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Comparative Study on the Analysis of Commercial Building with and Without Shearwall by Using ETABS

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ABSTRACT

In the seismic design of buildings, reinforced concrete structural wall, or shear wall, acts as a major earthquake resisting member. Structural walls provide an efficient bracing system and offer great potential for lateral load resistance. 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. The properties of these seismic shear walls dominate the response of the buildings, and therefore, it is important to evaluate the seismic response of the walls appropriately. In this study the main focus is to compare the dynamic responses of frame structure with and without shear wall. Two models are generated with and without shear wall.G+18 R-C frame model with and without shear walls are generated with varying structural member dimensions according to height. The models are analysed by Static Method and Response Spectrum Method considering seismic zone II in ETABS2015. Parameters like lateral displacement, story drift, base shear and mode shapes are determined for all the models (with and without shear walls) by the two methods and are compared and the effectiveness of shear walls is enumerated. Also, comparisons are made based on some studies previously done by the other authors.

Keywords: Base Shear, Response Spectrum Method, Shear Wall, Static Method

I. INTRODUCTION

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. In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes. Examples are the reinforced-concrete wall or vertical truss. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants; create powerful twisting (torsion) forces. These forces can literally tear (shear) a building apart. Reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape of the frame and prevents rotation at the joints. Shear walls are especially important in high-rise buildings subjected to lateral wind and seismic forces. In the last two decades, shear walls became an important part of mid and high-rise residential buildings. As part of an earthquake resistant building design, these walls are placed in building plans reducing lateral displacements under earthquake loads. So shear-wall frame structures are obtained. Shear wall buildings are usually regular in plan and in elevation. However, in some buildings, lower floors are used for commercial purposes and the buildings are characterized with larger plan dimensions at those floors. In other cases, there are setbacks at higher floor levels. Shear wall buildings are commonly used for residential purposes and can house from 100 to 500 inhabitants per building.

II. OBJECTIVES

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. Shear walls are quick in construction, and in a country like India where shelter is very important in a short lapse of time shear walls can be built very quickly. The precision to which they are built is also very high compared to normally built brick structures. Hence the key objective of shear wall is to build a safe, tall, aesthetic building. Two models are generated with and without shear wall.G+18 R-C frame models with and without shear walls are generated with varying structural member dimensions according to height. The models are analyzed by Static Method and Response Spectrum Method considering seismic zone II in ETABS2015. Parameters like lateral displacement, story drift, base shear and mode shapes are determined for all the models (with and without shear walls) by the two models are compared and the effectiveness of shear walls is enumerated.

III. LITERATURE REVIEW

Review of literature:

Development of shear wall system for construction has advanced dramatically over the past few years. Shear wall systems were initially developed to reduce damage due to earth quakes labour requirements, increase strength of the building, shorten construction time reduce cost increase quality of life.

U.H. Varyani described about shear walled buildings under horizontal loads. Considering in his design “Reinforced concrete framed buildings are adequate for resisting both the vertical and the horizontal loads acting on shear walls of a building”. In this 2^{nd} edition 2002 of “Design of structures”. He gave rigidity of shear wall, torsional rigidity and shear center of a building in a detailed description.

S.K. Duggal on his profound interest on structures gave a detailed description about reinforced concrete buildings in his book “Earth quake resistant design of structures “describing a wall in a building which resist lateral loads originating from wind or earthquakes are known as shear walls”. He considered flexural strength in the wall to be dominant force based on which design of structure to be carried out in tall shear walls. He described in detail about various types of shear walls with their load bearing capacities as per code requirements.

IV. SHEAR WALLS

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.

In building construction, a rigid vertical diaphragm capable of transferring lateral forces from exterior walls, floors, and roofs to the ground foundation in a direction parallel to their planes. Examples are the reinforced-concrete wall or vertical truss. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and occupants; create powerful twisting (torsion) forces. These forces can literally tear (shear) a building apart. Reinforcing a frame by attaching or placing a rigid wall inside it maintains the shape of the frame and prevents rotation at the joints. Shear walls are especially important in high-rise buildings subjected to lateral wind and seismic forces.

V. TYPES OF STRUCTURES

1 Braced structures
2 Unbraced structures
3 Dual structures

As shown in in all the three cases , the resistance to gravity loads (DL+LL) is provided invariably by beam column and space frames. However, they differ in carrying horizontal loads. Braced, unbraced and dual structures are briefly described as follows:

Braced structures

A typical braced frame is shown in figure. In braced frames the lateral loads like wind earthquake etc, are resisted by special arrangements like shear walls, shear trusses, bracing or special supports. Thus the beam column frames are not subjected to horizontal loads. In other words the sidesway or joint translation is not possible in column. The structure is called a braced structure and columns occurring in such structure are called the braced column.

The shear walls, shear trusses or bracing provided in the building must have stiffness to act as effective bracings. According to SP: 24 the bracing system must provide a total stiffness equal to at least six times the sum of stiffness of all the columns, within the storey. They may become uneconomical for larger height as shear walls are designed as vertical cantilevers from the ground.

Unbraced structures

A typical Unbraced frame is shown in figure, where resistance to horizontal loads is provided by bending in the beam and column in that plane. In other words, the sides way or joint translation do occur in such frames. These structures are called Unbraced structures and the columns occurring in such structures are called Unbraced columns.

Dual structures

Dual structures are combination of the above two. The resistance to horizontal loads is provided by both, the bending in frames and by shear walls. The frames and shear walls will resist horizontal forces in proportion to their relative stiffness . However, the frame should be designed to carry minimum 25% horizontal shear.

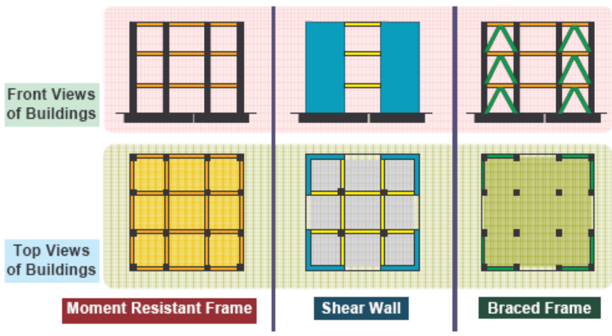

Figure 1

VI. LOADS ON STRUCTURE

Vertical Loads

Structurally speaking, buildings are built to support loads. The load, which is ever present and ever acting on a building, is the dead load which consists of the self-weight of member, finishes, plaster, etc. Dead load should be calculated very accurately, as it comprises most of the building load. IS: 1911-1967 gives schedule of unit-weights of building materials and it is used extensively to calculate the dead load. Next in importance to dead load, is the live load, which is caused by the use of building. Live loads are given in IS: 875. Live loads are generally high (150 kg/m^2 to 1500 kg/m^2) on floors depending on the activity that is carried on there, while it is of a low value (75 kg/m^2 to 150 kg/m^2) on a roof, which may or may not be accessible. Snow loads on roofs in hilly areas are also specified in IS: 875. In snow-incident areas, roofs are to be made sloping due to snow at 2.5 kg/m^2 per cm depth of snow. With 30 cm snow depth, the snow loading will work out to be 75 kg/m^2, which may be reasonable for sloping roofs. Thick brick walls anywhere add substantially to the building and it affects the design of slabs, beams, columns and footings too. But in the present practice, for flexibility in the use of the building, this provision is made in most of the buildings and wherever possible, brick walls should be replaced by wooden partitions to achieve in lighter partition loading, which finally leads to economy in structural design. In practice, wooden partitions are provided in office buildings, while in hospitals and institutional buildings, brick walls are used as partition walls.

Temperature and shrinkage loading

Temperature and shrinkage also act on a building and these can also be regarded as a load on it. Shrinkage is equivalent to -15 ^{0}C, where negative stands for fall of temperature . The temperature differential is taken at $\pm$ 17 $^2/_3(t_1-t_2)$, where t_1 and t_2 are the maximum and the minimum temperatures observed in a day (24 hours) for a given place or locality . Fall of temperature together with shrinkage will govern the design, while the rise of temperature will be substantially reduced in effect by the Indian Road Congress at ±17 ^{0}C for moderate climates and at ±25 ^{0}C for extreme climates. The combined effect of temperature and shrinkage is given below.

For moderate climates : ± 17 - 15 = +2, - 32 (^{0}C)
For extreme climates : ± 25 - 15 = +10, - 40 (^{0}C)
IS: 456 1978 (hereafter called simply that Code) states in its clause number 17.5.1 that "in ordinary buildings, effect due to temperature fluctuations and shrinkage and creep can be ignored in the design calculations".

Wind loading

Dead and live loads are vertical or gravity loads. While wind and earthquake cause horizontal loads on a building. Temperature and shrinkage also results in horizontal loads on a building. Blast effect, earth and water pressure also a horizontal loads on a structure. IS: 875 gives values of wind pressure varying from 100kg/m^2 acting on building up to a height of 30m above the mean retarding surface i.e. the mean level of the adjoining ground. For buildings of height up to 10.0m, these wind pressure values can be reduced by 25 %.

VII. DESIGN OF SHEAR WALLS

The walls, in a building, which resist lateral loads originating from wind or earthquakes, are known as shear walls. A large portion of the lateral load on a building, if not the whole amount, as well as the horizontal shear force resulting from the load, are often assigned to such structural elements made of RCC. These shear walls, may be may be added solely to resist horizontal force, or concrete walls enclosing stairways, elevated shafts, and utility cores may serve as shearwalls. Shear walls not only have very large in-plane stiffness and therefore resist lateral load and control deflection very efficiently, but may also help to ensure development of all available plastic hinge locations throughout the structure prior to failure. The other way to resist such loads may be to have the rigid frame augmented by the combination of masonry walls. The use of shear walls or their equivalent becomes imperative in certain high-rise buildings, if inter- storey deflections caused by lateral loadings are to be controlled. Well-designed shear walls not only provide adequate safety, but also give a great measure of protection against costly non-structural damage during moderate seismic disturbances. The term shear wall is actually a misnomer as far as high-rise buildings are concerned, since a slender shear wall when subjected to lateral force has predominantly moment deflections and only very insignificant shear distortions. High-rise structures have become taller and more slender, and with this trend the analysis of shear walls may emerge as a critical design element. More often than not, shear walls are pierced by numerous openings. Such shear walls are called coupled shear walls. The walls on both sides of the openings are interconnected by short, open deep, beams forming part of the wall, or floor slab, or both of these. The structural engineer is fortunate if these walls are arranged in a systematic pattern. The scope of the book limits the discussion to shear walls without any openings.

Earthquake loading

IS 1893:2002 Criteria for earthquake resistant design of structures part 1 general provisions and buildings

The Code is now split into five parts

Part 1 - General provisions and buildings

Part 2 - Liquid retaining tanks - Elevated and ground supported

Part 3 - Bridges and retaining walls

Part 4 - Industrial structures including stack like structures

Part 5 - Dams and embankments

Design Strength

The design strengths for concrete and steel are obtained by dividing the charac- teristic strength of the material by a partial factor of safety, γ . The values of γm used in the program are as follows:

Partial safety factor for steel, γ = 1.15, and (IS 35.4.2.1)

Partial safety factor for concrete, γ= 1.15. (IS 35.4.2.1)

These factors are already incorporated in the design equations and tables in the code. Although not recommended, the program allows the defaults to be over- written. If the defaults are overwritten, the program uses the revised values consistently by modifying the code mandated equations in every relevant place.

Boundary Conditions

There are the portions along the wall edges and may have the same or greater thickness than the wall web. These are provided throughout the height with special confining reinforcement. Wall sections having stiff and well confined boundary elements develop substantial flexural strength, are less susceptible to lateral buckling and have better shear strength and ductility in comparison to plane rectangular walls not having stiff and well-confined boundary elements.

(a) During a severe earthquake, the ends of a wall are subjected to high compressive and tensile stresses. Hence, the concrete needs to be well confined so as to sustain the load reversals without a large deterioration in strength. Thus, the boundary elements are provided along the vertical boundaries of walls, when the extreme fibre compressive stress in the wall due to factored gravity load plus factor earthquake force exceeds 0.2fck. The boundary element may be discontinued where the calculated compressive stress becomes less than 0.15fck.

(b) The boundary element is assumed to be effective in resisting the design moment due to earthquake induced forces, along with the web of the wall. The boundary element should have an adequate axial load carrying capacity so as to carry an axial compression equal to the sum of the factored gravity load plus compressive load due to seismic load.

(c) Moderate axial compression results in higher moment capacity of the wall. Hence, the beneficial effect of axial compression by gravity loads should not be fully relied upon in a design, due to the possible reduction in its magnitude by vertical acceleration. When gravity loads add to the strength of the wall, a load factor of 0.8 may be taken

(d) The percentage of vertical reinforcement in boundary elements should range between 0.8 and 6 percent.

(e) During a severe earthquake, boundary elements may be subjected to stress reversals. Hence, they have to be confined adequately to sustain the cyclic loading without a large degradation in strength. Therefore, these should be provided throughout their height.

(f) Boundary elements need not be provided if the entire wall section is provided with special confining reinforcement.

VIII. COMPARISON OF MAXIMUM JOINT DISPLACEMENTS

TABLE: Maximum Joint Displacements						
Storey	With Shear Wall	Without Shear Wall	With Shear Wall	Without Shear Wall	With Shear Wall	Without Shear Wall
18F	-59.3	-109.6	-61.6	-109.7	-35.3	-39.6
18F	-59.3	-109.6	-61.6	-109.7	-35.3	-39.6
18F	-59.3	-109.6	-61.6	-109.7	-35.2	-39.5
18F	-59.3	-109.6	-61.6	-109.7	-35.2	-39.5
18F	-59.3	-109.6	-61.6	-109.7	-35.1	-39.4
18F	-59.3	-109.6	-61.6	-109.7	-35.1	-39.4
18F	-59.3	-109.6	-61.6	-109.7	-35.1	-39.3
18F	-59.3	-109.6	-61.6	-109.7	-35	-39.3
18F	-59.3	-109.6	-61.6	-109.7	-35	-39.2
18F	-59.3	-109.6	-61.6	-109.7	-35	-39.2
18F	-59.2	-109.5	-61.5	-109.6	-35	-39.2
18F	-59.2	-109.5	-61.5	-109.6	-34.9	-39.2
18F	-59.2	-109.5	-61.5	-109.6	-34.9	-39
18F	-59.2	-109.5	-61.5	-109.6	-34.9	-39
18F	-59.2	-109.5	-61.5	-109.6	-34.8	-39
18F	-59.2	-109.5	-61.5	-109.6	-34.8	-39

IX. CONCLUSION

Thus shear walls are one of the most effective building elements in resisting lateral forces during earthquake. By constructing shear walls damages due to effect of lateral forces due to earthquake and high winds can be minimized. Shear walls construction will provide larger stiffness to the buildings there by reducing the damage to structure and its contents.

From the above analysis it is observed that shear wall building is less deflection compared to without shear wall building.

Not only its strength, in order to accommodate huge number of population in a small area tall structures with shear walls are considered to be most useful.

Hence for a developing nation like India shear wall construction is considered to be a back bone for construction industry.

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