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STUDY ON SEISMIC BEHAVIOR OF RC STRUCTURE WITH AND WITHOUT SHEAR WALL

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ABSTRACT

From the past records of earthquake, there's increase in the demand of earthquake resisting building which might be fulfilled by providing the shear wall systems in the buildings. For achieving economy in reinforced concrete building structures, design of crucial section is carefully done to induce reasonable concrete sizes and optimum steel consumption in members. in the present study, a trial has been made to model 04 story building with and without shear walls by static analysis method for earthquake zone III. Software is employed for the analysis. The target of this study is to assess the comparative seismic performance of buildings in terms of displacement, story drift, base shear and cost and carpet area. Buildings with shear wall area unit economical as compared to without shear wall.

1. INTRODUCTION

1.1 General

Shear walls are vertical elements of the horizontal force resisting system. Shear walls are constructed to counter the effects of lateral load acting on a structure. In residential construction, shear walls are straight external walls that typically form a box which provides all of the lateral support for the building .When shear walls are designed and constructed properly, and they will have the strength and stiffness to resist the horizontal forces. Shear Walls are structural elements in addition to slabs, beams and columns. These walls generally start at foundation level and are continuous throughout the building height. Their thickness can be low as 150mm, or as high as 400mm in high rise buildings. Shear walls are usually provided both length and width of buildings. Shear walls are like vertically – oriented wide beams that carry earthquake loads downwards to the foundation. Properly designed and detailed building with shear walls has shown very good performance in past earthquakes. Shear wall in high seismic regions require special detailing. Shear wall buildings are commonly used for residential purposes.

1.2 Need-

Shear walls are not only designed to resist gravity / vertical loads (due to its1self-weight and other living / moving loads), but they are also designed for Lateral loads of earthquakes / wind. The walls are structurally integrated with roofs / floors (diaphragms) and other Lateral walls running across at right angles, thereby giving the three Dimensional stability for the building structures. Shear wall structural systems are more stable. Other lateral wall running across at right angle, thereby giving the three dimensional stability for the building structures.

1.3 Objective-

1. To study seismic effect of RC building.
2. To study methods of Seismic Analysis.
3. To study Analysis of Design process of share wall.
4. To study steel shear wall.
5. To study RCC shear wall.
6. To do comparative Study of steel and RCC shear wall.

2. DETAIL STUDY

2.1 What is a Shear Wall Building?

Shear walls are vertical elements of the horizontal force resisting system. **Shear walls** are constructed to counter the effects of lateral load acting on a structure. In residential construction, shear walls are straight external walls that typically form a box which provides all of the lateral support for the building

2.2 PURPOSE OF CONSTRUCTING SHEAR WALLS

Shear walls are not only designed to resist gravity / vertical loads (due to its self-weight and other living / moving loads), but they are also designed for lateral loads of earthquakes / wind. The walls are structurally integrated with roofs / floors (diaphragms) and other lateral walls running across at right angles, thereby giving the three dimensional stability for the building structures.Shear wall structural systems are more stable. Because, their supporting area (total cross-sectional area of all shear walls) with reference to total plans area of building, is comparatively more, unlike in the case of RCC framed structures.

Walls have to resist the uplift forces caused by the pull of the wind. Walls have to resist the shear forces that try to push the walls over. Walls have to resist the lateral force of the wind that tries to push the walls in and pull them away from the building.

2.3 FUNCTIONS OF SHEAR WALL

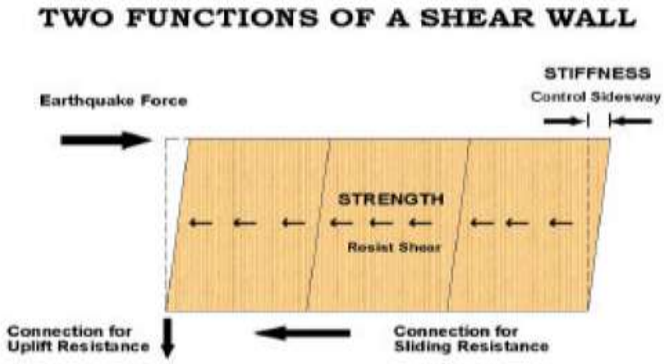


Fig.1 showing functions of shear wall Shear walls must provide the necessary lateral strength to resist horizontal earthquake forces. When shear walls are strong enough, they will transfer these horizontal forces to the next element in the load path below them. These other components in the load path may be other shear walls, floors, foundation walls, slabs or footings.

Shear walls also provide lateral stiffness to prevent the roof or floor above from excessive side-sway. When shear walls are stiff enough, they will prevent floor and roof framing members from moving off their supports. Also, buildings that are sufficiently stiff will usually suffer less non-structural damage.

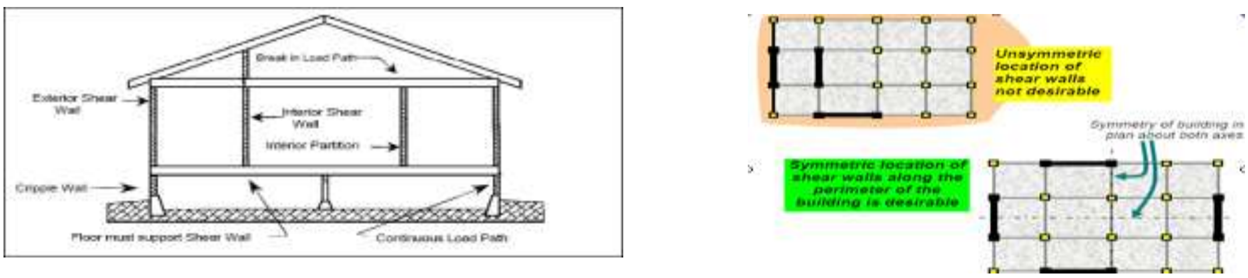


Fig.2 showing location of shear walls

Shear walls should be located on each level of the structure including the crawl space. To form an effective box structure, equal length shear walls should be placed symmetrically on all four exterior walls of the building. Shear walls should be added to the building interior when the exterior walls cannot provide sufficient strength and stiffness. Shear walls are most efficient when they are aligned vertically and are supported on foundation walls or footings. When exterior shear walls do not provide sufficient strength, other parts of the building will need additional strengthening. Consider the common case of an interior wall supported by a sub floor over a crawl space and there is no continuous footing beneath the wall. For this wall to be used as shear wall, the sub floor and its connections will have to be strengthened near the wall. For Retrofit work, existing floor construction is not easily changed. That's the reason why most retrofit work uses walls with continuous footings underneath them as shear walls.

2.4 METHODS OF DESIGN OF SHEAR WALL

There are three types of design methods

- Segmented shear wall method
- Force transfer –ground openings method
- Perforated shear wall method

2.4.1 Segmented shear wall method

The segmented shear wall method uses full height shear wall segments that comply with ratio requirements and are usually restrained against overturning by hold down devices at the ends of each segment.

2.4.2 Force transfer –ground openings method

The second method force transfer-ground openings method consider the entire shear wall with openings and the wall piers adjacent to openings are segments. The method requires the forces around the perimeter of the openings to be analyzed, designed, and detailed. With this method, the hold-down devices generally occur at the ends of the shear wall, not at each wall pier, and special reinforcement around the opening is often required.

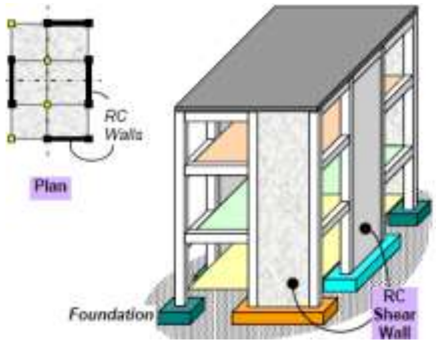
The perforated shear wall method, however, specifically requires hold-down devices at each end of the perforated shear wall.

2.5 TYPES OF SHEAR WALLS

- RC Shear Wall
- Plywood Shear Wall
- Midply Shear Wall
- RC Hollow Concrete Block Masonry Wall
- Steel Plate Shear Wall

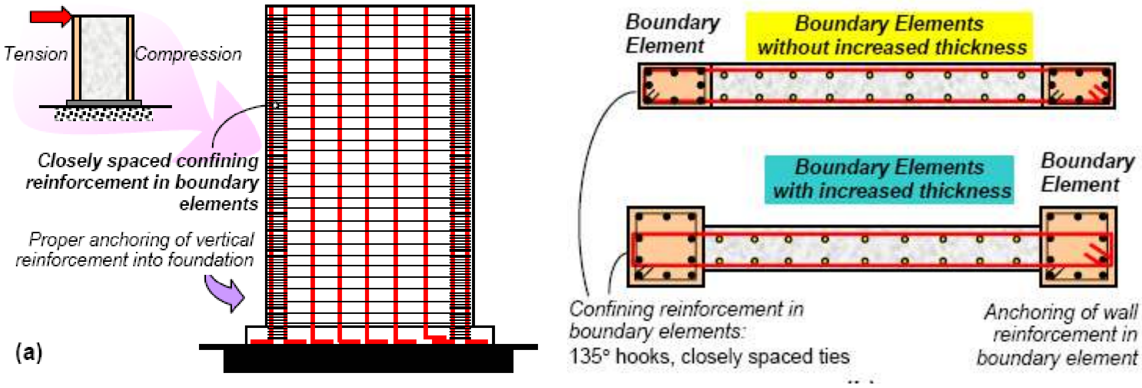
4.5.1 RC SHEAR WALL

It consists of reinforced concrete walls and reinforced concrete slabs. Wall thickness varies from 140 mm to 500 mm, depending on the number of stories, building age, and thermal insulation requirements. In general, these walls are continuous throughout the building height; however, some walls are discontinued at the street front or basement level to allow for commercial or parking spaces. Usually the wall layout is symmetrical with respect to at least one axis of symmetry in the plan.



Floor slabs are either cast-in-situ flat slabs or less often, precast hollow-core slabs. Buildings are supported by concrete strip or mat foundations; the latter type is common for buildings with basements. Structural modifications are not very common in this type of construction.

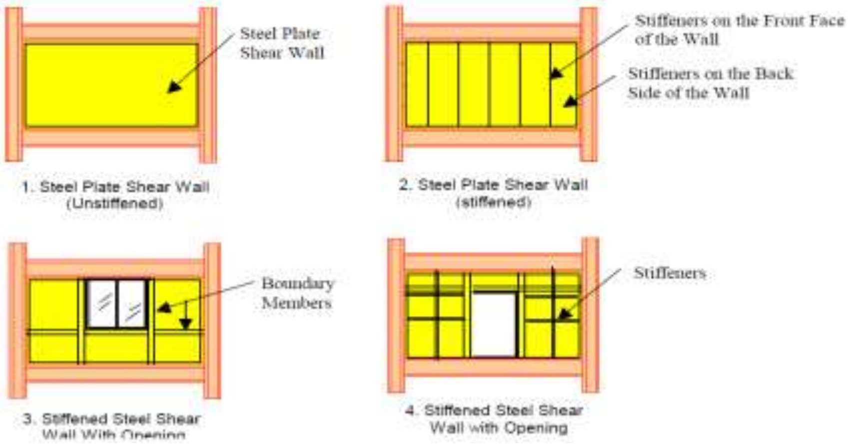
Reinforcement requirements are based on building code requirements specific for each country. In general, the wall reinforcement consists of two layers of distributed reinforcement (horizontal and vertical) throughout the wall length. In addition, vertical reinforcement bars are provided close to the door and window openings, as well as at the wall end zones (also known as boundary elements or barbells).



4.5.2 STEEL PLATE SHEAR WALL

In general, steel plate shear wall system consists of a steel plate wall, boundary columns and horizontal floor beams. Together, the steel plate wall and boundary columns act as a vertical plate girder. The columns act as flanges of the vertical plate girder and the steel plate wall acts as its web. The horizontal floor beams act, more-or-less, as transverse stiffeners in a plate girder.

Steel plate shear wall systems have been used in recent years in highly seismic areas to resist lateral loads. Figure shows two basic types of steel shear walls; un stiffened and stiffened with or without openings.



4.5.3 Advantages of Steel Plate Shear Wall

- The system, designed and detailed properly is very ductile and has relatively large energy dissipation capability. As a result, steel shear walls can be very efficient and economical lateral load resisting systems.
- The steel shear wall system has relatively high initial stiffness, thus very effective in limiting the drift.
- Compared to reinforced concrete shear walls, the steel shear wall is much lighter which can result in less weight to be carried by the columns and foundations as well as less seismic load due to reduced mass of the structure.
- By using shop-welded, field-bolted steel shear walls, one can speed-up the erection process and reduce the cost of construction, field inspection and quality control resulting in making these systems even more efficient.

2.6 ARCHITECTURAL ASPECTS OF SHEAR WALLS

Most RC buildings with shear walls also have columns; these columns primarily carry gravity loads (i.e., those due to self-weight and contents of building). Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents.

2.6.1 Ductile Design of Shear Walls

Just like reinforced concrete (RC) beams and columns, RC shear walls also perform much better if designed to be ductile. Overall geometric proportions of the wall, types and amount of reinforcement, and connection with remaining elements in the building help in improving the ductility of walls. The Indian Standard *Ductile Detailing Code* for RC members (IS:13920-1993) provides special design guidelines for ductile detailing of shear walls.

2.6.2 Geometry of Walls

Shear walls are oblong in cross-section, *i.e.*, one dimension of the cross-section is much larger than the other. While rectangular cross-section is common, L- and U-shaped sections

2.6.3 Reinforcement Bars in RC Walls

Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids. The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called curtains. Horizontal reinforcement needs to be anchored at the ends of walls. The minimum area of reinforcing steel to be provided is 0.0025 times the cross-sectional area, along each of the horizontal andvertical directions. This vertical reinforcement should be distributed uniformly across the wall cross-section.

2.7 Determination of base shear:

For the determination of seismic forces, the country is classified in four seismic zones as shown in fig. 4.2. The total design lateral force or design base shear along any principal direction shall be determined by this expression:

Vb =Ah W ----------(2.6)
Where, Ah = design horizontal seismic coefficient for a structure
W= seismic weight of building

The design horizontal seismic coefficient for a structure Ah is given by:

Ah = (ZISa)/ (2Rg) --------(2.7)

Z is the zone factor given in Table 4.1 of IS 1893:2002 (part 1) for the maximumconsidered earthquake (MCE) and service life of a structure in a zone. The factor 2 isto reduce the MCE to the factor for design base earthquake (DBE).

Table 2.1: Zone factor, Z

Seismic zone	II	III	IV	V
Seismic intensity	Low	Moderate	Severe	Very severe
Z	0.10	0.16	0.24	0.36

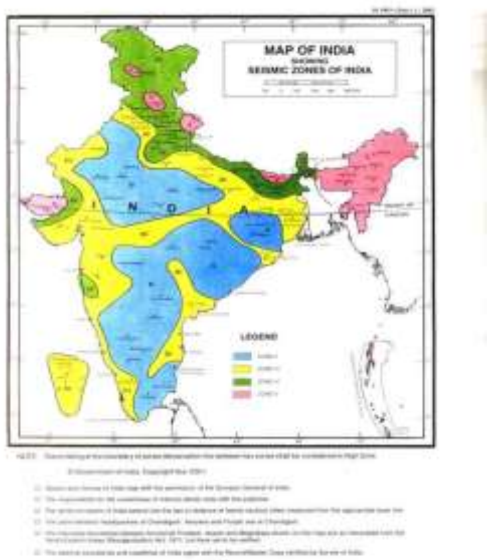


Fig. 2.3 Seismic zones of India

I is the importance factor, depending upon the functional use of the structure, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical or economic importance. The minimum values of importance factor are given in table 4.2 of IS 1893:2002.

Table 2.2: Importance factor, I

Structure	I
Important service and community building, such as hospitals; schools; monumental structures; emergency buildings like telephone exchanges television stations, radio stations, fire station buildings; large community halls like cinemas, assembly halls; and subway stations, power stations.	1.5
All other buildings	1

R is the response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. The need for introducing R in base shear formula is an attempt to consider the structure's inelastic characteristics in linear analysis. as it is undesirable as well as uneconomical to design a structure on the basis that it will remain in elastic range for all major earthquakes. Note: IS code recommends that the value of I/R should not exceed 1.0 the values of R are given in Table 4.3 of IS 1893:2002 (part 1).

Table 2.3: Response reduction factor for building systems, R

Lateral load-resisting system	R
Building frame systems	3
Ordinary RCC moment-resisting frame (OMRF)	5
Special RCC moment-resisting frame (SMRF)	
Steel frame with	
a) Concentric braces	4.0
b) Eccentric braces	5.0
Steel moment-resisting frame designed as per SP 6 (6)	5.0
Building with shear walls	
Load bearing masonry wall building	
a) Unreinforced	1.5
b) Reinforced with horizontal RCC bands	2.5
c) Reinforced with horizontal RCC bands and vertical bars at corner of rooms and jambs of openings	3.0
Ordinary RCC shear walls	3.0
Ductile shear walls	4.0
Building with dual systems	3.0
Ordinary shear wall with OMRF	4.0
Ordinary shear wall with SMRF	4.5
Ductile shear wall with OMRF	5.0
Ductile shear wall with SMRF	

Sa/g is the average response acceleration coefficient for rock and soil sites as given in figure 4.3 of IS 1893:2002 (part 1). The values are given for 5 % of damping of the structure.

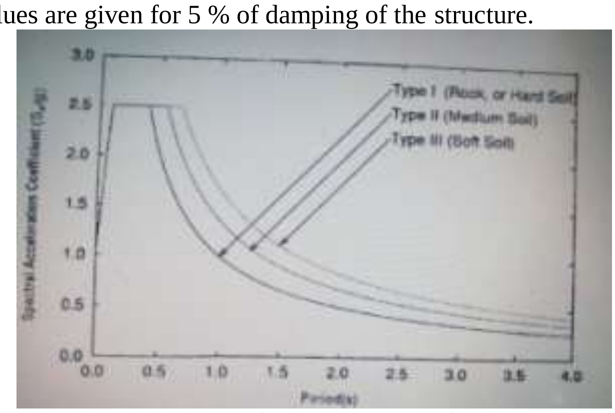


Fig2.4: Response spectra for rock and soil sites for 5% damping

T, the fundamental natural period for buildings are calculated as per Clause 7.6 of IS 1893:2002 (part 1).

Ta = 0.075h0.75 for moment resistant frame without infill walls.

Ta = 0.085 h0.75 for moment resistant steel frame without infill walls.

Ta = 0.09h/√d for all other building including moment resistant RC frames.

Where, h is the height of building in meter and d is the base dimension of the building at plinth level in meter.

2.8 Boundary Elements

Under the large overturning effects caused by horizontal earthquake forces, edges of shear walls experience high compressive and tensile stresses. To ensure that shear walls behave in a ductile way, concrete in the wall end regions must be reinforced in a special manner to sustain these load reversals without loosing strength. End regions of a wall with increased confinement are called boundary elements. This special confining transverse reinforcement in boundary elements is similar to that provided in columns of RC frames. Sometimes, the thickness of the shear wall in these boundary elements is also increased. RC walls with boundary elements have substantially higher bending strength and horizontal shear force carrying capacity, and are therefore less susceptible to earthquake damage than walls without boundary elements.

2.8.1 Shear Strength

4.9.1.4.1 The nominal shear stress, τv, shall be calculated as:

τv =Vu / bd ……..(from clause no. 9.2.1 IS:13920)

where,

Vu = factored shear force,

tw = thickness of the web, and

dw = effective depth of wall section. This may bytaken as 0.8 lw for rectangular sections.

4.8.2.2 Limiting shear stress(from clause no. 9.1.5)

If the factored shear stress in the wall exceeds 0.25 √Fckor if the wall thickness exceeds 200 mm, reinforcement shall be provided in two curtains, each having bars running in the longitudinal and transverse directions in the plane of the wall.

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2.9 Steel Required

2.9.1: clause 9.1.4 IS :13920

Shear walls shall be provided withreinforcement in the longitudinal and transverse directions in the plane of the wall. The minimum reinforcement ratio shall be

0.0025 of the gross area in each direction. This reinforcement shall be distributed uniformly across the cross section of the wall.

2.9.2: clause 9.1.7 IS :13920

The maximum spacing of reinforcement in either direction shall not exceed the smallerof lw/5, 3 tw, and 450 mm; where lw is the horizontal length of the wall, and tw is the thickness of the wall web.

2.10 Design Shear Strength of Concrete

When τv exceeds τc, given in Table 19,20 from IS-456, shear reinforcement shall beprovided in any of the followingforms:

a) Vertical stirrups,

b) Bent-up bars along with stirrups, and

c) Inclined stirrups,

Where bent-up bars are provided, their contribution towards shear resistance shall not be more than half that of the total shear reinforcement. Shear reinforcement shall be provided to carry a shear equal to Vu - z, bdThestrength of shear reinforcement Vu, shall be calculated as below:

a) For vertical stirrups:

Vus $=\frac{0.87 \times Fy \times Asv \times d}{Sv}$ ……. (from cl.40.4, IS-456)

2.11 Flexural capacity of Web (from Annex A: IS-13920)

The moment of resistance of a slender rectangular shear wall section with uniformly distributed vertical reinforcement may be estimated as follows:

a) for Xu/lw<Xu/lw*

$$\frac{\text{Muv}}{\text{Fcr tw } lw^2} = \phi\left[\left(1+\frac{\lambda}{\phi}\right)\left(\frac{1}{2}-0.416\frac{Xu}{lw}\right)-\frac{Xu^2}{lw}\left(0.168+\frac{\beta^3}{3}\right)\right]$$

Where,

Muv=0.026 x Fck x tw x lw^2

λ = Pu/ Fcktwlw

ϕ = 0.75 Fy ρ / Fck

β = (0.87Fy/0.0035) x Es

Xu/lw = (ϕ+λ)/ 2ϕ+0.36

Xu/lw* = 0.0035/(0.0035+(0.87FyEs)

ρ= vertical reinforcement ratio = Ast/(twlw),

A_{st} = area of uniformly distributed vertical reinforcement,
$\beta = 0.87\ f_y/(0.003\,5\ E_s)$,
E_s = elastic modulus of steel, and
P_u = axial compression on wall.

2.12 Force on Boundary Elements

Load on Web Pw = Load x Web Area/ Total area
Load on Boundary Element = Load x BE /Total area

2.13 Design of Boundary Element

Pu=0.4 Fck Ac + 0.67 FyAsc ………. (from cl.39.3,IS-456)

The area of cross section, Ash, of the bar forming rectangular hoop, to be used as special confining reinforcement shall not be less than

Ash= 0.18 Sh (Fck/Fy) ((Ag/Ak)-1)…... (from cl.7.4.8, IS-13920:1993)

Where, h = longer dimension of the rectangular confining hoop measured to its outerface.Ak = area of confined concrete core in the rectangular hoop measured to its outside dimensions.

3. OBSERVATION AND REMARKS

3.1 Observations:

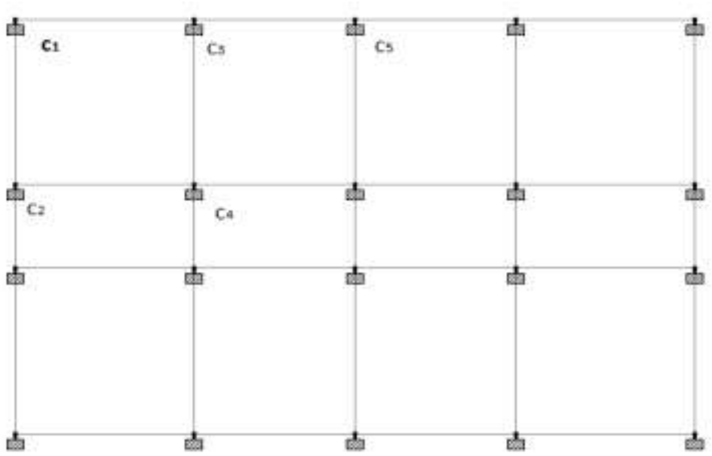
In the previous chapter to study the change in behavior of a structure is modeled and analyzed behavior of the building is subjected to same seismic forces with and without shear wall analysis is done for the following cases:

Case I: G+4 RCC structure with shear wall.

Case II: Same Structure without RC shear wall

On the basis of seismic coefficient method as per the IS 1893:2002 structured model is subjected to various load combinations and analysis the observation Related to Nodal displacement Value, Drift Value, Moment and shear force value, Reactions and story shear Value are drawn.

For the same structure the observations are made related to the nodal displacement values at the various column location along the vertical axis namely column along C1, C2, C3, C4, C5 respectively as shown in plan below.



Case A Table 1(Nodal Displacement)

Table- 3.1 Nodal Displacement and Graphs

C1	Node no.	Location(m)	Resultant(mm) max	Rotation		
				rX rad	rY rad	rZ rad
Case 1	169	17.50	9.214	0.001	0.002	0.001
Case 2	121		32.83	0.001	0.000	0.001
Case 1	141	14.30	7.238	0.001	0.002	0.001
Case 2	101		29.335	0.001	0.000	0.001
Case 1	113	11.10	5.271	0.001	0.002	0.001
Case 2	81		23.533	0.002	0.000	0.002
Case 1	85	7.90	3.343	0.001	0.001	0.001
Case 2	61		16.48	0.002	0.000	0.002
Case 1	57	4.70	1.658	0.001	0.001	0.002
Case 2	41		7.920	0.002	0.000	0.002
Case 1	29	1.50	0.443	0.000	0.000	0.002
Case 2	21		1.107	0.002	0.000	0.002

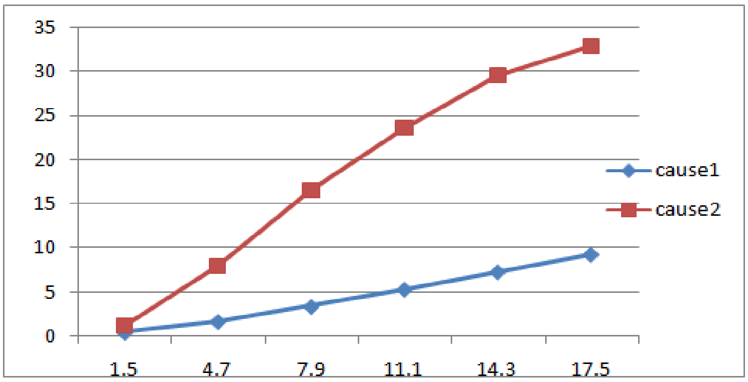


Table- 3.2 Nodal Displacement and Graphs

C5	Node no.	Location(m)	Resultant(mm) max	Rotation		
				rX rad	rY rad	rZ rad
Case 1	171	17.50	30.595	0.001	0.001	0.000
Case 2	123		34.160	0.001	0.000	0.001
Case 1	143	14.30	27.413	0.002	0.001	0.001
Case 2	103		30.338	0.001	0.000	0.001
Case 1	115	11.10	20.821	0.002	0.001	0.001
Case 2	83		24.192	0.002	0.000	0.001
Case 1	87	7.90	12.483	0.003	0.000	0.001
Case 2	63		16.370	0.002	0.000	0.002
Case 1	59	4.70	4.794	0.003	0.000	0.000
Case 2	43		7.967	0.002	0.000	0.002
Case 1	31	1.50	0.95	0.002	0.000	0.000
Case 2	23		1.138	0.001	0.000	0.001

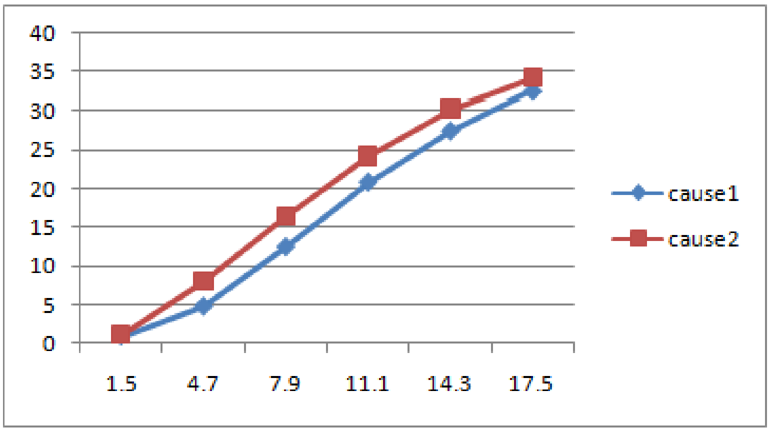


Table 2(Drift Values)

Table -3.3 Drift Values and Graphs

For C1 Location	Node no.	Case 1	Case 2
17.50	169	Na	Na
14.30	141	1.976	3.495
11.10	113	1.967	5.802
7.90	85	1.928	7.053
4.70	57	1.685	8.56
1.50	29	1.215	6.813

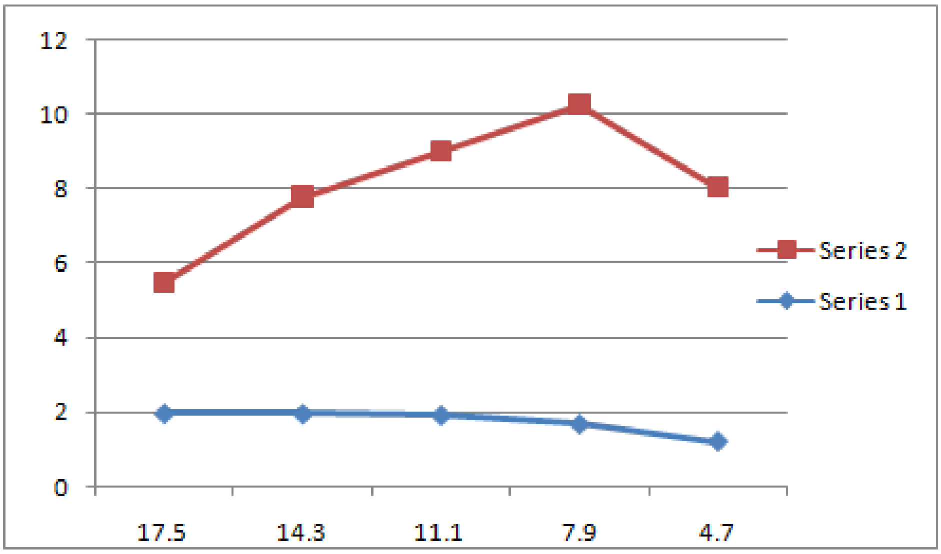


Table -6.10 Drift Values and Graphs

For C5 Location	Node no.	Case 2	Case 1
17.50	171	Na	Na
14.30	143	3.822	4.182
11.10	115	6.146	6.146
7.90	87	7.822	8.338
4.70	59	8.403	8.689
1.50	31	6.829	6.699

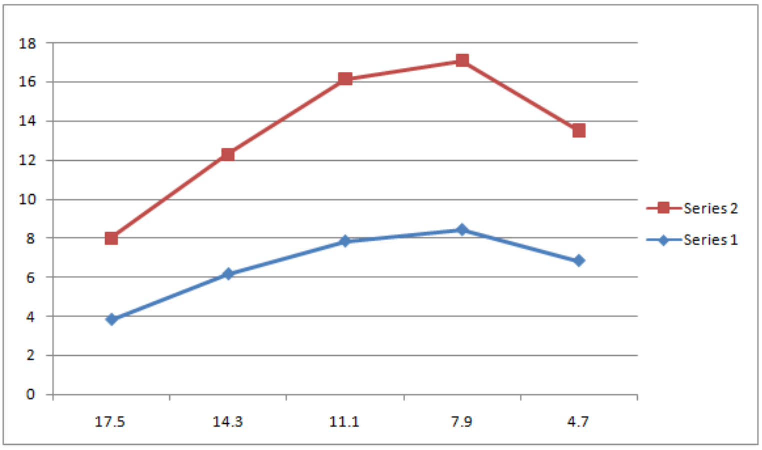
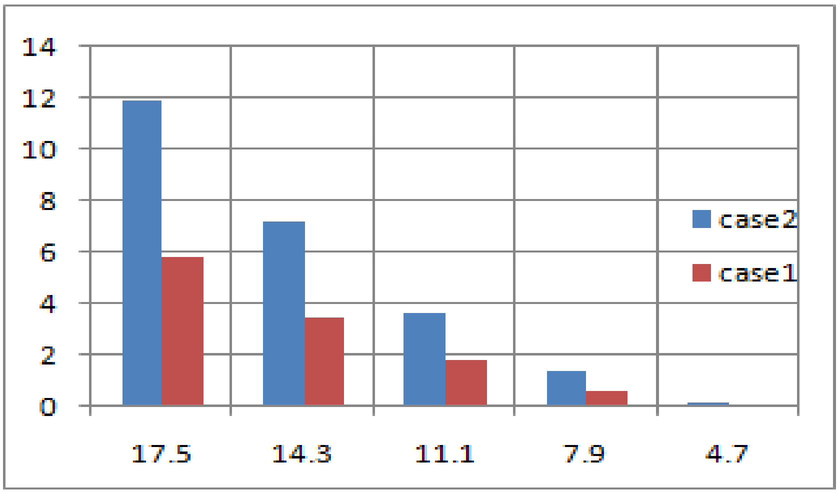


Table 3(Base Shear Forces)

C1	Fx (kN)	Fz (kN)	Fx (kN)	Fz (kN)
121	10.339	10.339	4.643	4.643
151	11.897	11.897	5.779	5.779
115	7.168	7.168	3.482	3.482
79	3.631	3.631	1.764	1.764
43	1.285	1.285	0.624	0.624
1	0.124	0.124	0.060	0.060
	0	0		
	34.44	34.44	16.352	16.352
C5				
183	13.413	13.413	13.694	13.694
153	14.968	14.968	15.649	15.649
117	9.018	9.018	9.429	9.429
81	4.568	4.568	4.776	4.776
45	0.35	1.617	1.690	1.690
3	0.159	0.159	0.165	0.165
Total Base shear	42.47	42.47	45.40	45.40

Base Shear Forces) C1



It is observed that at the bottom the values for base shear of model 1 i.e. with shear wall decreases than the values for model 2 i.e. without shear walls. It is observed that storey shear value is maximum at top and decreases with decrease in Height When the comparison is done for the corner and intermediate Nodes the Value is more.

Table 4(Beam End Forces)

For C1	Beam no.	Fx kN	Fy kN	Fz kN	Mx KNm	My KNm	Mz KNm
Case 1	375	26.989	5.242	3.199	-2.385	-5.206	-8.669
Case 2	287	164.894	28.185	33.714	-0.597	-71.446	-74.956
Case 1	308	59.036	4.029	2.814	-3.486	-4.504	-6.886
Case 2	236	391.632	41.786	44.654	-0.837	-70.472	-106.401
Case 1	214	130.563	3.995	2.770	-4.588	-4.849	-6.899
Case 2	185	618.094	51.765	51.074	-0.845	-90.228	-116.256
Case 1	174	232.774	4.059	2.610	-4.791	-5.198	-6.563
Case 2	134	843.82	53.889	53.929	-0.948	-70.652	-131.688
Case 1	107	361.920	4.755	2.866	-3.708	-5.597	-12.028
Case 2	83	1068.702	62.026	60.810	-1.046	-121.880	-231.136
Case 1	40	760.674	22.878	12.918	-2.033	-12.925	-28.465
Case 2	32	1273.365	82.279	70.377	-0.931	-108.177	-249.445

For C5	Beam no.	Fx kN	Fy kN	Fz kN	Mx KNm	My KNm	Mz KNm
Case 1	377	222.066	10.653	40.320	-3.364	-74.641	-27.359
Case 2	289	219.944	29.741	36.596	-0.216	-76.228	-82.923
Case 1	310	524.467	14.002	40.595	-5.679	-81.194	-26.223
Case 2	238	519.288	48.132	44.739	-0.014	-84.299	-109.168
Case 1	243	826.895	11.951	46.821	-7.040	-83.306	-23.422
Case 2	187	818.293	61.199	52.355	-0.305	-91.160	-111.659
Case 1	176	1129.464	10.134	49.085	-7.105	-82.566	-25.539
Case 2	136	1117.434	66.199	55.820	-0.522	-90.592	-124.342
Case 1	109	1432.299	15.218	43.173	-4.778	-111.726	-49.338
Case 2	85	1416.796	62.577	59.000	-0.583	-116.612	-172.494
Case 1	42	1716.421	29.583	64.152	-4.910	-102.486	-80.548
Case 2	34	1699.386	61.081	71.533	-0.463	-101.812	-190.463

Table 5(Reactions)

Column No.	Model No.	Fx kN	Fy kN	Fz kN	Mx KNm	My KNm	Mz KNm
For C1	Case 1	182.279	1477.233	179.608	8.889	2.043	-23.656
	Case 2	57.515	1377.405	96.206	113.939	0.512	-167.562
For C2	Case 1	48.866	1052.113	-20.962	-16.260	0.889	-52.525
	Case 2	82.279	1273.365	-70.377	-108.177	0.931	249.445
For C3	Case 1	-67.377	2349.559	81.484	138.094	9.562	275.166
	Case 2	-66.573	1763.329	-71.607	-101.789	-0.425	192.026
For C4	Case 1	59.801	1361.082	-55.693	-75.012	-11.345	-78.214
	Case 2	-83.777	1920.278	122.770	195.078	0.719	-327.367
For C5	Case 1	29.583	1716.421	-64.152	-102.486	4.910	80.548
	Case 2	61.081	11699.386	-71.533	-101.812	0.463	190.463
For C6	Case 1	54.356	2243.901	97.476	178.397	4.565	268.277
	Case 2	79279	1845.145	122.482	195.056	0.730	330.486

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