Study on Effectiveness of Outrigger Truss in Composite High-Rise Buildings by Simplified Method

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Abstract: The design of tall and slender structures is controlled by three governing factors, strength (material capacity), stiffness (drift) and serviceability (motion perception and accelerations), produced by the action of lateral loading, such as wind and earthquake. Outrigger systems are generally very effective in fulfilling the serviceability requirements of tall buildings. This research conducted a study on effectiveness of outrigger truss by simplified method to introduce the normal buildings that can be minimized the deflection as the buildings with outrigger. Two and three outrigger levels are used in 40 and 50 storey square shape buildings respectively. From this result, the engineers can run the buildings without using outrigger to get the minimum deflection as the buildings with outrigger but the base shear is larger than outrigger buildings significantly. Therefore, for the proposed buildings to get minimum deflection, the outrigger is more effective than simplified method.

Key Words: Stiffness; serviceability; Deflection; Simplified Method; Outrigger Truss.

Introduction:

The fundamental design criteria for high-rise building are strength, serviceability and stability whereas human comfort should also be included in these. Outrigger systems are generally very effective in fulfilling the serviceability requirements of tall buildings especially in deflection. The outriggers and belt girder should be at least one and often two to three stories deep to realize adequate stiffness. Usually structural engineers have to conduct a rigorous analysis with trial and error approach before a conceptual set of information can be achieved. Many researches are done about the number and level of outrigger that can give optimization result of normal building. Moreover, structural engineers needed to know the simplified method to introduce the normal building that can be minimize the deflection as the building with outrigger. So the stiffness modification factor is also needed that can get minimum deformation as outrigger buildings.

Methodology:

The structural systems of tall buildings for all the types, namely, steel buildings, reinforced concrete buildings, and composite buildings. There exists a myriad of lateral bracing systems that may be grouped into distinct categories, each with an applicable height range. For outrigger and belt truss system, the buildings with 40-50 storey are more effective [3].

Outrigger Systems

Outrigger systems are modified form of braced frame and shear-walled frame systems, and utilized in steel and composite constructions. As an innovative and efficient structural system, the outrigger system comprises a central core, including either braced frames or shear walls, with horizontal ‘‘outrigger’’ trusses or girders connecting the core to the external columns. If the building is subjected to the horizontal loading, the rotation of the core is prevented by the column-restrained outriggers. They are generally positioned at plant levels to reduce the obstruction they create [4].

Analysis: The method of analysis is based on the following assumptions:

1. The outriggers are rigidly attached to the core.
2. The core and columns are rigidly attached to the foundation.
3. The sectional properties of the core are uniform throughout the height.
4. The axial stiffness of column decreases linearly with the structural height.

1. Case Study

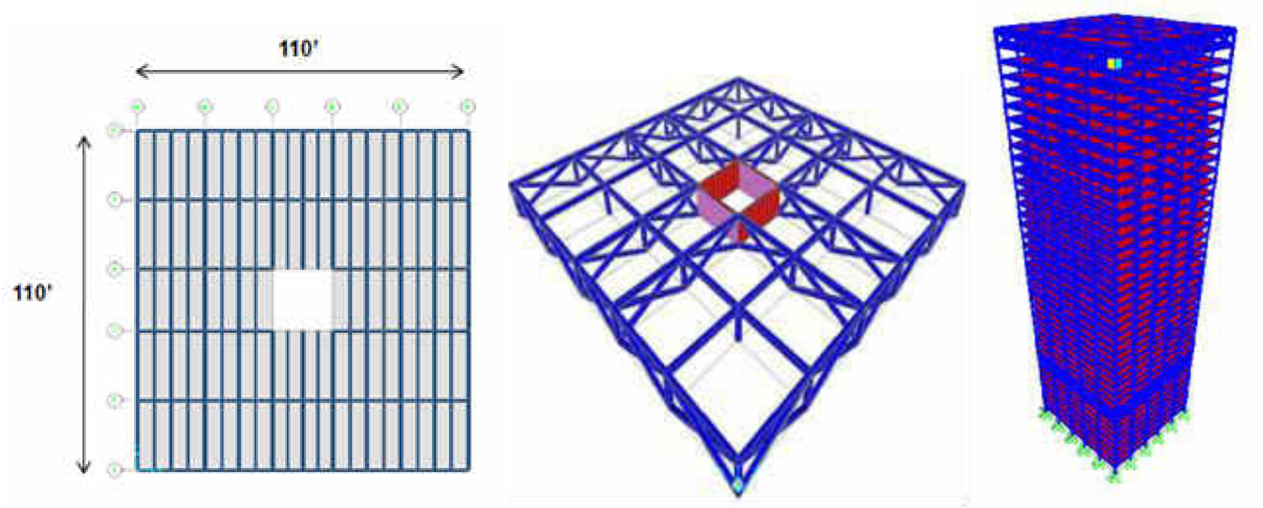

Fig.2 Floor Plan and 3D View of Square Shape Model

For the effect of earthquake, linear dynamic response spectrum at zone 2B is used. Data preparation for analysis and design are according to Uniform Building Code 1997 and AISC-LRFD. Two outrigger levels at top and 0.75 times from base of the building are used in 40 storey building and three outrigger levels at top, 0.75 and 0.5 times from base of the building are used in 50 storey buildings. The plan layouts selected is square shape model. This has equal plane dimensions and hence can represent circular building [1] and [2].

2. Analysis Procedure

The analysis is made as the following procedure;

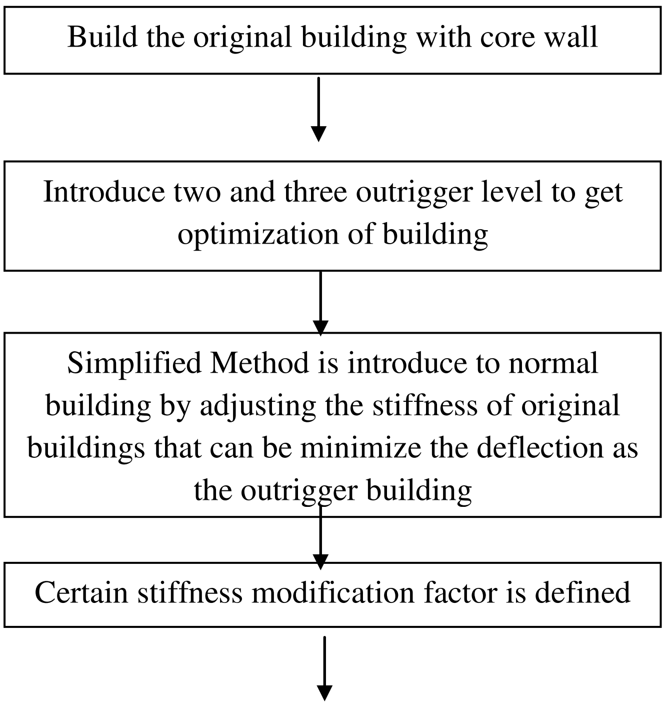

Fig.1 Analysis Procedure

Result: For 40 storey buildings, the difference of maximum displacement between the buildings with outrigger and by simplified method is nearly the same in X and Y direction. The different of maximum displacement between original building and the building with outrigger is 13.33%. The different of maximum displacement between original building and by simplified method is 13.79%.

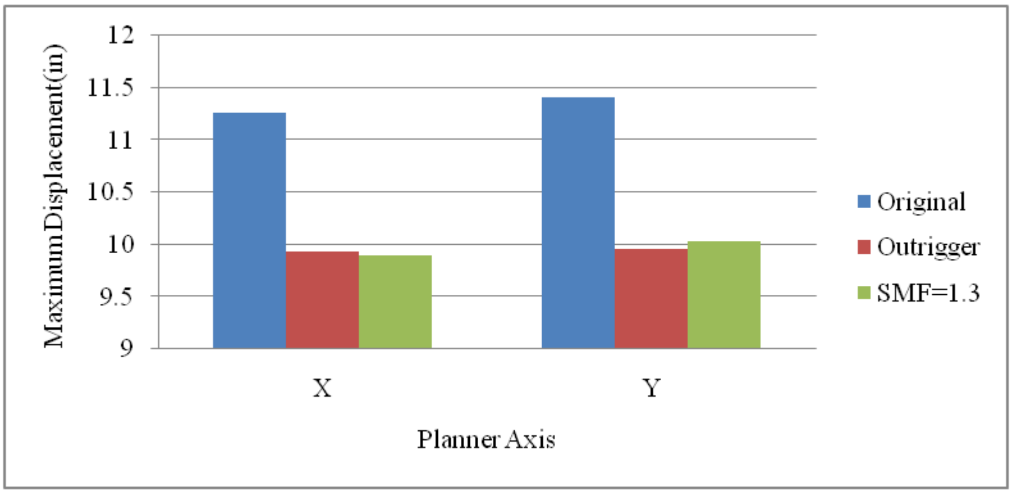

Fig.3 Maximum Displacement of 40 Storey Square Shape Buildings in X and Y Direction

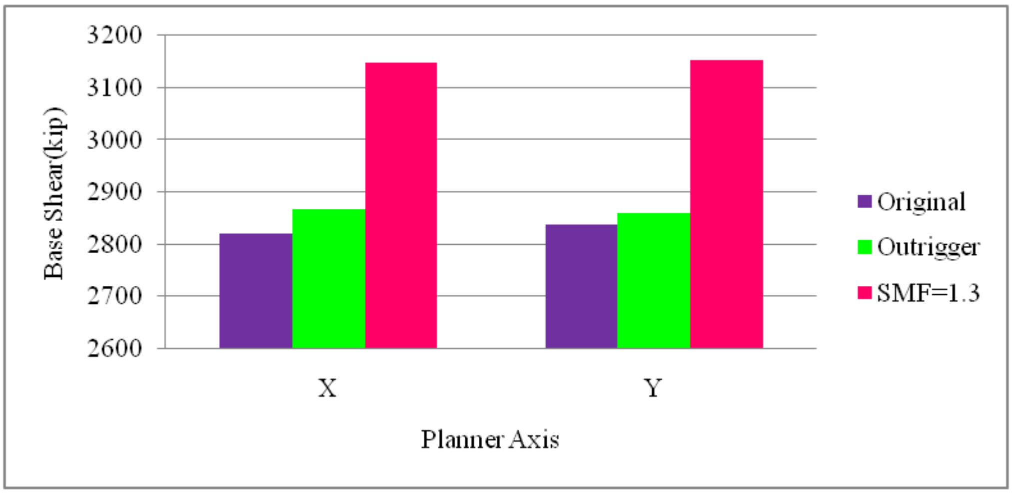

Fig.4 Base Shear of 40 Storey Square Shape Buildings in X and Y Direction

But the base shear between the buildings with outrigger and by simplified method is significantly different. The different of base shear between original building and the building with outrigger is 1.63%. The different of base shear between original building and by simplified method is 11.59%.

The difference of period between the buildings with outrigger and by simplified method is not significantly in X and Y direction. The different of period between original building and the building with outrigger is 10.12%. The different of period between original building and by simplified method is 13.8%.

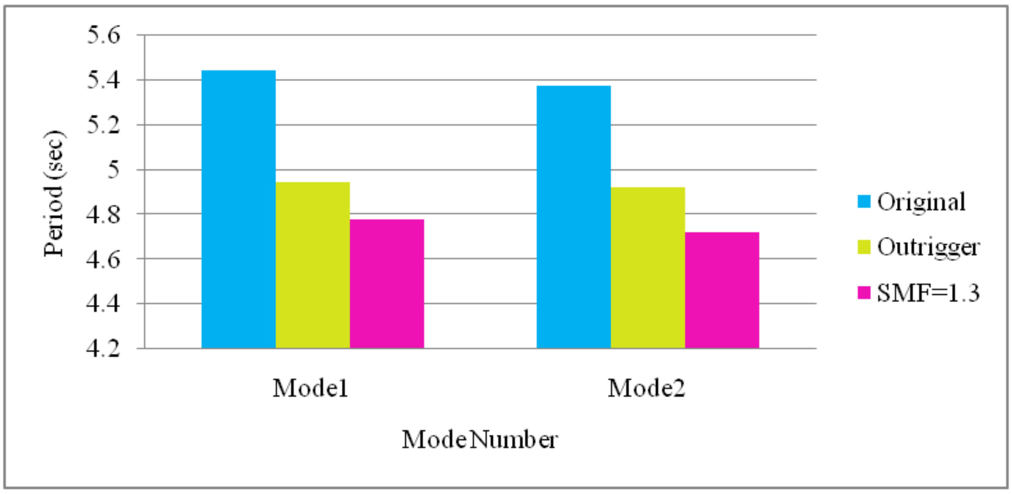

Fig.5 Period of 40 Storey Square Shape Buildings in X and Y Direction

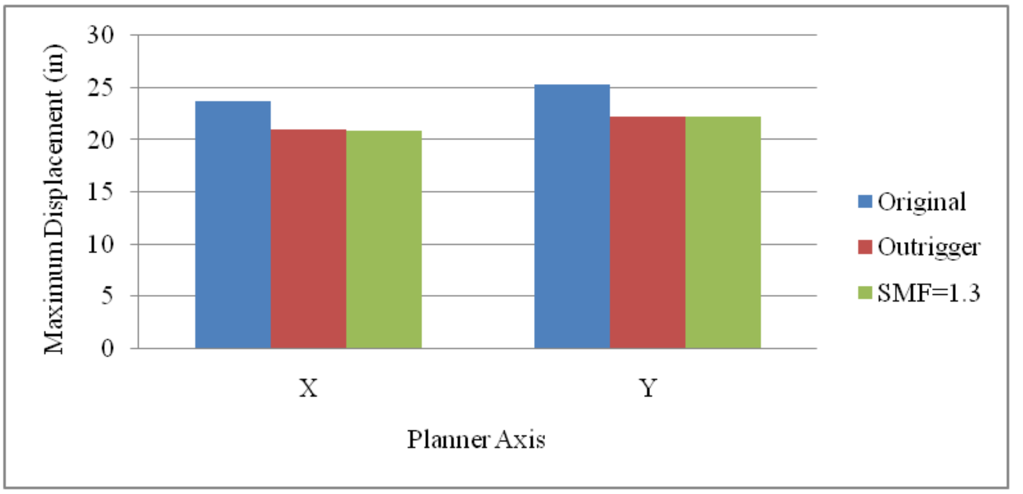

Fig.6 Maximum Displacement of 50 Storey Square Shape Buildings in X and Y Direction

For 50 storey buildings, the difference of maximum displacement between the buildings with outrigger and by simplified method is nearly the same in X and Y direction. The different of maximum displacement between original building and the building with outrigger is 13.23%. The different of maximum displacement between original building and by simplified method is 13.87%.

But the base shear between the buildings with outrigger and by simplified method is significantly different. The different of base shear between original building and the building with outrigger is 5.95%. The different of base shear between original building and by simplified method is 12.33%.

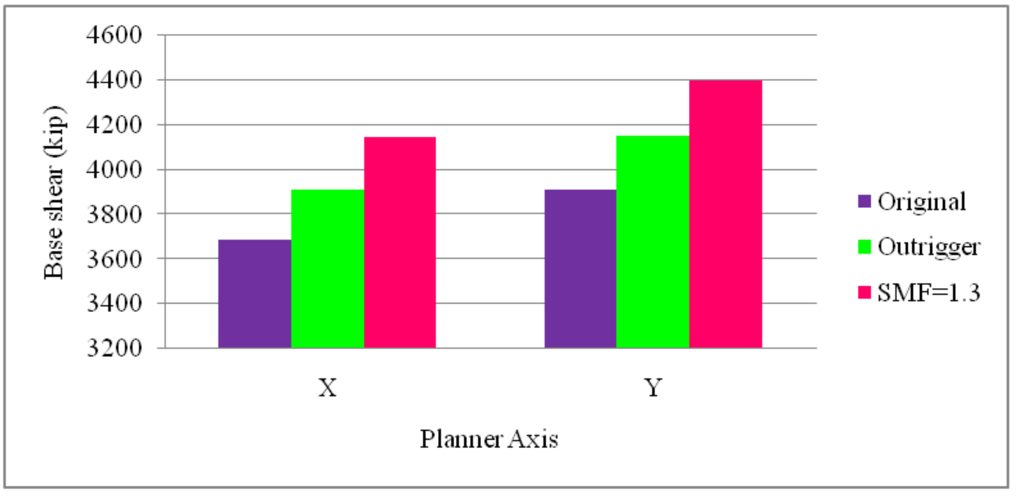

Fig.7 Base Shear of 50 Storey Square Shape Buildings in X and Y Direction

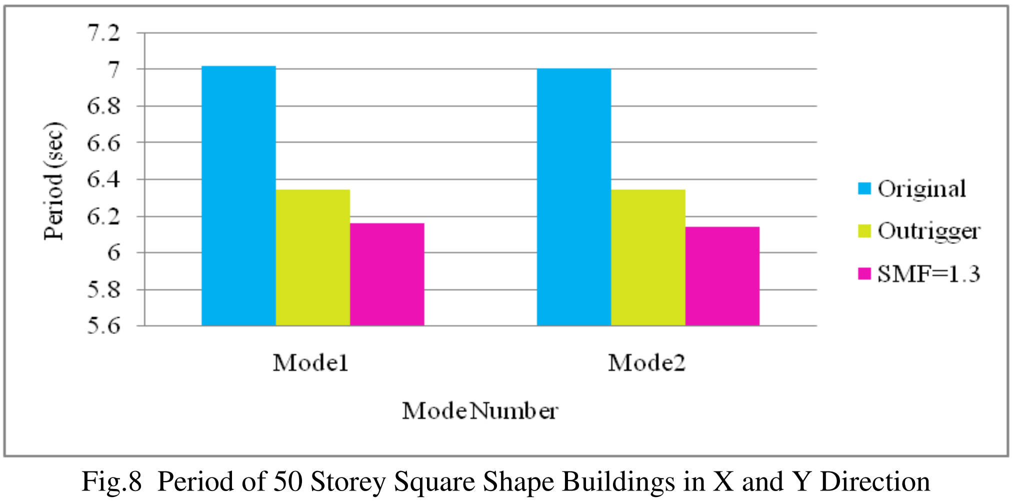

Fig.8 Period of 50 Storey Square Shape Buildings in X and Y Direction

SMF= Stiffness Modification Factor

The difference of period between the buildings with outrigger and by simplified method is not significantly in X and Y direction. The different of period between original building and the building with outrigger is 10.68%. The different of period between original building and by simplified method is 14%.

Recommendations: The following studies are recommended that

1. Considering wind dynamic load on the design of tall building.
2. Introduction of a soft storey in model.
3. Detail connection need to research for tall building especially composite building.

Conclusion: According to the results from this study, the following conclusion can be made. For square shape 40 storey original buildings, stiffness modification factor needed to increase 1.3 times at the whole building to get minimum deformation of two outrigger level buildings. For square shape 50 storey original buildings, stiffness modification factor needed to increase 1.3 times at the whole building to get minimum deformation of three outrigger level buildings. But the base shear of the building by simplified method is larger significantly than the building with outrigger building. The period of the building by simplified method is smaller than the building with outrigger building. Therefore, for the proposed buildings to get minimum deflection, the outrigger is more effective than simplified method.

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