EFFECT OF PERIMETER FRAMES IN SEISMIC PERFORMANCE OF TALL CONCRETE BUILDINGS WITH SHEAR WALL CORE AND FLAT SLAB SYSTEM.

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ABSTRACT :
Tall buildings are being increasingly designed with structural system comprising of flat slab or flat plate system and shear wall core with or without perimeter beams. The behaviour of this system under lateral loads is dependent on numerous parameters such as the height of the building, floor plate size, size and location of the shear wall core, flat slab spans, amongst others. Importantly, it is also dependent on the provision or otherwise of a perimeter frame. The paper studies the effect of perimeter frames for structural systems with flat slab structure and shear wall core for different locations of the shear wall core and for different heights and spans of three concrete towers. In a structure with a central shear core, the effective depth of structure resisting lateral loading is practically equal to the depth of the shear wall core. Providing outriggers to such a system greatly helps in improving its behaviour by engaging the perimeter columns with the shear wall core and thus increasing the effective depth of structure participating in lateral load resistance. The effect of such perimeter frame with outrigger system is also studied.

KEYWORDS:
Perimeter frame, flat slab, shear wall core

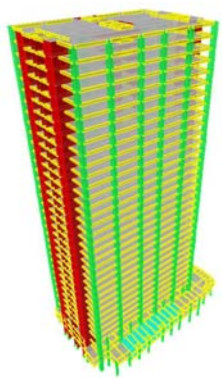
1. INTRODUCTION

Three concrete towers having concrete flat slabs with shear walls have been analysed for their behaviour with and without a perimeter framing beam. One of the models is also analysed with addition of outrigger system. For simplicity, following assumptions have been used for the parametric studies of all models:

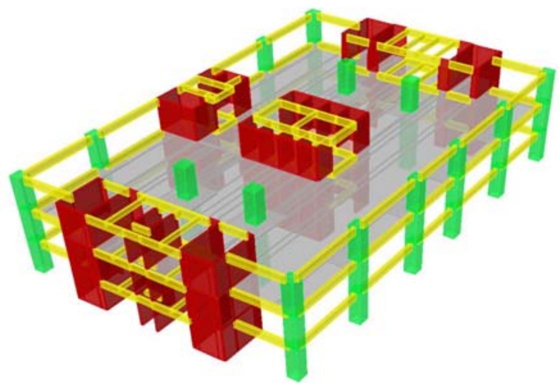
- All models are concrete towers.
- For the purpose of this study, only linearly elastic behavior is considered.
- The sizes and locations of the columns, beams and walls are unaltered from base to roof.
- Model includes the stiffness of all structural elements occurring in the model including the floor slab which has been modeled using shell elements. All slab cutouts have been modeled.
- Shear walls are modeled as shell elements. All elements including perimeter frame and internal columns are modeled as having axial, flexural and shear stiffness.
- Moment of inertia of all members is based on cracked sections.

2. MODEL A

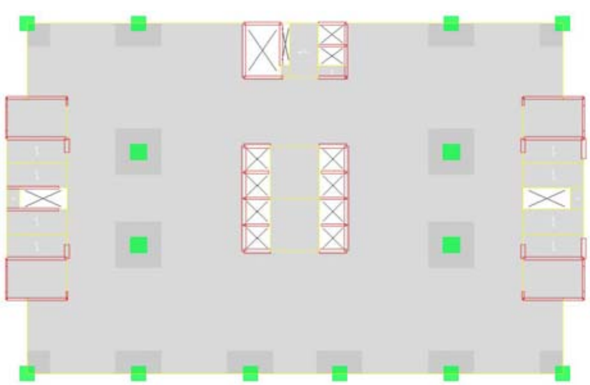
Model A is a tower with height of 144 m and rectangular floor plate of 79 m x 38 m. There are a total of 36 slabs. The typical floor height is 4m. The tower has a central shear wall core of 11m x 11 m and two shear wall cores 21.5m x 6.6 m. along the centre of the shorter edges of structure and a smaller shear wall core of 6m x 11m along centre of one long edge. Perimeter columns have been provided at about 11m spacing. The locations of the shear wall cores have emerged from the architectural layout and functional requirements to account for passenger elevators, staircase and utility blocks and car elevators. The slab is a flat slab with drop panels. Figure 1 gives plan and isometric view of model.



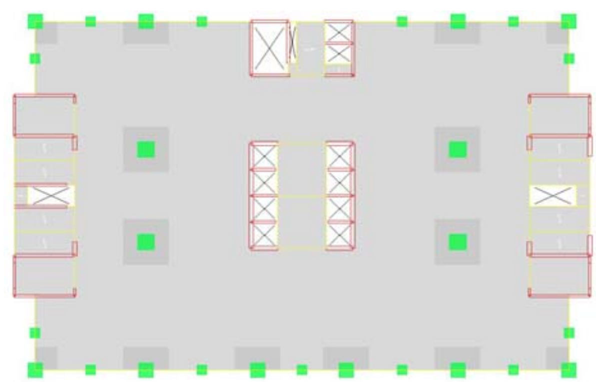
Isometric view of Model A1, A2



Enlarged Part Isometric view of Model A1, A2



Plan of Model A1 and A2



Plan of Model A3

Fig 1- Model A

The model is studied for three cases. In case A1, no perimeter beam is provided. In case A2, a perimeter beam of size 400 mm x 900 mm is introduced connecting all periphery columns. For case A3, additional columns between the existing perimeter columns have been introduced and spandrel beam of 400 x 900 has been provided.

2.1 Structure Behaviour

The resulting maximum drift, and participation of the perimeter frames (as % of sum of lateral shear in perimeter columns at base versus the total base shear) in each of the cases is shown in Table 1. Figure 2 gives graphical comparison of these results.

Table 1. Maximum Drift, % Base Shear in Perimeter Columns and Time Period for Models A1, A2, A3

Model Case	Maximum Drift	% of Lateral load in Perimeter frame Columns	Fundamental time Period (secs)
A1- No perimeter beam	0.0029	0.29%	7.55
A2 – with perimeter frame	0.0021	11.30%	6.5
A3 – with perimeter frame using additional perimeter columns	0.0008	34.38%	4.39

2.2 Inferences

From the results it is seen that presence of periphery frame impacts performance of building significantly. Further, perimeter frame with closer spaced columns is far more effective in improving behaviour of the building than farther spaced columns. This is because the frame with closer spaced columns is able to achieve tube action.

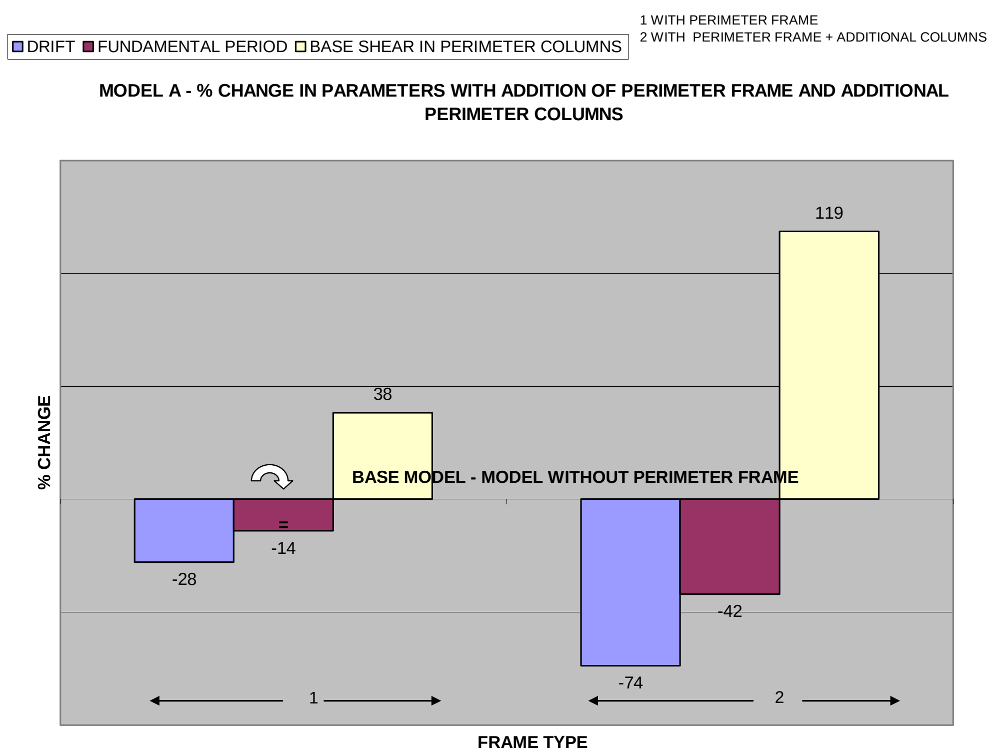


Figure 2- Graphical comparison of the systems with and without Perimeter frame in Model A

3 MODEL B

Model B has height of 139 m and an 144 m and an ovoid floor plate of maximum 170 m x 94 m.. There are total of 38 slab levels. The typical floor height is 4.2 m. The structural system comprises of central shear wall core of maximum dimensions of 53m x 14 m. There are perimeter columns at spacing varying between from 10.6 to 13.1 m. Columns are approximately 1500 mm diameter. The slab is a flat slab with drop panels. Perimeter beams when provided are 400 x 900. The model is studied for its behaviour in three cases.
i) Case B1 – There are no periphery beams

ii) Case B2- Beam of 400 mm x 900 mm connecting all periphery columns is provided
iii) Case B3- Two outriggers at levels 92 m and 134 M have been added to model of Case B2. The outriggers are placed at mechanical plant room floors. These outrigger trusses are 4.2 m deep (one floor height) The outriggers engage the perimeter columns with the central shear wall core. Figure 3 gives plan and isometric view of model.

The model was not studied for closer spaced perimeter columns due to the ratio of length and width of the building. The ratio being almost 2, efficient tube action was unlikely to be developed. Also, as the fundamental displacement mode was in the shorter direction, increasing effective depth of resisting frame in that direction by means of outriggers appeared to be a more efficient option.

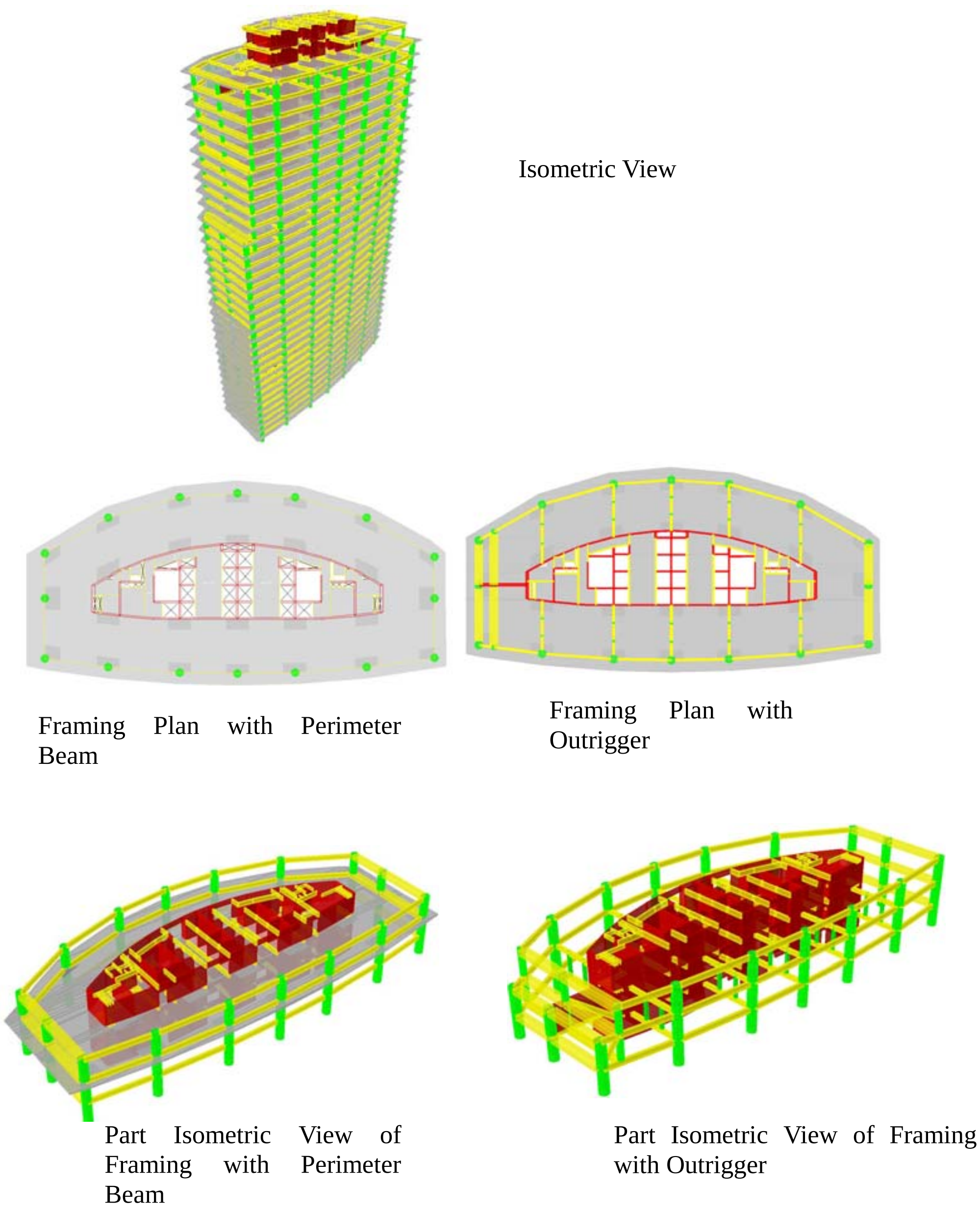


Figure 3 – Model B

3.1 Structure Behaviour

The fundamental mode shape in this case is the Y (shorter) direction in all cases. The drift, fundamental period and perimeter columns participation are given in Table 2.

Table 2. Maximum Drift, % Base Shear in Perimeter Columns and Time Period for Models B1, B2, B3

Model Case	Maximum Drift	% of Lateral load in Perimeter frame Columns	Fundamental Period (secs)
B1- No perimeter beam	0.0024	2.94%	4.85
B2 – with perimeter frame	0.0021	3.13%	4.66
B3 – with perimeter frame and outriggers	0.0010	3.15%	3.55

3.2 Inference

The perimeter frame while adding some stiffness does not significantly improve behaviour. On the other hand the outriggers, especially those parallel to shorter edge greatly increase the effective depth of the building structure and thus its participation in resisting the lateral loads. As can be seen in Figure 4, there is a 66% reduction in the drift in the model A3 with outriggers as compared to Model A1 without perimeter beams while there is only a 13% reduction in drift with introduction of perimeter frame without outriggers.

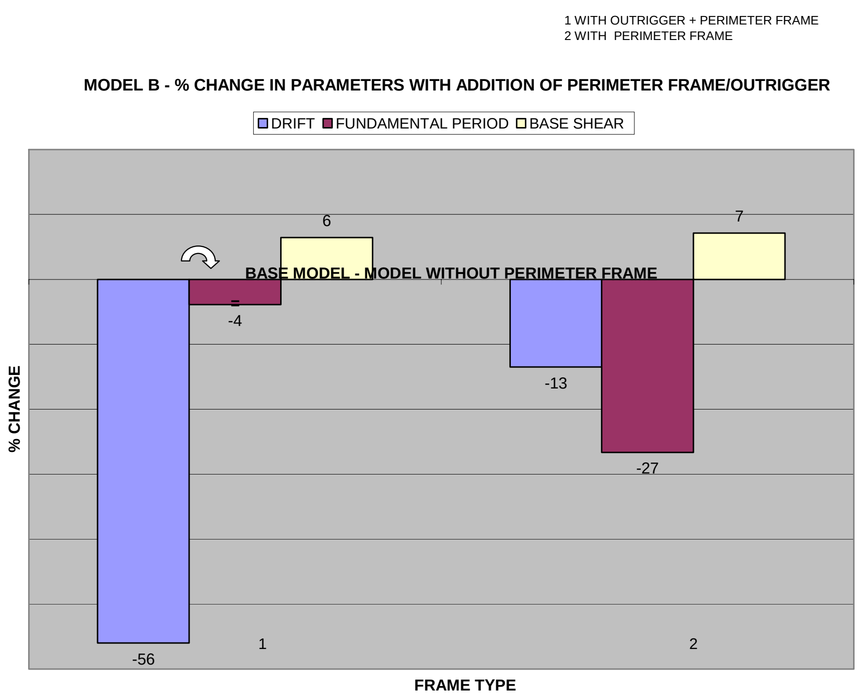
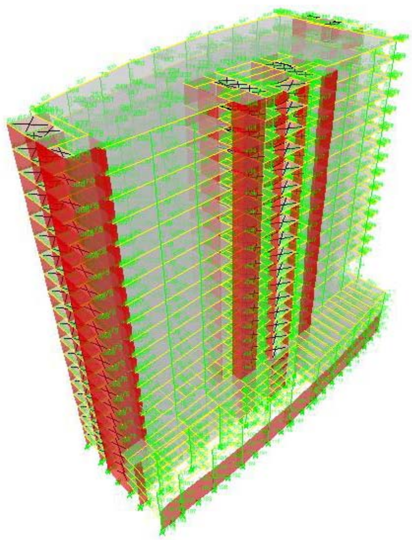
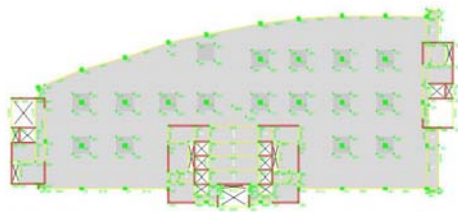


Figure 4: Graphical comparison of the systems with and without Perimeter frame and Outriggers in Model B

4 MODEL C

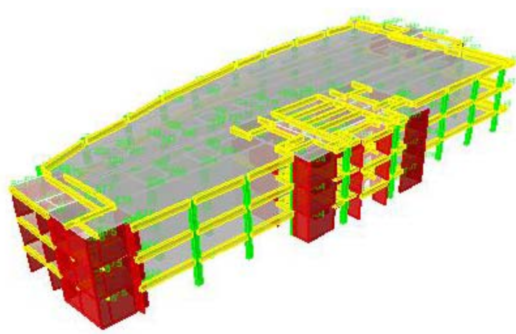
Model C is a concrete tower shaped like the segment of a circle. It is about 88 m in length and is maximum 30 m wide. The building is 75 m high and has 20 suspended slabs with a typical floor height of 4.1m. There is a central shear wall core of 25m x 15m but offset towards the bottom of the building. There are two shear wall cores 7m x 17 m along the centre of the shorter edges of structure. The columns spacing is 7.5 m to 8.5 m including along the perimeter. The slab is a flat slab with drop panels. Columns are 900 mm diameter and 600 x 900 sizes and perimeter beams when provided are 300 x 900. Figure 5 gives the plan and isometric view of the tower.





Framing Plan with Perimeter Beams

Isometric View



Part Enlarged Isometric View

Figure 5- Model C

The model is studied for its behaviour in two cases.
i) Case C1 – There are no periphery beams
ii) Case C2- Beam of 300 mm x 900 mm connecting all periphery columns is provided

The model was not studied for closer spaced perimeter columns due to the ratio of length and width of the building. The ratio being almost 3, efficient tube action was unlikely to be developed.

4.1 Structure Behaviour

The drift, fundamental period and perimeter columns participation are as shown in Table 3.

Table 3. Maximum Drift, % Base Shear in Perimeter Columns and Time Period for Models C1 and C2

Model Case	Maximum Drift	% of Lateral load in Perimeter frame Columns	Fundamental Period (secs)
C1- No perimeter beam	0.00238	2.94%	4.85
C2 – with perimeter frame	0.00206	3.13%	4.66

4.2 Inferences

The building is of less height as compared to Models A and B. The proportionate stiffness of this model is more than in Models A and B and is reflected in the low drift. Due to large stiffness of shear walls and large spacing of the perimeter columns, the effect of perimeter frame is negligible.

As can be seen in Figure 6, there is a little less than 13% reduction in drift if perimeter beam is added to the system. The % of base shear with or without perimeter frame in perimeter columns remains practically unchanged. Likewise, there is a 6% decrease in fundamental period with introduction of perimeter frame. Overall, the effect of perimeter frame is not significant in this case.

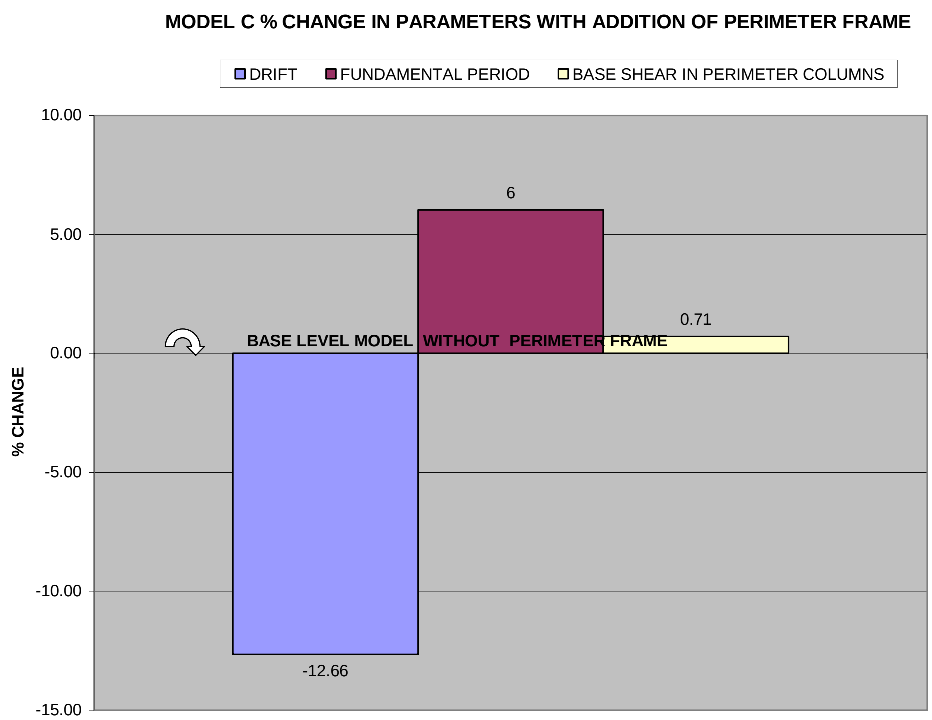


Figure 6: Graphical comparison of the systems with and without Perimeter frame in Model A

5. CONCLUSIONS:

From the above three models it may be inferred that for tall buildings of compact size, regular shape and distributed shear wall core such as in Model A, there is a very marked improvement in performance of the structure with flat slab system and shear wall core when a perimeter frame with closely spaced columns is added to the structure. Farther spaced perimeter column frame has a relatively less impact on reducing drift. In buildings such as Model B with a central shear wall core and with length to width ratio exceeding 2, the performance is enhanced by adding outriggers and perimeter frame. A perimeter frame without outriggers does not help significantly in resisting lateral loads. For shorter towers of non compact size and with distributed cores, the perimeter frame does not greatly impact the structural behaviour.

There is a growing inclination amongst architects and clients to do away completely with the perimeter frames. While this may be acceptable in towers with distributed shear wall cores and of relatively less height as in Model C, lack of a perimeter frame compromises the behaviour of the structure in term of drift and overall stiffness.

REFERENCES

Taranath Bungale. (2005). Wind and Earthquake Resistant Buildings –Structural Analysis and Design, Taylor and Francis, USA

Chang King-Le and Chen Chun-Chung (October 2004). Outrigger System for Tall Building Structure with Central Core and Square Floor Plate. Council of Tall Buildings and Urban Habitat (CTBUH) 2004 Proc. Seoul, Korea.

Smith S. and Salim I.(Octiober 1981) Parameter Study of Outrigger-Braced Tall Building Structures. Proc. ASCE 107, ST10.

Smith S and Coull A. (1991). Tall Building Structure Analysis and Design. John Wiley and Sons, Inc, USA