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Effect of Lift Core Wall Location in High Rise Buildings

Atif Khan[1], Asif Shahzad[1], Adil Shahzad[1], Usama Hanif[1] and Dawood Israr[1]

1. Department of Civil Engineering, COMSATS University Islamabad, Abbottabad campus, Pakistan.

   Email: atif52452@gmail.com ,

2. Department of Civil Engineering, COMSATS University Islamabad, Abbottabad campus, Pakistan.

   Email: shahzaasif@gmail.com ,

3. Department of Civil Engineering, COMSATS University Islamabad, Abbottabad campus, Pakistan

   Email:adilshahzad482@gmail.com ,

4. Department of Civil Engineering, COMSATS University Islamabad, Abbottabad campus, Pakistan

   Email: usamahanifseven@gmail.com ,

5. Department of Civil Engineering, COMSATS University Islamabad, Abbottabad campus, Pakistan

   Email: dawoodisrarkhan@gmail.com

Abstract

High Rise buildings are designed as frame structures with shear walls to provide sufficient strength, stability and stiffness against these lateral earthquake forces acting on the building. For the convenience of users, a Lift Core wall (LCW) is provided instead of shear wall which serves the same function as that of shear wall. In this study an attempt is made to study the different locations of the LCW in a 10-storey building, analysed using ETABS 2016 Static Force Method as per UBC-97 in Seismic Zone-3 of Pakistan. A LCW is provided at 4 different locations and the results are compared on the basis of displacement, Storey drift and Storey stiffness to select the best location of a LCW. It was found that LCW offers maximum seismic resistance at the centre of the building.

Key Words: Lift Core Wall (LCW), Lateral Stiffness, Storey Drift, Torsional irregularity, Static force method.

1. Introduction

The damages caused by an earthquake must be kept in mind before designing a building because it has caused enormous calamities in Asia and other continent (Azad & Gani, 2016). Lateral earthquake forces are greater in case of Reinforced Concrete multi-storey buildings, so they are designed to resist these loads. A Shear wall is the best solution to give structural stability to high rise buildings (Schodek, Subagdja, & Suryoatmono, 1999). Shear wall is a structural element which provides stiffness, strength and stability against the lateral forces that are acting upon it. So, high rise buildings are designed as framed structures with shear walls to resist the cracks or bending in order to ensure the stability of the tall buildings (Chandiwala, 2012). For architectural purposes and for the convenience of users, a shear wall is replaced by LCW, which provides the desired strength and stability to the buildings and with open sections it also accommodates an elevator shaft or a staircase (Constantin & Beyer, 2012; Goud & Pahwa, 2016). A LCW must be provided at such a location where it provides maximum seismic resistivity (Varna & Bhavana, 2017).In this paper, we will study the effect of location of a LCW on the stiffness, lateral displacements and storey drift of the building.

2. Research Methodology

In this study, ten storey commercial building was analysed by Static Force Method. The building was assumed to be situated in seismic Zone 3 of Pakistan using ETABS 2016. Rectangular LCW was provided at 4 different locations and earthquake forces in both the x-direction and y-direction were considered.

2.1. Building Layout

The building considered had 5 bays in x-direction and 5 bays in y-direction. Length of each bay was 20 ft, so the total area of the building was 10,000 ft^2. Centre to centre height for each storey was 12 ft, so the total height of the building was 120 ft.

15 in x 18 in concrete beams, 18 in x 18 in columns, 7 in thick slab and 9 in thick rectangular LCW of 10 ft x 7 ft with 4 ft x 7 ft openings in y direction was selected for analysis. Column supports were assumed to be fixed.

2.2. Lift Core Wall Locations

LCW was provided at four different locations (Fig-1) and the building was analysed according to UBC-97. These locations were named as:

L_0 – Frame with no LCW
L_1 – First location of LCW (Corner)
L_2 – Second Location of LCW
L_3 – Third Location of LCW
L_4 – Fourth Location of LCW (Centre)

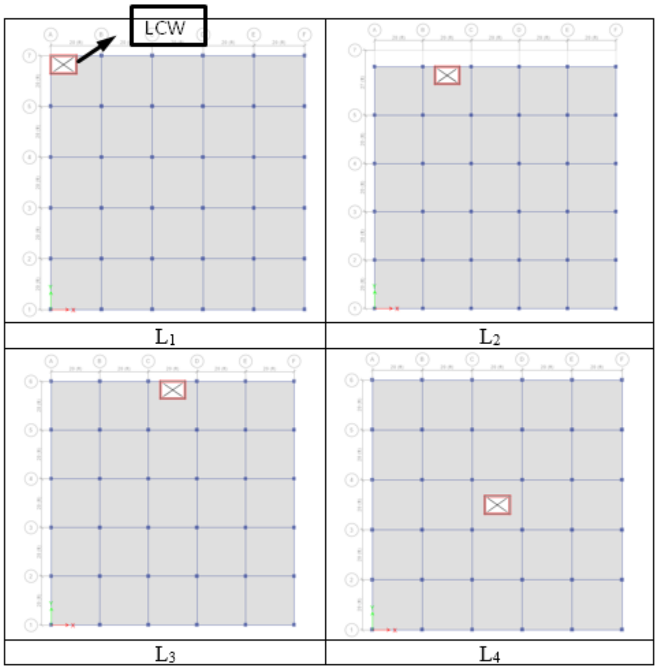


Figure 1- LCW Locations

2.3. Material Properties:

Table 1-Material Properties

Material Properties		
Material	Properties	Consider Value
Concrete	Concrete compressive strength, fc’	3000 psi
	Concrete Modulus of Elasticity, Ec	$57000 \sqrt{fc'}$ psi
	Weight per unit volume	150 pcf
	Poisson’s Ratio	0.2
Steel	Steel Type	Grade 60, ASTM A165
	Reinforcement Yield Strength,fy	60 ksi
	Tensile Strength, Fu	90 ksi
	Specific Weight	490 pcf
	Steel Modulus of Elasticity, Est	29,000 ksi
Site	Seismic Zone	3
	Soil Type	SD

2.4. Loads on the building:

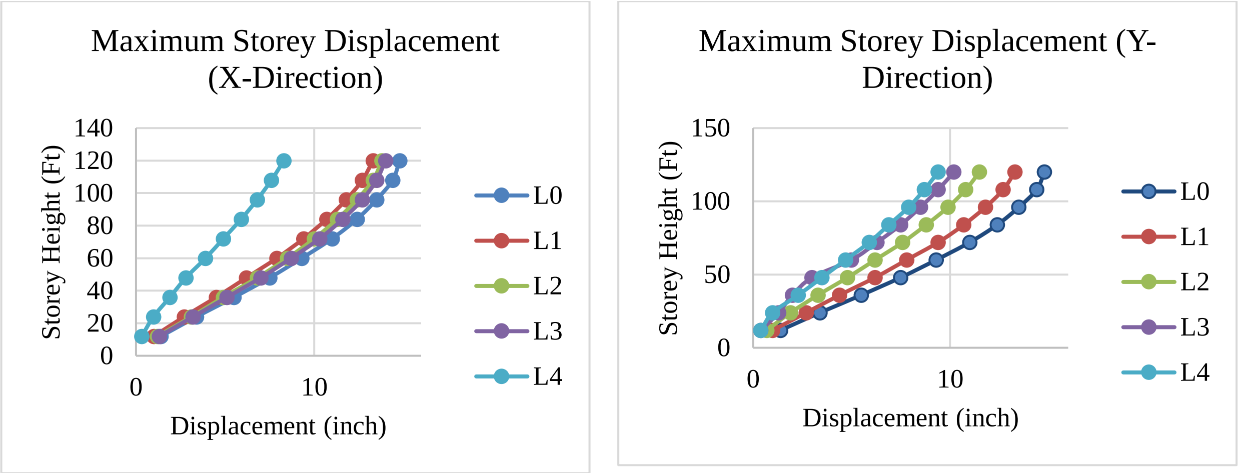
Load for the structure was considered as per UBC-97. Self-weight of the structure was considered as Dead load. 60 psf Live load was considered for typical floors, while for the roof it was reduced to 40 psf. Similarly, 3 in thick marble and 1 in thick tiles were considered as Floor finish loads whose value was found to be 43.75 psf. This value was considered for typical floors but for roof it was increased to 60 psf. For typical floors 9 in thick brick wall was considered with a height of 10.5 ft and its load was calculated to be

1 k/ft while for roof 4.5 in thick brick wall was considered whose load was calculated to be 0.135 k/ft (Table-2).

Table 2- Different Loads

Load type	Load Concentration	
	Typical Floor	Roof
Dead Load	Self-Weight of the structure	Self-Weight of the structure
Live Load	60 psf	40 psf
Partition Walls Load	21 psf	21 psf
Floor Finish (Mortar+Tile)	43.75 psf	60 psf
Wall Load on beams	1 kip/ft	0.135 kip/ft

3. Results and Discussions:



a.

b.

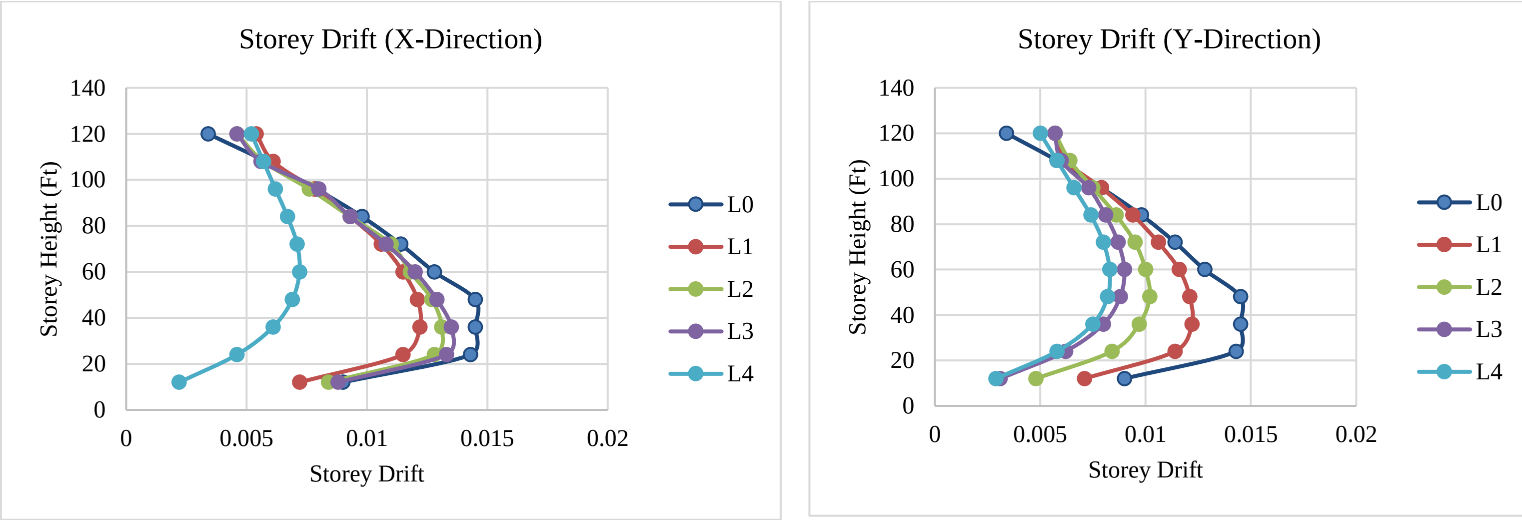
3.1. Maximum Storey Displacement:

Figure 2-Maximum Storey Displacement

The maximum storey displacements were decreased by incorporating LCW in the building (Fig-2). In both x and y direction, the maximum storey displacements were effectively reduced by the incorporation of LCW at L_4. In x-direction, the second best location was L_1 (Fig-2a) while in y-direction; the second best location was L_3 (Fig-2b).

The maximum displacements in y direction at L_3 and L_4 were almost the same because the LCW at both the locations is located at the centre of the building corresponding to earthquake.

3.2. Storey Drift

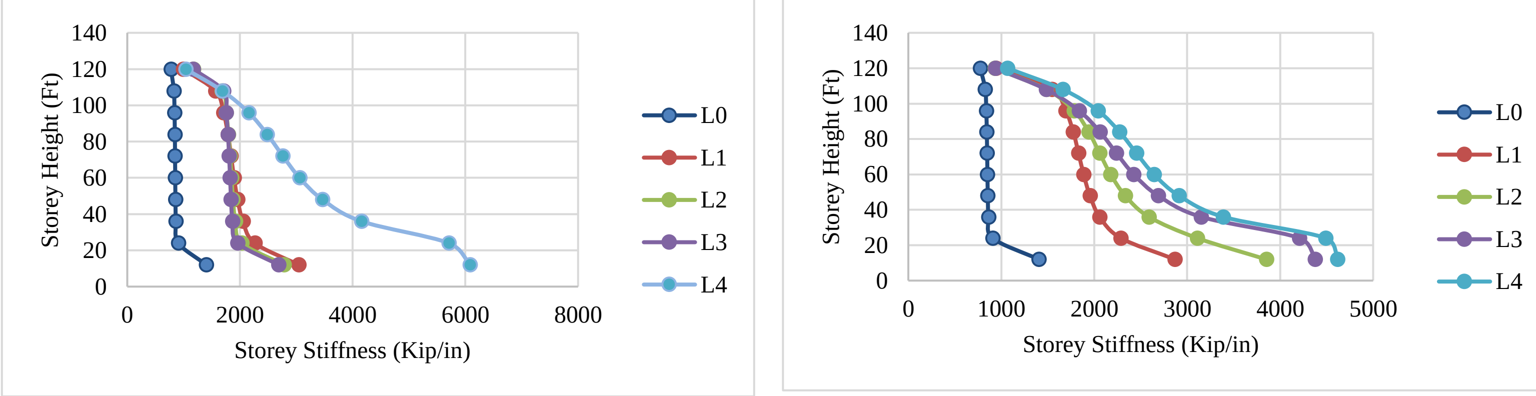


a. b.

Figure 3-Storey Drift

The storey drift was reduced by incorporating LCW in the building (Fig-4). At L_4, the storey drift was minimum in both x and y directions. However, at locations other than L_4, the results were different in x and y direction because of the different distribution of forces in both directions. For example, L_1 had second minimum value of drift in x-direction (Fig-4a) but it also had the largest drift value in y-direction (Fig-4b). Similarly, L_3 had second minimum drift value in y-direction while maximum drift value in x-direction.

3.3. Storey Stiffness

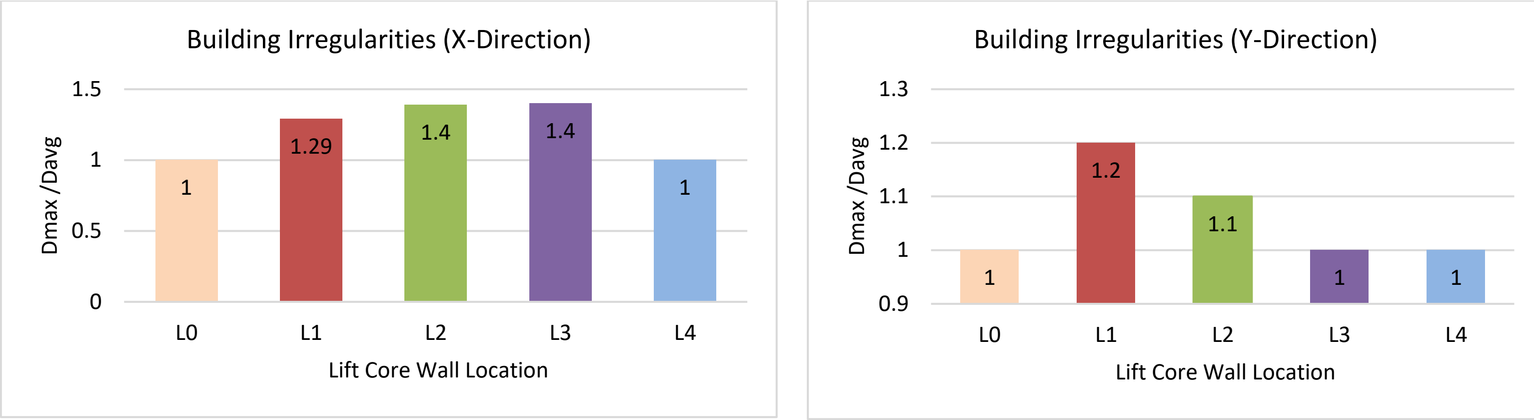


a. b.

Figure 5-Storey Stiffness

The storey stiffness in both the x and y direction was found at L_4 (Fig-5). The stiffness of the building in x-direction was more than that of y-direction because of the in-plane behaviour of LCW. The LCW is provided for in-plane forces. As the length of wall is more in x-direction compared to the length of wall in y-direction, so it will take more loads in x-direction and the stiffness of the building will be increased. At locations other than L4, the maximum stiffness in x-direction was found at the corner of the building (L_1) and this value decreased as the LCW location was changed from L_1 towards L_3 (Fig-4a). While in y-direction, the stiffness value was minimum at L_1 and it was increased as the LCW location was changed from L_1 towards L_3 (Fig-4b).

3.4. Torsional Irregularities:



a. b.

Figure 7-Irregularities in building

When a building does not have the same centre of mass and centre of rigidity, torsional irregularities are produced in the building. These torsional irregularities might cause the failure of the structure. $D_{max}/D_{avg}$is a factor that is used to find the torsional irregularities in buildings. If this value is more than 1.4, the building will have extreme torsional irregularities, if it is greater than 1.2, the building have moderate torsional irregularities, while if it is less than 1.2, the building does not have any torsional irregularities.

From Fig-7, it can be seen that:

At L_0 and L_4 there were no torsional irregularities in building because of the same centre of mass and centre of rigidity.

At L_1, the building had moderate torsional irregularities in both x-direction and y-direction.

At L_2 and L_3, the building had extreme torsional irregularities in x-direction, while there were no torsional irregularities in y-direction, because, there was more distance between the centre of mass and centre of rigidity in x-direction while in y-direction there was less distance between them.

3.5. Base Shear

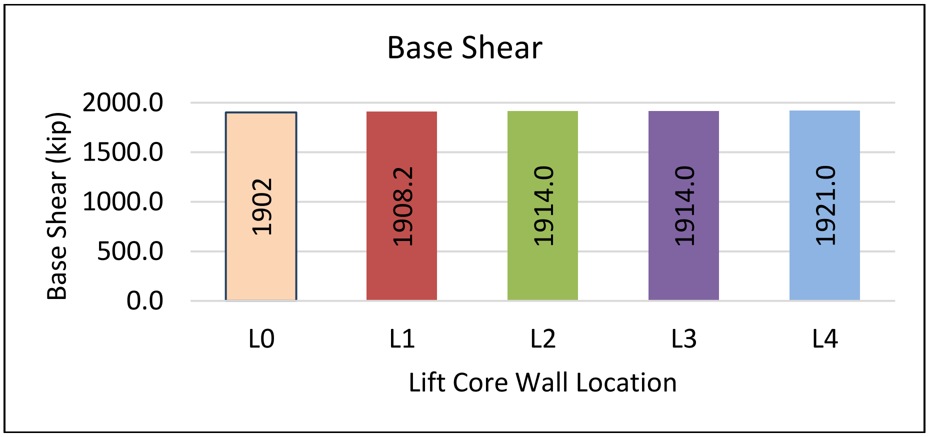


Figure 4-Base Shear

In static force method Natural time period is a function of height. As height of the building is same so the natural time period T was also same (1.088 sec) for all the locations of LCW. Other factors Cv, R, Importance factor and weight of the building was same for all the locations of LCW, so the Base Shear for all the locations was also almost the same.

4. Conclusions

1) LCW reduces the displacement and storey drift and increases the lateral stiffness of the building, so it is better to use LCW in buildings to resist earthquake forces.
2) LCW must be provided at the center of the building because it gives maximum stiffness, minimum displacement and minimum storey drift and produces no torsional irregularities.
3) Building must be checked for torsional irregularities if LCW is to be provided at different location other than the center of the building because LCW produces torsional irregularities.

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