Structural Configuration Optimization of a Multistorey Building by Optimum Positioning of Shear Wall

M. Tamim .A Tanwer

Assistant Professor, Civil engineering, Pacific School of Engineering, Surat, Gujarat, India

Abstract: *The shear wall is a structural element which is used to resist earthquake forces. These wall will consumptives shear forces & will prevent changing location-position of construction & consequently destruction. On other hand, shear wall arrangement must be absolutely accurate, if not, we will find negative effect instead. For example if the shear walls make an increase distance between mass centre and hardness centre, we cannot expect a good tensional behavior from the structure. In case of mass centre and hardness centre coincide with each other, at that time the distance of shear wall from the mass centre also plays an important role in the shear contribution of the shear wall. The bending moment, shear force, torsion, axial force contribution by rest of the structural element and the ultimate design of all the structural components also affected by that. A study has been carried out to determine the optimum Structural configuration of a multistory building by changing the shear wall locations radically. Four different cases of shear wall position for a 10 storey residential building with keeping zero eccentricity between mass centre and hardness centre have been analyzed and designed as a space frame system by computer application software, subjected to lateral and gravity loading in accordance with IS provisions.*

Keywords: Shear walls, Lateral loading, Zero eccentricity, Stresses, Design configuration.

1. Introduction

Reinforced Concrete walls, which include lift wells or shear walls, are usual requirements of Multistory Buildings. Constructing the Shear wall in tall, medium and even short buildings will reinforce the significantly and either more economic than the bending frames. By the Shear walls, we can control the side bending of the structure, much better than other elements like closed frames and certainly the shear walls are more flexible than them. However, on many occasions the design has to be based on the off center position of the Lift and stair case walls with respect to the centre of mass. The design in these cases results into an excessive stresses in most of the structural members, unwanted torsional moments and sways. Design by coinciding Stiffness centre and mass of the building is the ideal for a structure. In this case there is no eccentricity, but as per IS 1893(1):2002 the minimum eccentricity is to be considered. The lateral force in a wall due to rotational moment is given by, $F_{ir} = $

$$\frac{k_i r_i}{\sum k_i r_i^2} (Fe_d)$$

r_i = Radial distance of shear wall "i"
F = Design Shear force e_d = Design eccentricity

From the above equation, it is observed that the distance of any shear wall from the centre of stiffness increases, the Shear generated in the Shear wall is decreased. The distance of Shear wall from the Centre of Stiffness is also an important Criteria for the Stresses generated in the Structural members and overall behavior of the whole structure.

The nature of stresses generated in the Shear wall according to its position is also different. The shear wall kept at very near to the Centre of stiffness act as a Vertical bending element and the shear wall kept at corner of the building are may be in axial compression or in axial tension according to the direction of the Lateral Force. In the bending nature of the wall the drift generated is more compare to shear walls kept at the corner of the building. So it is necessary and important to know, what should be the exact location of the shear walls that can results in minimum stresses in all the structural members of the multistoried building.

2. Aim and Objectives

AIM: - To locate shear wall at radial distance from the centre of mass for optimum configuration of a multistorey building, by keeping the features of shear wall constant.

Objective:-
1. To Study the operation of computer aided software "STRUD."
2. Validation of "STRUD." by designing a model building having existing design data.
3. Preparation of problem building drawing from the data.
4. Model generation of problem building in "STRUD."
5. Comparison of analysis and design data of four different cases having various radial position of shear

wall generated in the "STRUD."

3. Literature Review

Dr. Ali Memari (Carl hubben structural option) has given a technical report for „office building-G, Eastern United state" on a comprehensive examination of the lateral force resisting system. This report covered the existing superstructure, design loads and deflections, controlling load cases, load paths, strength checks, estimated drifts and displacements, and overturning effects. Upon completion of the report a broad understanding of the lateral system of Office Building-G was obtained. **M.Y.Kaltakci** et al. (2010) have carried out an experimental study dealing with a widely used strengthening method in Turkey, by using shear walls, was carried out for which the location of the shear wall was selected as the basic parameter of the analysis. In the light of the scaled experimental elements and the data obtained from the experiments, they concluded that;

- Shear walls and frame columns worked monolithically in both the application, and any anchorage debonding was not seen at the column-shear joint.
- Although the external shear wall type was expected to display a higher horizontal load bearing capacity than that of the partially infilled shear wall type, the partially infilled type presented higher horizontal load bearing and lower horizontal displacement with respect to the external shear wall type during the tests.

M. Ashraf, et al. (2008) has been carried out a study to determine the optimum configuration of a multistory building by changing shear walls location. Four different cases of shear wall position for a 25 storey building have been analyzed as a space frame system using a standard package ETAB subjected to lateral and gravity loading in accordance with UBC provisions. They have found that columns and beams forces are found to increase on grids opposite to the changing position of shear wall away from the centroid of the building. Twisting moments in members are observed to be having increasing trend with enhancement in the eccentricity between geometrical centroid of the building and shear wall position. Stresses in shear wall elements have more pronounced effect in elements parallel to displaced direction of shear wall as compared to those in perpendicular direction. The lateral displacements of the building are uniform for a zero eccentricity case. On the contrary, the drift is more on grids on one side than that of the others in case of eccentric shear wall position. They concluded that the shear wall should be placed at a point by coinciding center of gravity and centroid of the building.

Dr. Sudhir K. Jain has published a document (Document no: IITK-GSDMA-EQ21-V2.0) titled "Explanatory Example on Indian seismic code IS 1893(part1)". He has explained distribution of lateral forces in shear walls in example 5 & 6.

Dr. H.J. Shah, et al. has published a document (Document No.IITK-GSDMA-EQ26-V3.0) titled "Design example of a six storey building". They have explained analysis &

Paper ID: 14061402

78

design of a six storey building with considering earthquake forces.

IS 1893(part 1):2002 deals with assessment of seismic loads on various structure and earthquakes resistant design of building.

IS 13920:1993 covers the requirements for designing and detailing of monolithic reinforced concrete building so as to give them adequate toughness & ductility to resist severe earthquake shocks without collapse. In this code, "Annex A" (clause 9.3.1) gives the expression for moment of resistance of rectangular shear wall section.

4. Scope of Work

1) **To Study the operation of computer aided software "STRUD."**
   When any type of high-rise structure is going to be design, it should be analyze as the space frame rather than plain frame or plain grid. As the analysis of the high-rise structure as a space frame is very difficult or it seems to be impossible manually, so we need computer aided software which helps us to analyze the high-rise structure. So we are going to use the computer aided software "STRUD." And for this we are first of all going to study the operation by the tutorial of the software.

2) **Validation of "STRUD." by designing a model building having existing design data.**
   Whenever any structure is to be analyzing in any type of computer aided software first of all validation should be done about the software that the result given by the software are fair? For this purpose we are going to take one identical problem whose design have been done by manually or by any other means and we are going to input the same data into the above software and compare the result.

3) **Preparation of problem building drawing from the data.**
   We will develop an identical model by using Auto CA 2008 in the computer. We have taken a structure having six bays in both the horizontal direction. From these drawing we have created four different cases by placing the shear wall radically away from the centre of the stiffness in sequence. Also we will generate the centerline plan in AutoCAD 2008.

4) **Model generation of problem building in "STRUD."**
   After generating the centerline plan in AutoCAD 2008, we will input the above data in computer aided Structure Designing software. The input in the software is done in sequence from bottom to top. The design of structure is done in descending order from slab-beam-column-footing sequence.

5) **Comparison of analysis and design data of four different cases having various radial position of shear wall generated in the "STRUD."**
   After inputting the data in software and after

attaching all the sections / after doing all the preliminary data the analysis is carried out. With the help of this analysis of all the four different cases we will find the bending moment, shear force, axial force and sway in various elements of the structure. After obtaining the final results from all the above four cases we are going to make the comparison of ……

- Beam moments.
- Column axial forces.
- Storey displacement & drift.
- Percentage of steel in beams.
- Percentage of steel in column.
- Percentage of steel in footings.
- Overall economy of each case.

4.1 Data of the Example

A typical building (G+8) having three various position of shear wall and one without shear wall having following data Floor to Floor height = 3000mm
Height of Plinth = 450mm above ground level.
Depth of Foundation = 2100mm below ground level.
External Walls = 230 mm
Internal Walls = 115 mm

4.2 Imposed Loads

Roof:
Roof Finish = 1.5 KN/m^2
Live Load = Variable parameter
Floor :
Floor Finish = 1.0 KN/m^2
Live Load = Variable parameter

4.3 Earthquake Load

EQ load generation method = Response Spectrum Method
Seismic Zone = Zone 3
Soil Type = Medium Soil
Percentage Damping = 5 %
Modal Combination method = SRSS

4.4 Materials

Concrete = M20,
Steel: Main & Secondary = Fe 415
Unit Weight of Concrete = 25 KN/m^2
Unit Weight of Bricks Masonry = 19 KN/m^2
Design Basis: =Limit State Method based on
IS: 456-2000

5. Result

For Trial 1:
Live Load = 2 KN/m^2
Preliminary Beam Size = 230 x 450 mm

Total Quantity Of Concrete & Steel (Case Wise)		
Case	Quantity Of Concrete (m^3)	Quantity Of Steel (Kg)
A	427.527	40502.543
B	443.462	43519.958
C	437.365	47777.905
D	436.07	46638.293

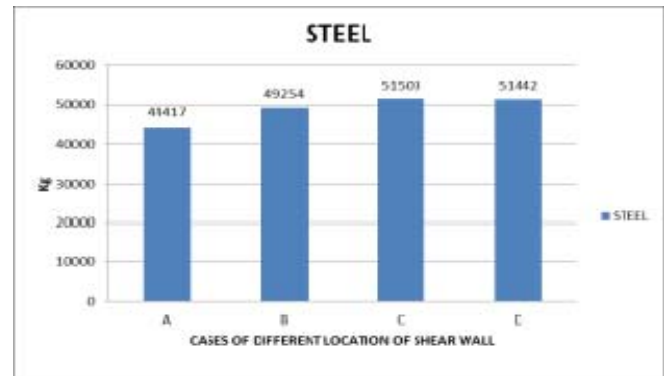**Figure 6.1:** comparison of concrete for trial 1

Figure 6.2: comparison of steel for trial 1

For Trial 2:
Live Load = 2 KN/m^2
Preliminary Beam Size = 230 x 300 mm

TOTAL QUANTITY OF CONCRETE & STEEL (CASE WISE)		
Case	Quantity of Concrete (m^3)	Quantity Of Steel (Kg)
A	346.343	44417.093
B	372.689	49253.937
C	379.097	51502.924
D	371.64	51442.215
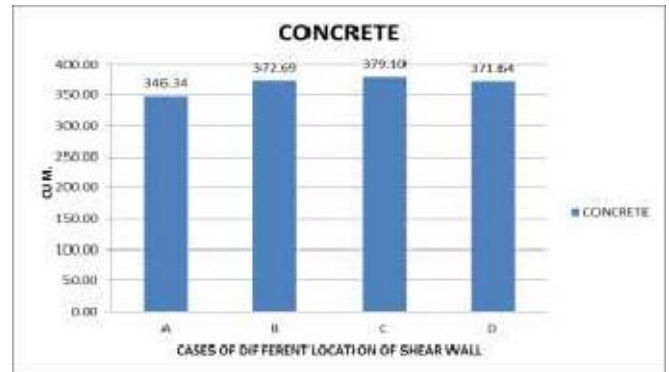
Figure 6.3: comparison of concrete for trial 2

Figure 6.4: comparison of steel for trial 2

For Trial 3:
Live Load = 3 KN/m^2
Preliminary Beam Size = 230 x 300 mm

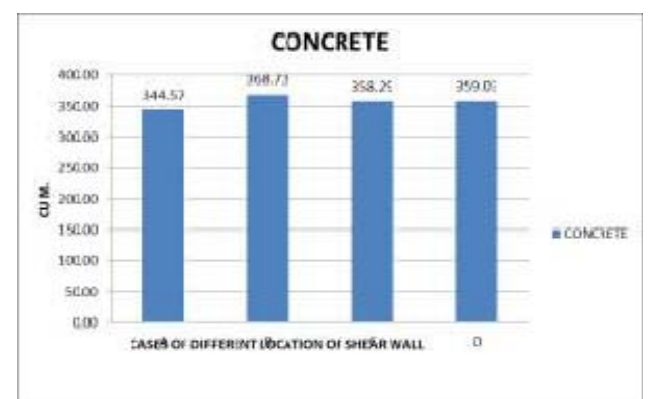| Total Quantity Of Concrete & Steel (Case Wise)		
Case	Quantity Of Concrete (m^3)	Quantity Of Steel (Kg)
A	344.573	42026.571
B	368.732	40526.971
C	358.288	43556.985
D	359.032	41639.221

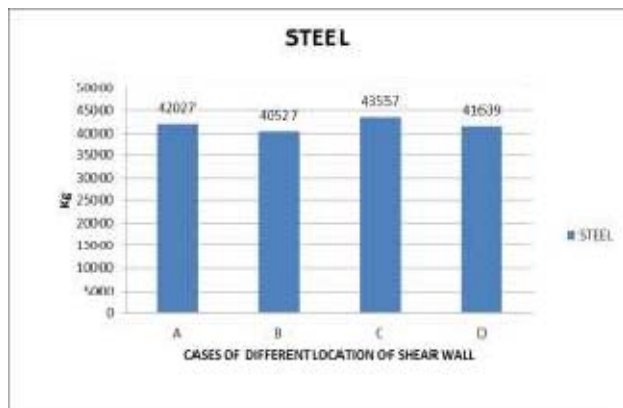**Figure 6.5:** Comparison of concrete for trial 3

Figure 6.6: Comparison of steel for trial 3

6. Remarks

When live load 2 KN/m2 and beam size is 230 x 450mm, quantity of steel is increase (approx 17%) at location of shear wall near to the center of building, compare to shear wall at corner of building.

When the shear wall kept near to the center with live load is 2KN/m2 and preliminary dimension of beam is 230 x 300mm, quantity of steel in beam increase (approx 15%), while quantity of steel in column is decrease (approx 8.77%) as compare to shear wall at corner of building.

When live load 3 KN/m2 and beam size is 230X300mm, quantity of steel is increase (approx 13%) at location of shear wall near to the center of building, compare to shear wall at corner of building.

When live load 3 KN/m2 and beam size is 230 x 300mm, quantity of steel is decrease (approx 22%) at location of shear wall near to the center of building, compare to building without shear wall.

The location of shear wall at corners of building is much effective while increasing live load 3 KN/m2 with preliminary dimension of beam 230 x 300mm.

The shear wall gives beneficial effect of more clear head way in case of providing it at corners of building or away from the center of building.

Quantity of steel and concrete is less in case of without shear wall so it is said that for G+8 building with 2 KN/m2 live load and preliminary beam size is 230 x 450 mm or 250 x 300mm, there is no economical beneficial effect of shear wall.

7. Scope for Further Work

Here the G+8 building is taken one can take higher no. of floor as G+15 or G+20 more than that, it may be given

More effective beneficial effect of shear wall.

The problem building is only symmetric square building; one can take rectangle, L-shape, C-shape building with eccentricity.

Identical building of (6 bay x 6 bay) is taken in problem for simplicity, but commercial and residential building irregular shape in plan can also take for further work for implementation to this project. Shape of shear wall is taken in this building is "L shape"; one can take different shape for further work.

References

[1] IS:456-code of practice for plain and reinforced concrete
[2] IS:875(part 1-5)- code of practice for structural safety of building loading standards
[3] IS 1893(Part-1):2002, Criteria for earthquake resistant design of structures.
[4] IS 13920:1993, Ductile detailing of reinforced concrete structure subjected to seismic forces-code of practice.
[5] SP:16-design aids for reinforced concrete
[6] Dr. Memari Ali, (2010), office building G, Eastern United States. Technical report, vol-3.
[7] M.Ashraf, Siddiqi Z.A. & Javed M.A., (2008), Configuration of a multistorey building subjected to lateral forces, vol-9, page no:-525-537.
[8] Kaltakci M.Y., Arslan M.H.,Yavuz G., (2010), Effect of internal & external shear wall location on strengthening weak RC frames, vol-17, page no:- 312-323.
[9] Onkar V. Sapate, Dr.A.M.Pande/International journal of Engineering Research and Applications. Vol. 1, Issue 4. pp.1515-1521
[10] Dr. Jain k., Explanatory example on indian seismic code IS 1893 (Part-1).
[11] Dr. Shah H.J. & Dr. Jain Sudhir k., Design example of a six storey building.
[12] Earthquake tips (1 to 24), Learning earthquake design and construction.
[13] www.World-housing.net/wp-content/uploads/..../type-RC-Wall.pdf
[14] www.nibs.org/.../Topic11-...
[15]www.iitk.ac.in/nicee/EQTips/EQTip23.pdf
[16]www.structech.us/SHEARWALL-Rev1.ppt
www.iitk.ac.in/.../SeismicBehaviour_Design & Detailin gofShearWalls-...
[15] www.wisegeek.com/what-is-a-shear-wall.htm