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Research Article

Seismic Analysis of Multi-Storied Building with Shear Walls using ETABS

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Abstract

Shear walls are structural members used to elongate the strength of R.C.C. structures. These shear walls will be construct in each level of the structure, to form an effective box structure. Equal length shear walls are placed symmetrically on opposite sides of outer walls of the building. Shear walls are added to the building interior to provide more strength and stiffness to the building when the exterior walls cannot provide sufficient strength and stiffness. It is necessary to provide these shear walls when the tolerable span- width ratio for the floor or roof diaphragm is exceeded. The present work deals with a study on the improvement location of shear walls in symmetrical high rise building. Position of shear walls in symmetrical buildings has due considerations. In symmetrical buildings, the center of gravity and center of rigidity coincide, so that the shear walls are placed symmetrically over the outer edges or inner edges (like box shape). So, it is very necessary to find the efficient and ideal location of shear walls in symmetrical buildings to minimize the torsion effect. In this work a high rise building with different places of shear walls is considered for analysis. The multi storey building with 8 story's is analyzed for its displacement, strength and stability using ETABS-2015 software. For the analysis of the building for seismic loading with Zone-III is considered with soil III. The analysis of the building is done by using equivalent static method and dynamic method.

Keywords: *ETABS-2015, SHEAR WALL, IS 456-2000, IS1893-2002*

1. Introduction

Adequate stiffness is to be ensured in high rise buildings for resistance to lateral loads induced by wind or seismic events. Reinforced concrete shear walls are designed for buildings located in seismic areas, because of their high bearing capacity, high ductility and rigidity. In high rise buildings, beam and column dimensions work out large and reinforcement at the beam-column joins are quite heavy, so that, there is a lot of clogging at these joints and it is difficult to place and vibrate concrete at these places which does not contribute to the safety of buildings. These practical difficulties call for introduction of shear walls in High rise buildings.

1.1 Structural forms

Lateral loads can develop high stresses, produce sway movement or cause vibration. Therefore, it is very important to have sufficient strength for the structure against vertical loads. Earthquake and wind forces are the only major lateral forces that affect the buildings. The function of lateral load resisting systems or structure form is to absorb the energy induced by these lateral forces by moving or deforming without collapse. The determination of structural form of a tall building or high rise building would perfectly involve only the arrangement of the major structural elements to resist most efficiently the various combinations of lateral loads and gravity loads. The internal planning

1) The material and the method of construction
2) The nature and magnitude of the horizontal loading
3) The external architectural treatment
4) The height and proportions of the building and
5) The planned location and routing of the service systems

The taller and more the slender a structure, the more important the structural factors become and the more necessary it is to choose an appropriate structural form or the lateral loading system for the building. In high rise buildings which are designed for a similar purpose and of the same height and material, the efficiency of the structures can be compared by their weight per unit floor area.

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1.2 Factors affecting earthquake design of structure

1) Natural frequency of the building
2) Damping factor of the structure
3) Type of foundation of the structure
4) Importance of the building
5) Ductility of the structure

Quite a few methods are available for the earthquake analysis of buildings; two of them are presented here:

a. Equivalent Static Lateral Force Method (pseudo static method).
b. Dynamic analysis.

- Response spectrum method.

- Time history method.

1.3 Required Indian Standard Codes

IS 456:2000 As per clause 32, design for wall describes, design of horizontal shear in clause 32.4 given details of how shear wall have to be constructed.

IS 1893-2002 Criteria of Earth Quake resistant Buildings Part (3) page23, clause 4.2 gives the estimation of earth quake loads.

IS 13920:1993 it gives the ductile detailing of shear wall as per clause9, where 9.1 gives general requirements, 9.2 shear strength 9.3 give flexural strength 9.6 give openings in shear walls.

Ductile detailing, as per the code **IS: 13920:1993** is considered very important as the ductile detailing gives the amount of reinforcement required and the alignment of bars.

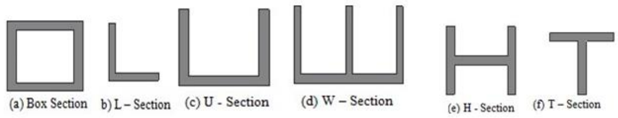
1.4 Shear Wall

A shear wall is a wall that is used to resist the shear, produced due to lateral forces. Many codes made the shear wall design for high rise buildings a mandatory. Shear walls are provided when the center of gravity of building area and loads acted on structure differs by more than 30%. To bring the center of gravity and center of rigidity in range of 30%, concrete walls are provided i.e. lateral forces may not increase much. These shear walls start at foundation level and extend throughout the building height. Shear walls are oriented in vertical direction like wide beams which carry earthquake loads downwards to the foundation and they are usually provided along both width and length of the buildings. Shear walls in structures located at high seismic regions require special detailing. The construction of shear walls is simple, because reinforcement detailing of walls is relatively straight forward and easy to implement at the site. Shear walls are effective both in construction cost and effectiveness in minimizing earthquake damage to the structural and nonstructural elements also.

1.4.1 Shapes or Geometry of Shear Walls

Shear walls are rectangle in cross section, i.e. one dimension is much larger than the other. While rectangular cross-section is frequent, L- and U-shaped sections are also used. Thin- walled hollow RC shafts around the elevator core of the structure also act as shear walls, and should be taken advantage of to resist earthquake forces. The Shear Wall sections are classified as six types.

(a) Box Section
(b) L – Section
(c) U - Section
(d) W – Section
(e) H – Section
(f) T – Section



1.5 Components of Shear Walls

Reinforced concrete and reinforced masonry shear walls are seldom-simple walls which resist the lateral forces. Whenever a wall has doors, windows, or other openings, the wall must be considered as an assemblage of relatively flexible components like column segments and wall piers and relatively stiff elements like wall segments.

Column segments: A column segment is a vertical member whose height exceeds three times its thickness and whose width is less than two and one-half times its thickness. Its load is usually mainly axial. Although it may contribute little to the lateral force resistance of the shear wall is rigidity must be considered. When a column is built integral with a wall, the portion of the column that project from the face the wall is called a pilaster. Column segments shall be designed according to ACI 318 for concrete. **Wall piers**: A wall pier is a segment of a wall whose horizontal length is between two and one-half and six times its thickness whose clear height is at least two times its horizontal length.

Wall segments: Wall segments are components of shear wall that are longer than wall piers. They are the primary resisting components in the shear wall.

Important features in planning and design of shear walls: For all high rise buildings, the problem of providing adequate stiffness and preventing large displacements, are as important as providing adequate strength. Thus shear wall system has two distinct advantages over a frame system

2. Methodology

Design Aspect

Earthquakes can occur on both land and sea, at any place on the surface of the earth where there is a major fault. When earthquake occurs on land it affects the manmade structure surrounding its origin leading to human lose. When a major earthquake occurs underneath the ocean or sea, it not only affects the structures near it, but also produces large tidal waves known as Tsunami, thus affecting the places far away from its origin. All the structures are designed for the combined effects of gravity loads and seismic loads to verify that sufficient vertical and lateral strength and stiffness are achieved to satisfy the structural concert and acceptable deformation levels prescribed in the governing building code. Because of the innate factor of safety used in the design specifications, most structures tend to be adequately protected against vertical shaking. Vertical acceleration should also be considered in structures with large spans, those in which stability for design, or for overall stability analysis of structures.

Serviceability limit state

The structure undergoes little or no structural damage in this case. Important buildings such as hospitals, atomic power stations, places of assembly etc., which affects a community, should be designed for elastic behavior under expected earthquake forces. These types of structures should be serviceable even after the occurrence of earthquake or cyclones.

Damage controlled limit state

In this case, if an earthquake or cyclone occurs, there can be some damage to the structure but it can be repaired even after the occurrence of the disaster. Most of the permanent buildings should come under this category, so, the structure should be designed for limited ductility response only.

Survival limit state

In this case, the structure is allowed to be damaged in the event of earthquake or cyclone disasters. But, the supports should stand and support the permanent loads coming on to it so that there should be no caving in of the structure and no loss of life. Limited ductile response is cheaper and full ductile response is cheapest. The full ductile detailing is achieved by the theory of plastic hinge formation and also by careful ductile detailing. The current design practice is to construct the structures for the first two limit states as the other is under development stage

2.1 Design approach in IS 1893 (2002)

The title of IS 1893-2002 is “Criteria for earthquake resist design of structures” and part 1 of this code deals with General Provisions and buildings [1]. According to this code we consider the following magnitudes of earthquakes:

a) Design basic earthquake (DBE): It is the earthquake which occurs reasonably at least once during the designed life of the structure.
b) Maximum considered earthquake (MCE): This is the most severe earthquake that can occur in that region as considered by the code. It is divided by factor 2 to get design basic earthquake.

The value of Z, the seismic zone factor given in the code relates the realistic values of effective peak ground acceleration considering MCE and the service life of the structure. The following principles are the basis for the design approach recommended by IS 1893-2002.

1) The structure should have the strength to withstand minor earthquakes less than DBE without any damage.
2) The structure should able to resist earthquakes equal to DBE without significant damage though some nonstructural damage may occur
3) The structure should able to withstand an earthquake equal to MCE without collapse so that there is no loss of life

2.1.1 Equivalent Static Method

The equivalent static method of finding lateral forces is also known as the static method or the seismic coefficient method. This method is the simplest one and it requires less computational attempt and is based on formulae given in the code of practice. In all the methods of analyzing a multi storey buildings recommended in the code, the structure is treated as discrete system having concentrated masses at floor levels which comprise the weight of columns and walls in any storey should be equally distributed to the floors above and below the storey. In addition, the suitable amount of imposed load at this floor is also lumped with it. It is also assumed that the structure flexible and will deflect with respect to the position of foundation; the lumped mass system reduces to the solution of a system of second order differential equations. These equations are formed by distribution of mass and stiffness in a structure, together with its damping characteristics of the ground motion.

Seismic Weight

The seismic weight of a structure is the sum of seismic weight of all the floors in the structure. The seismic weight of every floor is the sum of its full dead load and appropriate amount of imposed load, the latter being that element of the imposed loads that may sensibly be expected to be attached to the structure at the time of earthquake movement. It includes the weight of permanent and movable partitions, permanent equipment, a part of the live load, etc. While computing the seismic weight of walls and columns in any storey shall be equally distributed to the floors above and below the storey.

Distribution of Design Force

The computed base shear is now distributed along the height of the building. The shear force, at any level depends on the mass at that level and tends to deform the shape of the structure. Earth quake forces deflect the structure into number of shapes known as the natural mode shapes and the number of natural mode shapes depends up on the degree of freedom of the system. Generally a structure has continuous system with infinite degree of freedom. The magnitude of the lateral force at a particular floor depends on the mass of the node, the distribution of stiffness over the height of the structure and the nodal displacement in the given mode.

The design base shear (V_B) computed by using the above expression shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i\, h_i^2}{\sum_{j=1}^{n} W_j\, h_j^2}$$

Where
Q_i
W_i
H_i
N = Number of stores in the building i.e., the number of levels at which the masses are located.

The distribution suggested in the code gives parabolic distribution of seismic forces such that seismic shears are higher near top storey for the same base shear. The assumptions involved in the static procedure reflected in the expression are

a Fundamental mode of the building makes the most significant contribution to base shear, and The total building mass is considered as against the modal mass that would be used in a dynamic procedure.
b The mass and stiffness are evenly distributed in the building.

2.2 Dynamic Analysis

Dynamic analysis shall be carried out to obtain the design seismic force, and its distribution in different levels along the height of the building, and in the various lateral loads resisting element, for the following buildings:

Regular buildings*:* Those greater than 40m in height in zones IV and V, those greater than 90m in height in zone II and III.

Irregular buildings*:* All framed buildings higher than 12m in zones IV and V, and those greater than 40m in height in zones II and III.

The analysis of model by dynamic analysis of buildings with unusual configuration should be such that it sufficiently models the types of irregularities present in the building configuration. Buildings with plan irregularities, as defined in Table 4 of IS code: 1893-2002 cannot be modeled for dynamic analysis.

Dynamic analysis may be performed either by the TIME HISTORY METHOD or by the RESPONSE SPECTRUM METHOD,

3. Numerical Modeling and Analysis

Table 1 General dimension of frame structure

Sr no.	Particular	Dimension	Sr no.	Particular	Dimension
1	Length of building	33.87(M)	9	Live load on roof	1.5 KN/M^2
2	Width of building	10.51(M)	10	Floor finishing	1KN/M^2
3	Height of building	22(M)	11	Water proofing load	1 KN/M^2
4	Typical story height	3(M)	12	Density of concrete	25 KN/M^2
5	Top story height	1.5(M)	13	Density of wall	10 KN/M^2
6	Bottom story height	2.5(M)	14	Grade of concrete	M25 KN/M^3
7	Live load on floor	3 KN/M^2	15	Grade of steel	HYSD500
8	Wall load	2.3KN/M	16	Thickness of slab	0.15(M)
9	Live load on roof	1.5 KN/M^2	17	Zone 3	Z.F.= 0.16

Shear wall structure data

1	Width of building	10.87(M)	10	Floor finishing	1KN/M^2
2	Height of building	22(M)	11	Water proofing load	1 KN/M^2
3	Typical story height	3(M)	12	Density of concrete	25 KN/M^3
4	Top story height	1.5(M)	13	Density of wall	10 KN/M^3
5	Bottom story height	2.5(M)	14	Grade of concrete	M25
6	Live load on floor	3 KN/M^2	15	Grade of steel	HYSD500
7	Wall load	2.3KN/M	16	Thickness of slab	0.15(M)
8	Live load on roof	1.5 KN/M^2	17	Thickness of shear wall	0.3 (M)
			18	Zone 3	Z.F.= 0.16

Table 2 Dimension of shear structural member residential building (beam)

Sr.no	Elements	Property(m)
1	Main beam	0.5 X 0.6

Table 3 Dimension of shear structural member residential building (column)

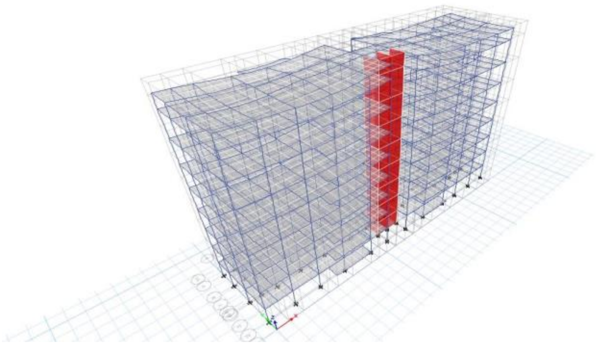
Sr.no	Elements	Property(m)
1	Main Column	0.6 X 0.6

Table 4 Dimension of slab

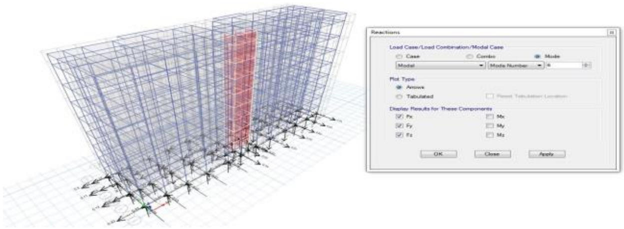
Sr.no	Elements	property(m)
1	Slab 1way	0.15
2	Slab2way	0.15

4. Results

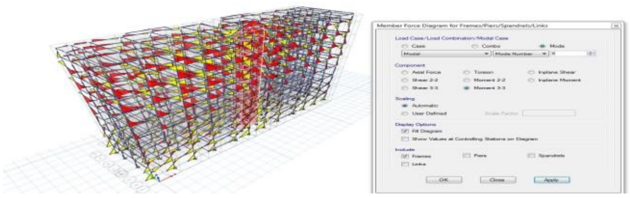
4.1 Frame Structure



Displacement due to shaking



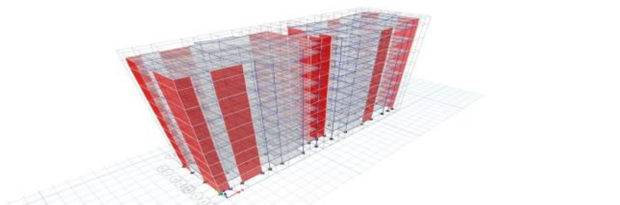
Support reaction

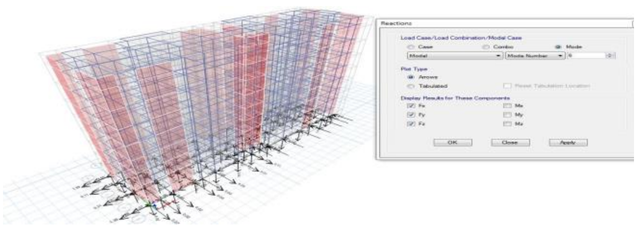


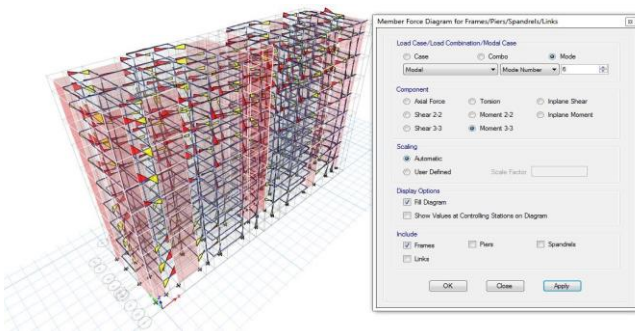
Member force dia. for frames

Shear Structure

Displacement due to shaking







Member force diagram

Conclusion

- The analysis of building with Core shear wall and edge shear wall shows that Shear wall at core shows stiffer behavior.
- When shear walls are provided on edge maximum storey displacement of buildings is increased comparing to when shear walls are provided on center portion.
- When dynamic analysis is done storey drift decreases.
- When shear wall is placed on edge time period of building increases.
- When shear walls are provided on edge storey drift of buildings is increased comparing to when shear walls are provided on center portion.
- For good seismic performance a building should have adequate lateral stiffness. Low lateral stiffness leads to large deformation and strains, damage to non-structural component, discomfort to occupant.
- Stiff structures though attracts the more seismic force but have performed better during past earthquake (Jain S.K. and Murty C V R, 2002).
- So from above results Building with shear wall at core proves to be a better alternative for building in earthquake prone area.
- Dynamic analysis reduces storey shear, storey displacement, storey drift etc; this shows that dynamic analysis gives improved estimate of forces and therefore analysis of building become more accurate as well as economical.

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