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SENSITIVITY OF LIFT CORE POSITIONS FOR T-SHAPED REINFORCED CONCRETE BUILDINGS SUBJECTED TO SEISMIC LOADS

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ABSTRACT

T-shaped buildings are classified as buildings with plan irregularity and vulnerable to damages under seismic loading. This study investigates the sensitivity of lift core positions by comparing the percentage difference of the maximum torsional moment and building deformation for T-shaped reinforced concrete buildings. Building models having 6-storey and 12-storey were generated and analysed with the aid of SAP2000 software package. The results showed that the locations of the lift core significantly influenced the magnitude of the torsional moment and particularly true for all building heights. It is highly recommended that the position of the lift core must be carefully determined in order to reduce or arrest the failure associated to torsional moment.

1. Introduction

Natural disasters such as earthquakes can cause significant impacts and possess a threat to the surrounding. Earthquakes cannot be prevented but the impact can be notably reduced by improving the strength and stability of the structures. There are many factors that can lead to the failure of a building during an earthquake event. Apart from the magnitude of earthquake force, other factors such as soft storey, setback, and irregularities can influences the stability of the buildings (Setia and Sharma, 2012; Sarkar et al., 2010). A building with plan irregularity is sensitive to torsional response during an earthquake event due to the unbalanced distribution of mass, strength and stiffness (Rajalakshmi et al., 2000).

At present scenario many asymmetric buildings in plan and/or in elevation were constructed nowadays, particularly warranted by the architect. These buildings are commonly equipped with lift core(s) and the positioning of the lift core during planning stage can play a vital role in enhancing the seismic capacity of a particular building (Vadahane and Sir, 2016). Hoult et al. (2015) reported that placing a single lift core at the perimeter of a building created plan asymmetry in plan and subsequently, produce large torsional response. The objectives of this study are to determine the seismic response of a 6-storey T-shape building with different lift core locations and to study the effect of building height on the seismic response of T-shape buildings.

2. Methods

2.1 Building data

T-shape wall-frame building models with heights 18 m and 36 m were used in this study. The wall section was contributed by the presence of 2 m × 2 m lift core. Four different lift core positions were selected in order to study the sensitivity with respect to the building responses. The plan view of the T- shape building and the proposed lift core positions are shown in Figure 1. The details of the building models are shown in Table 1.

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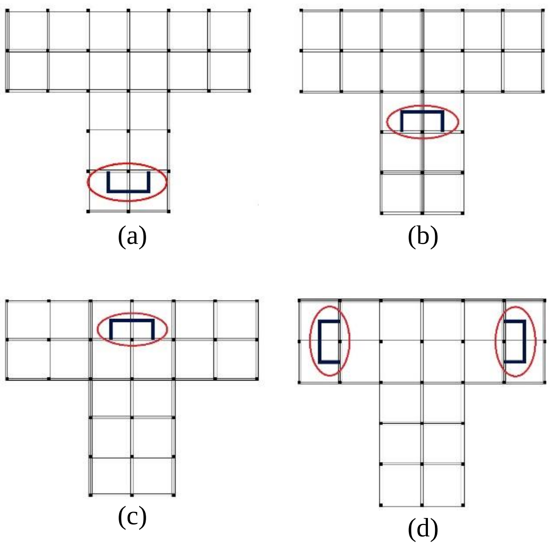

Figure 1: Typical plan view of T-shape building model showing shear wall position at (a) bottom wing, single (B-SGL); (b) center, single (C-SGL); (c) top, single (T-SGL) and (d) top wing at both ends (T-DBL).

Table 1: Details of the building models

Height of building	6-storey	18 m
	12-storey	36 m
Size of column	6-storey	0.6 m × 0.6 m
	12-storey	0.7 m × 0.7 m
Beam size		0.3 m × 0.75 m
Slab size		4.0 m × 4.0 m
Slab thickness		0.150 m
Shear wall thickness		0.200 m
Concrete grade		C35

2.2 Load combination

The seismic analysis was carried out using the load combinations as follow (EN 1998-1, 2004):-

i. $1.35\ G_k + 1.5\ Q_k$
ii. $1.0\ G_k + 0.3\ Q_k + 1.0\ E$
iii. $1.0\ G_k + 0.3\ Q_k - 1.0\ E$

where,

G_k = Dead Load
Q_k = Live Load
E = Earthquake Load

3. Results and Discussions

3.1 Maximum building displacement

Figure 2 shows the maximum displacement of the models in x-direction with respect to the lift core positions. The maximum building displacement was calculated to be 72.4 mm (6-T-SGL), 67.7 mm (6-B-SGL), 60.5 mm (6-T-DBL) and 53.8 mm (6-C-SGL). It can be seen that for 6-storey model, the maximum deflection occurs when the lift core position is located at top wing of the building. This phenomenon is particularly true due to the fact that the top wing of the building possess highest lateral stiffness (columns and lift core) while the bottom wing suffer less stiffness. As a result, the maximum displacement occurs at the far end of the bottom wing as shown in Figure 3.

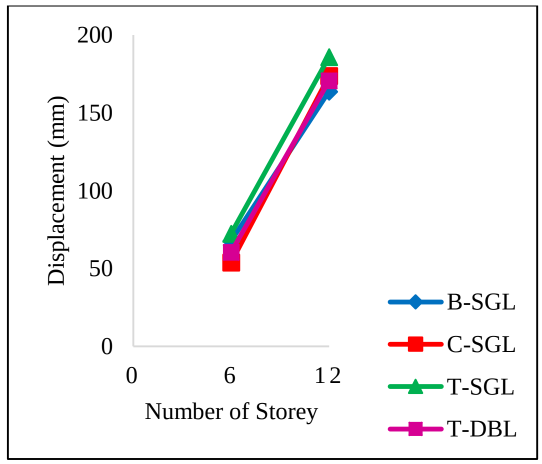

Figure 2: Building displacement in x-direction

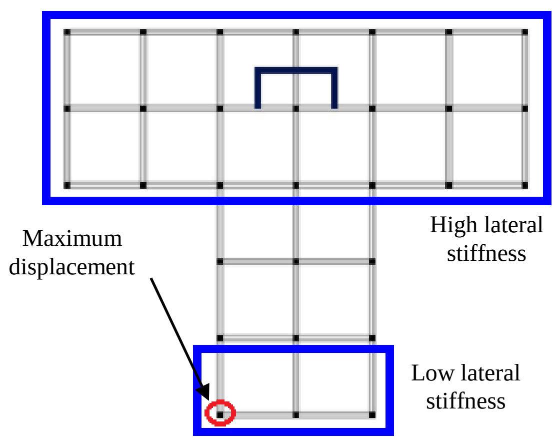

Figure 3: Location of the maximum displacement for model 6-T-SGL

The lift core at the bottom wing (6-B-SGL) showed lower displacement compared to 6-T-SGL. The location of the maximum displacement for this case is located at the perimeter corner column on the top wing of the model as shown in Figure 4. The stiffer section at the bottom resisted the displacement effectively making the building to behave similar to a cantilever structure where the top wing shows the highest displacement.

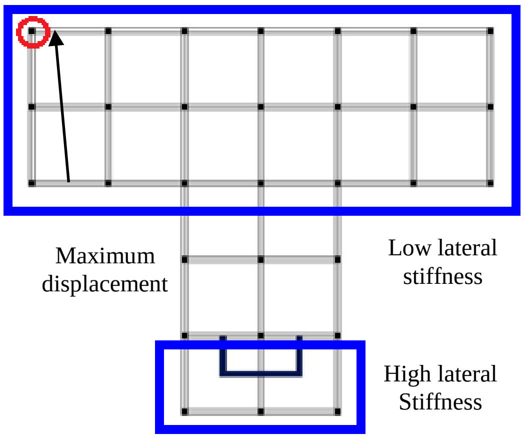

Figure 4: Location of the maximum displacement for model 6-B-SGL

Interestingly, the results showed that by having a single lift core along the axis of symmetry and closer to the centroid of the building produced the least displacement. It is expected that the closer the lift core to the centroid of the building reduces the eccentricity between the centre of mass and center of stiffness. This position is shown to be more efficient compared to providing two lift cores at the top wing of the building.

The maximum displacement for the 12-storey shows slightly different results compared to 6-storey building model. The highest maximum displacement was recorded to be 185.9 mm (12-T-SGL), followed by 173.6 mm (12-C-SGL), 170.6 mm (12-T-DBL) and 163.7 mm (12-B-SGL). It can be seen that the highest displacement is exhibited when the single lift core is placed on the top wing of the building. As mentioned earlier, this position enhanced the stiffness of the top wing leaving the bottom wing of building to be susceptible to large displacement.

On the contrary, the maximum displacement of the building model where the lift core was located at the center (12-C-SGL) showed higher value compared to two lift cores at top and lift core at bottom. The results suggest the effect of having lift core closer to the centroid is no longer effective in controlling the maximum displacement. The difference between the highest and lowest maximum displacement for 6-storey and 12-storey was calculated to be 34.6% and 13.6%. These relatively low percentage differences showed that the magnitude of the maximum displacement is not significantly influenced by the lift core positions.

Figure 5 shows the maximum recorded column torsion for all models. It can be seen that for 6-storey building, the maximum torsion in the column occurs for model 6-B-SGL followed by 6-T-SGL, 6-C-SGL and 6-T-DBL. The maximum torsion was observed to be 32.4 kNm, 26.7 kNm, 13.1 kNm, and 11.6 kNm accordingly. Building model with two lift cores on the top wing showed to generate the lowest column torsion. It is believed that such configuration has significantly reduced the unbalance distribution of mass, stiffness and strength of the plan asymmetric model. On the other hand, the highest torsion observed in model 6-B-SGL and this finding may be due to the fact that its location was relatively further to the centroid of the building. The lift core in 6-B-SGL act as the point of rotation for the model and as such any external column closer to the lift core at ground level experienced high torsion as shown in Figure 6.

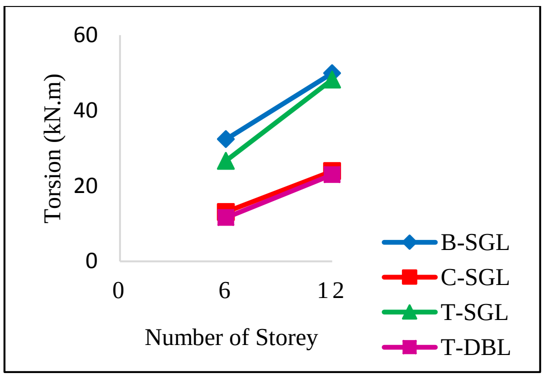

Figure 5: Maximum column torsion

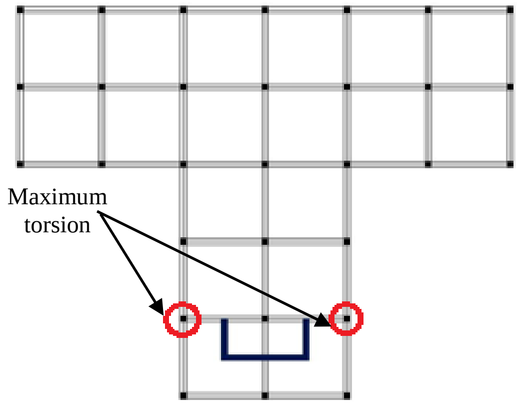

Figure 6: Location of the maximum torsion at ground level for 6-B-SGL.

In the case of 12-storey building model, the maximum torsion for 12-B-SGL, 12-T-SGL, 12-C-SGL and 12-T-DBL were recorded to be 49.9 kNm, 48.2 kNm, 23.9 kNm, and 23.0 kNm, respectively. The results showed that the trend remains the same with the increase in the building height. The percentage difference in terms of the maximum torsion with respect to the lift core location for 6-storey and 12-storey was calculated to be 179.3% and 117%, respectively. Unlike the trend showed earlier for maximum deformation, the difference in terms of the column torsion can be more than 100%. This finding reflects that inappropriate position of the lift core can pose potential danger due to torsional damage.

4. Conclusion

The column torsion of a T-shape plan asymmetric building is found to be sensitive with respect to the lift core locations where the difference can be significantly high. Designing two lift cores at the far end of the top wing is showed to be effective in reducing the torsion.

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