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Comparative Study of Shear Wall in Multi-Stored R.C Building

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ABSTRACT:

Shear wall systems are one of the most commonly used lateral load resisting systems in high-rise buildings. Shear walls have very high in plane stiffness and strength, which can be used to simultaneously resist large horizontal loads and support gravity loads, making them quite advantageous in many structural engineering applications. There are lots of literatures available to design and analyze the shear wall. However, the decision about the location of shear wall in multistory building is not much discussed in any literatures.

This research work focuses on comparison of seismic analysis of G+10 building stiffened with bracings and shear wall. The performance of the building is analyzed in Zone II, Zone III, Zone IV, Zone V. The study includes understanding the main consideration factor that leads the structure to perform poorly during earthquake in order to achieve their appropriate behavior under future earthquakes. The analyzed structure is symmetrical, G+10, Ordinary RC moment-resting frame (OMRF). Modelling of the structure is done as per staad pro. V8i software. Time period of the structure in both the direction is retrieve from the software and as per IS 1893(part 1):2002 seismic analysis has undergone. The Lateral seismic forces of RC frame is carried out using linear static method as per IS 1893(part 1) : 2002 for different earthquake zones. The scope of present work is to understand that the structures need to have suitable Earthquake resisting features to safely resist large lateral forces that are imposed on them during Earthquake. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing Earthquake damage in structure. Also the braced frames can absorb great degree of energy exerted by earthquake.

In this paper, therefore, main focus is to determine the solution for shear wall location in multistory building. A RCC building of G+10 placed in AHMEDABAD, subjected to earthquake loading in zone-II is considered. An earthquake load is calculated by seismic coefficient method using IS 1893 (PART–I):2002.

A study has been carried out to determine the strength of RC shear wall of a multistoried building by changing shear wall location.

Three different cases of shear wall position for a G+10 building have been analyzed. Incorporation of shear wall has become inevitable in multi-storey building to resist lateral forces.

Introduction

Looking at the past records of earthquake, there is increase in the demand of earthquake resisting building which can be fulfilled by providing the shear wall systems in the building.

Also due to the major earthquakes in the recent pats the codal provisions revised and implementing more weightage on earthquake design of structure.

Earthquakes have become a frequent event all over the world. It is very difficult to predict the intensity, location, and time of occurrence of earthquake. Structures adequately designed for usual loads like dead,

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live, wind etc may not be necessarily safe against earthquake loading.

It is neither practical nor economically viable to design structures to remain within elastic limit during earthquake. The design approach adopted in the Indian Code IS 1893(Part I): 2002 'Criteria for Earthquake Resistant Design Of Structures' is to ensure that structures possess at least a minimum strength to withstand minor earthquake occurring frequently, without damage; resist moderate earthquakes without significant structural damage though some non-structural damage may occur; and aims that structures withstand major earthquake without collapse.

Structures need to have suitable earthquake resistant features to safely resist large lateral forces that are imposed on them during frequent earthquakes. Ordinary structures for houses are usually built to safely carry their own weights.

Low lateral loads caused by wind and therefore, perform poorly under large lateral forces caused by even moderate size earthquake. These lateral forces can produce the critical stresses in a structure, set up undesirable vibrations and, in addition, cause lateral sway of structure, which could reach a stage of discomfort to the occupants.

The decision regarding provision of shear wall to resist lateral forces play most important role in choosing the appropriate structural system for given project.

Generally structures are subjected to two types of loads i.e. Static and Dynamic. Static loads are constant while dynamic loads are varying with time.

This concept extended to concrete frames. The various aspects such as size and shape of building, location of shear wall and bracing in building, distribution of mass, distribution of stiffness greatly affect the behaviors of structures. Bracing system improves the seismic performance of the frame by increasing its lateral stiffness and capacity.

To the addition of bracing system load could be transferred out of the frame and into the braces, by passing the weak columns. The stiffness added by the bracing system is maintained almost up to the peak strength. Stiffness is particularly important at serviceability state, where deformations are limited to prevent damage.

In majority civil structures only static loads are considered while dynamic loads are not calculated because the calculations are more complicated. This may cause disaster particularly during Earthquake due to seismic waves.

By providing shear wall in multi-storied building we can resist seismic waves of earthquake. The loads are calculated by E-TABS software by providing shear walls at various parts of building.

OBJECTIVE OF THE PROJECT

Tall building developments have been rapidly increasing worldwide. The growth of multistory building in the last several decades is seen as the part of necessity for vertical expansion for business as well as residence in major cities.

It is observed that there is a need to study the structural systems for R.C.C framed structure, which resists the lateral loads due to seismic effect. Safety and minimum damage level of a structure could be the prime requirement of tall buildings.

To meet these requirements, the structure should have adequate lateral strength, lateral stiffness and sufficient ductility. Among the various structural systems, shear wall frame or braced concrete frame could be a point of choice for designer.

Therefore, it attracts to review and observe the behavior of these structural systems under seismic effect.

The main objective of this project is to check and compare the seismic response of multi-storied building for different locations of shear wall, so that one can

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choose the best alternative for construction in earthquake-prone area.

Different location of shear wall in R.C. Building are being modeled in E-TABS software and the results in terms of natural period, frequency, storey displacement, storey drift, storey shear is compared.

Hence, it is proposed to study the dynamic behavior of reinforced concrete frame with and without shear wall and steel braced frame. The purpose of this study is to compare the seismic response of above structural systems. Axial forces and moments in members and floor displacements will be compared.

SEISMIC METHODS OF ANALYSIS

The analysis process can be categorized on the basis of three factors: the type of externally applied loads, the behavior of structure/ or structural materials and the type of structural model selected. A two or three dimensional model which includes bilinear or trilinear loaddeformation diagrams of all lateral force resisting elements are first created and gravity loads are applied initially.

A predefined lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased by some members yield. Based on the type of external action and behavior of structure, the analysis can be further classied as

1. Linear static analysis
2. Non-linear static analysis
3. Non-linear dynamic analysis
4. Linear dynamic analysis

Linear static analysis or equivalent static analysis can be used for regular structures with limited height .Linear dynamic analysis can be performed by response spectrum method or by the elastic time history. The signicant difference between linear static and linear dynamic analysis is the level of force and their distribution along the height of the structure.

Non-linear static analysis is an improvement over linear static or dynamic analysis in the sense that it allows inelastic behavior of the structure and provides information on the strength, deformation and ductility of the structure. Non-linear static analysis can be performed by push over analysis. A non-linear dynamic analysis or in elastic time history analysis is the only method to describe the actual behavior of a structure during an earthquake.

Nonlinear dynamic analysis is most accurate method to determine the seismic responses of structures. In this method the structure is subjected to actual ground motion which is the representation of the ground acceleration versus time. The ground acceleration is determined at small time step to give the ground motion record. Then the structural response is calculated at every time instant to know its time history and the peak value of this time history is chosen to be design demand. Hence, “A mathematical model directly incorporating the nonlinear characteristic of individual component and element of the building shall be subjected to earthquake shaking represented by ground motion time history to obtain forces and the displacement”. Since numerical model directly accounts for the effect of material nonlinearity, inelastic responses and calculated internal forces will be reasonably approximate to those expected during the design earthquake.

RC Shear Wall

Reinforced concrete (RC) buildings often have vertical plate-like RC walls called Shear Walls 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 as low as 150mm, or as high as 400mm in high rise buildings. The overwhelming success of buildings with shear walls in resisting strong earthquakes is summarized in the quote, “We cannot afford to build concrete buildings meant to resist severe earthquakes without shear walls.” as said by Mark Fintel, a noted consulting engineer in USA.

RC 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.

Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large. Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings.

They could be placed symmetrically along one or both directions in plan. Shear walls are more effective when located along exterior perimeter of the building such a layout increases resistance of the building to twisting.

Structural Modeling

The analytical model was created in such a way that the different structural components represent as accurately as possible the characteristics like mass, strength, stiffness and deformability of the structure. Non structural components were not modeled. The various primary structural components that were modeled are as follows:

(a) Beams and columns:

Beams and columns were modeled as 3D frame elements.

(b) Beam-column joints:

The beam-column joints were assumed to be rigid and were modeled by giving end-offsets to the frame elements. This was intended to get the bending moments at the face of the beams and columns.

(c) Foundation Modeling:

The foundation was modeled based on the degree of åxity which is provided. The effect of soil structure interaction was ignored in the analysis.

(d) Slab Modeling (Modeling of joints):

Slab is modeled as a rigid diaphragm. In rigid diaphragm case all the joints in the slab moves together as a single unit.

Analysis method:

As per the Indian Standard code for Earthquake IS:1893-2002, seismic analysis can be performed by two methods, i.e. Static method and Dynamic method. If static analysis is done then the method followed is Equivalent Static Coefficient Method and for dynamic analysis, there are two methods of analysis such as Time history analysis and Response spectrum analysis.

1. Static Method
A. Equivalent Static Coefficient Method

2. Dynamic Methods
A. Time history Method
B. Response Spectrum Method

Problem Statement

In present work in order to compare the response of reinforced concrete shear wall for use in Earthquake prone area multi storey building having plan dimension 18m x18m is modeled and analyzed in ETABS 9.2 Non Linear Version software. Equivalent static analysis and dynamic Response spectrum analysis is performed on the structure.

In present work total 2 models are prepared. Two models of G+9 storey buildings, which includes shear wall in different position at core of building and at edge of building. And for both the models Equivalent static analysis and dynamic Response spectrum analysis is performed.

Stepwise Procedure for modeling of Building in ETABS:

Step 1: Define Storey data like storey height, no. of storey etc.

Step 2: Select Code preference from option and then define material properties from define Menu

Step 3: Define Frame Section from Define menu like column, beam

Step 4: Define Slab Section

Step 5: Draw building Elements from draw menu

Step 6: Give Support Conditions

Step 7: Define Load cases and Load combinations

Step 8: Assign Load

Step 9: Define Mass Source

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Step 10: Give structure auto line constraint

Step 11: Give renumbering to the whole structure

Step 12: Select analysis option and Run Analysis

Modeling of Building Using ETABS

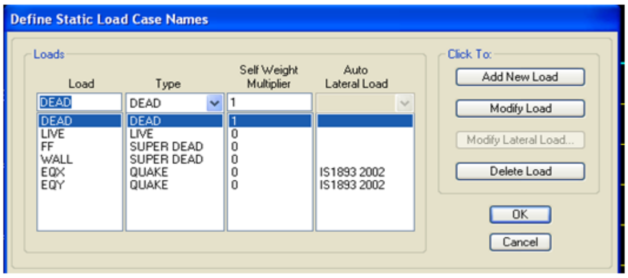
The building is modeled using the Software ETABS nonlinear v9.2. Different elements of building are modeled as below.

- Beams and Columns are modeled as line element.
- Slab is modeled as shell element. Shell element has both in plane and out of plane stiffness while membrane element has only out of plane stiffness.
- Shear wall is modeled as pier object in Etabs.

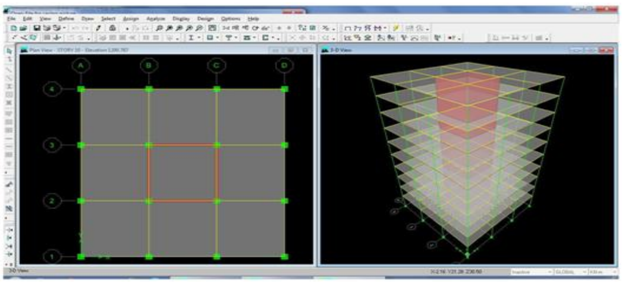
Fixing of Member Sizes

For shear wall minimum thickness required as per IS: 13920 is 150 mm. Hence a thickness of 200 mm was taken. As panel size of building for shear wall is same for all type of models, thickness of shear wall is kept same for all.

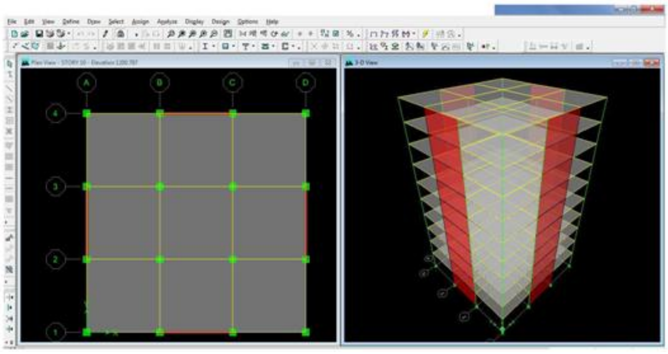
For loading purpose Live load, Dead loads are applied as area load. Earthquake load is applied as per IS 1893-2002. For defining load only once in dead load case self weight multiplier is taken one.



Defining Load cases in ETABS



ETABS model of 10 Storey ESW



Analysis, Result and Discussion

Storey drift, Base shear distribution, Storey displacement, time period, frequency, stiffness are tabulated and compared. As building symmetrical about X and Y axis, all comparison is made for X direction.

Seismic response is checked for different location of shear wall. Shear walls are provided at centre and at edge. Now onwards shear wall at core is referred as CSW (Core Shear Wall) and at edge as ESW (Edge shear Wall).

Table 3: Storey Shear in 10 Storey building for CSW and ESW (KN)

Storey	Static	Dynamic
10	247.13	204.06
9	509.11	424.57
8	717.04	605.25
7	877.17	755.46
6	995.73	880.85
5	1078.96	982.95
4	1133.09	1063.54
3	1164.35	1123.94
2	1178.99	1163.56
1	1183.30	1183.30

Table 4: Comparison Table of Storey Shear for static and dynamic analysis (%)

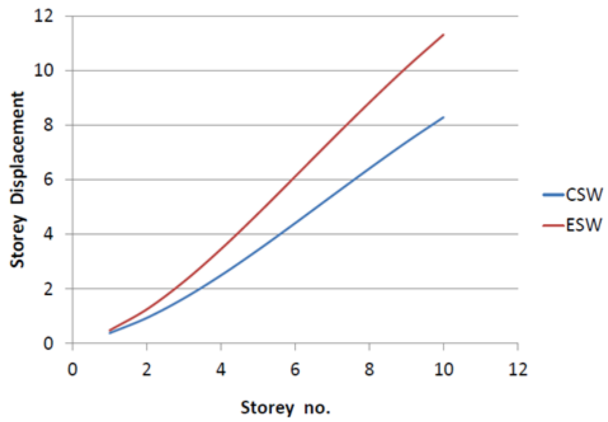
Storey	RCC
10	-17.43
9	-16.60
8	-15.59
7	-13.88
6	-11.54
5	-8.90
4	-6.14
3	-3.47
2	-1.31
1	0.00

Storey Displacement

Storey drift is calculated from the storey displacement. More storey displacement indicates less stiffness of structure.

Table 5. Maximum Storey Displacement for 10 Storey (mm)

Storey	Core Shear Wall(CSW)	Edge Shear Wall(ESW)
10	8.2970	11.3295
9	7.3834	10.1229
8	6.4141	8.8344
7	5.4158	7.4925
6	4.4103	6.1215
5	3.4259	4.7600
4	2.4946	3.4556
3	1.6510	2.2637
2	0.9323	1.2469
1	0.3760	0.4741



Storey Stiffness

Stiffness is calculated by assuming that supports are fixed and load is applied at floor level. Horizontal displacement is measured at floor level and lateral stiffness is calculated by dividing horizontal deflection to lateral load. In other words stiffness is the force needed to cause unit displacement and is given by slope of force displacement relationship.

Strength is a maximum force that a system can take.

Table 6. Storey Stiffness for 10 Storey CSW (mm)

Storey	CSW		ESW	
	Force	Displacement	Force	Displacement
10	247.13	5.53133	247.13	7.55297
9	261.98	4.92228	261.98	6.74858
8	207.94	4.27607	207.94	5.88961
7	160.13	3.61053	160.13	4.99499
6	118.56	2.94020	118.56	4.08098
5	83.23	2.28396	83.23	3.17334
4	54.13	1.66307	54.13	2.30376
3	31.26	1.10069	31.26	1.50914
2	14.64	0.62156	14.64	0.83124
1	4.31	0.25069	4.31	0.31605

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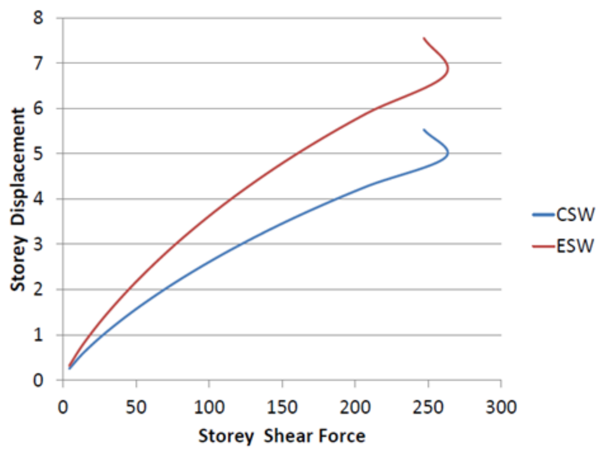

Time Period, Frequency and Storey Drift

The stiffer structures have lesser natural period and their response is governed by the ground acceleration; most buildings fall in this category. The flexible structures have larger natural period and their response is governed by the ground displacement, for example, large span bridges.

Storey drift is directly related to the stiffness of the structure. The higher the stiffness lowers the drift and higher the lateral loads on the structure.

Table 7: Time Period for 10 Storey (mm)

Mode	Core Shear Wall(CSW)	Edge Shear Wall(ESW)
	RCC	RCC
1	0.5450	0.6397
2	0.5450	0.6397
3	0.1779	0.1775
4	0.1779	0.1775
5	0.1761	0.1702
6	0.1525	0.1545
7	0.1374	0.1545
8	0.1374	0.0754
9	0.0668	0.0754
10	0.0668	0.0700
11	0.0668	0.0666
12	0.0604	0.0556

Table 8: Maximum Storey Drift for 10 Storey (mm)

Storey	Core Shear Wall(CSW)	Edge Shear Wall(ESW)
10	0.3045	0.4022
9	0.3231	0.4295
8	0.3328	0.4473
7	0.3352	0.4570
6	0.3281	0.4538
5	0.3104	0.4348
4	0.2812	0.3973
3	0.2396	0.3390
2	0.1854	0.2576
1	0.1074	0.1354

Table 9: Comparison of storey Drift when shear wall is placed on Edge (%)

Storey	RCC
10	32.07
9	32.92
8	34.42
7	36.35
6	38.31
5	40.05
4	41.30
3	41.49
2	38.91
1	26.07

Concluding Remarks

1. The analysis of building with Core shear wall and edge shear wall shows that Shear wall at core shows stiffer behaviour.
2. When shear walls are provided on edge maximum storey displacement of buildings is increased comparing to when shear walls are provided on center portion.
3. When dynamic analysis is done storey drift decreases.

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4. When shear wall is placed on edge time period of building increases.
5. When shear walls are provided on edge storey drift of buildings is increased comparing to when shear walls are provided on center portion.
6. For good seismic performance a building should have adequate lateral stiffness.
7. Low lateral stiffness leads to large deformation and strains, damage to non-structural component, discomfort to occupant.
8. Stiff structures though attracts the more seismic force but have performed better during past earthquake (Jain S.K. and Murty C V R, 2002).
9. So from above results Building with shear wall at core proves to be a better alternative for building in earthquake prone area.
10.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.

Future Scope

1. Nonlinear analysis by push over.
2. Effect of shear wall on seismic performance of building.
3. Dynamic nonlinear analysis by time history method.
4. Parametric study of models by varying height of building, number of bays of building etc.
5. Performance-based or capacity based design of structure.
6. Continue to innovate new systems.
7. FEM analysis to understand beam-column junction behavior under earthquake for RCC, Steel and Composite building.

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