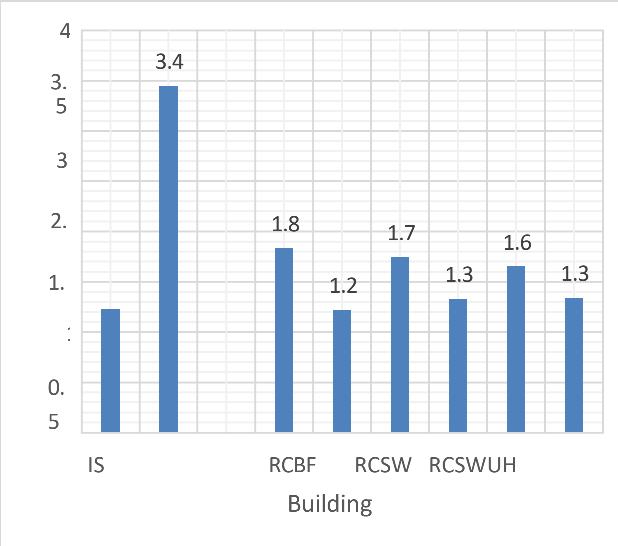

Fig 7: Time period(s)

Building models	Dynamic Base shear
RCBF	4140.048
RCSW	6036.053
RCSWUH	4474.275
RCSWLH	5493.73
RCSWUL3	5693.420
RCSWM3	4639.230

Table 3.2 Dynamic Base Shear (kN)

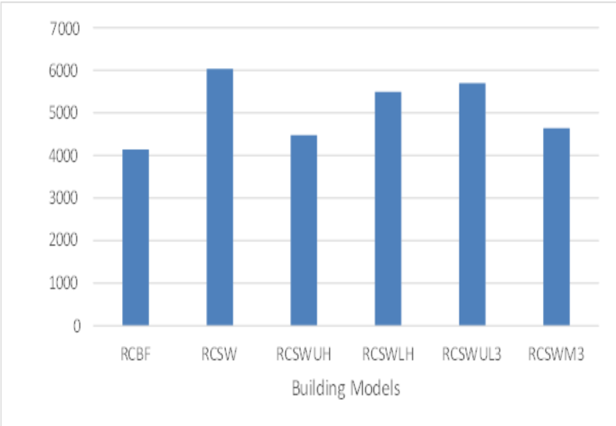

Fig 8: Dynamic base shear (kN)

Table 3.3 Storey Displacement (mm) of G+13 building

No of floors	RCBF	RCSW	RCSWUH	RCSWLH	RCSWUL3	RCSWM3
Base	0	0	0	0	0	0
Ground	3.526	1.213	3.809	1.096	1.103	3.951
1	9.615	3.361	10.385	3.02	3.003	10.778
2	16.06	6.053	17.355	5.411	5.319	17.991
3	22.297	9.17	24.116	8.146	7.921	24.807
4	28.165	12.583	30.474	11.09	10.658	30.343
5	33.612	16.18	36.242	14.11	13.795	33.474
6	38.625	19.87	40.826	17.402	19.056	36.259
7	43.195	23.577	43.359	22.312	24.914	39.075
8	47.306	27.241	45.572	27.598	30.41	41.959
9	50.932	30.813	47.785	32.514	34.909	45.335
10	54.023	34.257	49.948	36.817	37.697	48.522
11	56.517	37.55	52.032	40.348	40.115	51.147
12	58.352	40.686	54.028	42.96	42.431	53.07
13	59.531	43.459	55.81	44.605	44.482	54.276

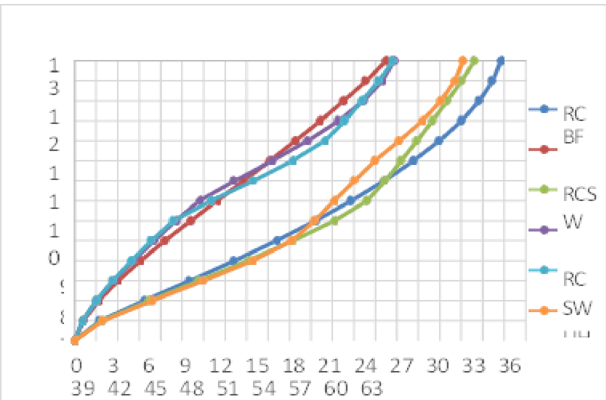

Fig 9: Storey Displacement(mm)

Table 3.4 Storey drift (10-4 mm) of G+13 building

No of floors	RCBF	RCSW	RCSWUH	RCSWLH	RCSWUL3	RCSWM3
Base	0	0	0	0	0	0
Ground	11.76	4.08	12.71	3.69	3.72	13.18
1	20.34	7.23	21.97	6.48	6.4	22.81
2	21.57	9.02	23.33	8	7.76	24.13
3	21.03	10.47	22.8	9.16	8.75	22.97
4	20.06	11.49	21.71	9.88	9.32	19.36
5	19.02	12.16	20.06	10.21	11.01	11.31
6	17.99	12.54	16.73	11.43	19.04	10.03
7	16.95	12.68	9.86	18.16	20.86	10.04
8	15.81	12.61	8.72	19.5	19.98	10.47
9	14.46	12.36	8.63	18.62	16.8	13.29
10	12.78	11.96	8.42	16.82	10.05	12.82
11	10.65	11.47	8.08	14.23	8.52	10.89
12	8.02	10.87	7.67	10.83	8.08	8.21
13	2.8	10.02	7.07	6.97	7.45	5.21

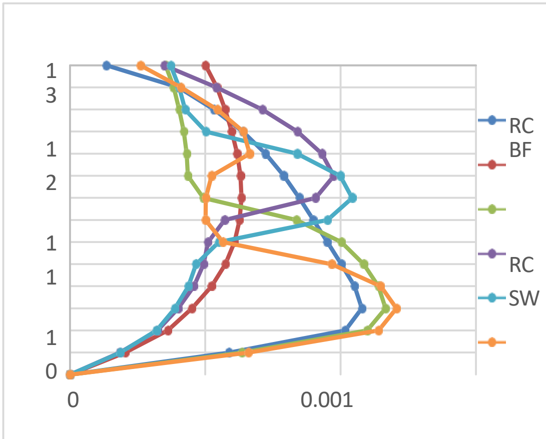

Fig 10: Storey drift

4. CONCLUSIONS

- Time Period of RC structure with complete shear wall is less compared to other models due to increase in stiffness.
- Time Period of RC structure with complete shear wall is 50% less, when compared to RC bare frame structure due to increase in stiffness.
- Time period of RC structure with shear wall for upper half of its height is 24% more,compared to RC structure with shear wall for lower half of its height due to influence of mass.

- ➢ Time period of RC structure with shear wall at upper and lower h/3 is 23% less, compared to RC structure with shear wall at middle h/3 due to increase in stiffness.
- ➢ Base shear is maximum for the RC structure with complete shear wall compared to all other models due to higher self-weight.
- ➢ Base shear of RC structure with complete shear wall is more with 31%, compared to RC bare frame structure, due to increase in its weight.
- ➢ Base shear of RC structure with shear wall at upper and lower h/3 is more with 19%, compared to RC structure with shear wall at middle h/3, due to increase in its weight.
- ➢ Base shear of RC structure with complete shear wall is 31% more compared to bare frame, 26% more in structure with shear wall for upper half of its height, 9% more in structure with shear wall for lower half of its height, 6% more for the structure for upper and lower h/3, and 23% more for structure with shear wall at middle h/3.
- ➢ RC structure with complete shear wall shows the minimum displacement compared to other cases due to increase in the stiffness.
- ➢ RC Bare Frame Structure is more displaced compared to other RC structure with complete shear wall and without shear wall at different positions due to ductility in the bare frame and lower self -weight.
- ➢ All displacements are within the permissible limit of h/500
- ➢ Displacement of RC structure without shear wall is more with 27%, compared to RC bare frame structure.
- ➢ Displacement of RC structure with shear wall for upper half of its height is more with 20%, compared to RC structure with shear wall for lower half of its height.
- ➢ Displacement of RC structure with shear wall at middle h/3 is more with 18% , compared to RC structure with shear wall at upper and lower h/3 due to increase in its ductility.
- ➢ Displacement of RC structure with complete shear wall is 37% less compared to bare frame, 28% less in structure with shear wall for upper half of its height, 3% less in structure with shear wall for lower half of its height, 2% less for the structure for upper and lower h/3, and 25% less for structure with shear wall at middle h/3.
- ➢ Storey drift for all the cases are within the permissible limit of 0.004h (h is storey height) as per IS 1893 (Part-1) 2016.
- ➢ Storey drift is reduced in all the Structures compare with RC structure with shear wall at middle h/3.0

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