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Development of practical models for the assessment of static and dynamic properties of belt truss outrigger systems in tall buildings

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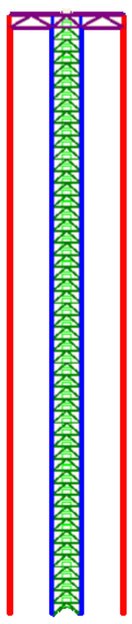
Introduction

An outrigger is a truss that ties the core of a building to its peripheral columns. By doing so, the axial stiffness of the peripheral columns may be used to reduce the sway of the structure. A belt-truss links the peripheral columns together around the perimeter of the building.

The development of analytical models is intended to speed up the process of design. They allow a number of quick iterations in the design process before a more detailed calculations are required.

Finite Element (FE) Model

The analytical models have been checked by comparing their results to an FE equivalent in OASYS GSA.



Core Column — Core Bracing
Outrigger — Mass Element
Peripheral Column

Figure 1: 2D GSA model

The 2D model had a total height of 200m and a width of 40m. The core width was 10m. Analyses were also carried out on a model with 2 outriggers and on a model with a height of 100m. Loading was applied directly to the core (diaphragm action was assumed from floor slabs).

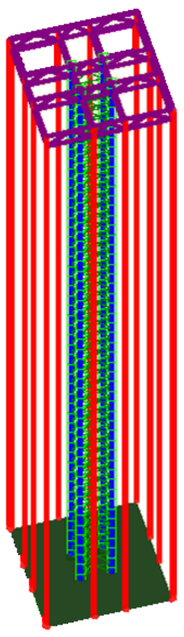


Figure 2: 3D GSA model

The 3D model is comprised of several bays, each similar to the 2D model. A belt-truss was added to tie the bays together at the outrigger level.

Wind Loading

One of the project's scopes was to be able to model the response of the structure under dynamic loading. Figure 3 shows a plot for the wind velocities generated as a tornado passes close by the structure.

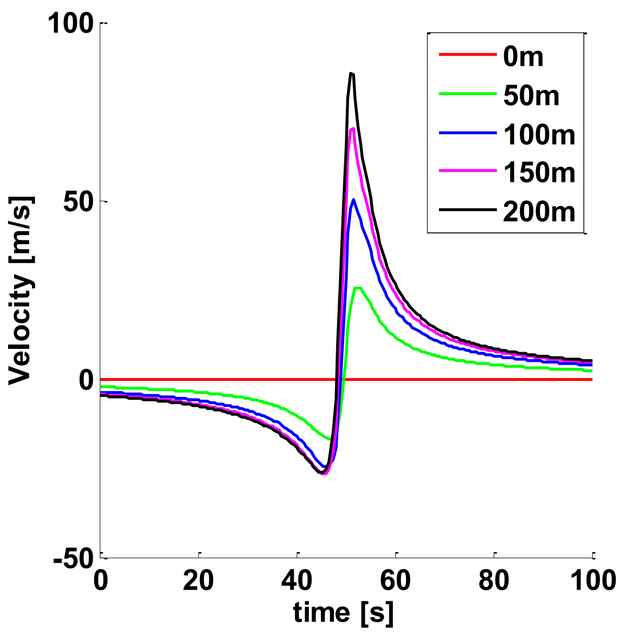


Figure 3: Wind velocities from a tornado at different elevations

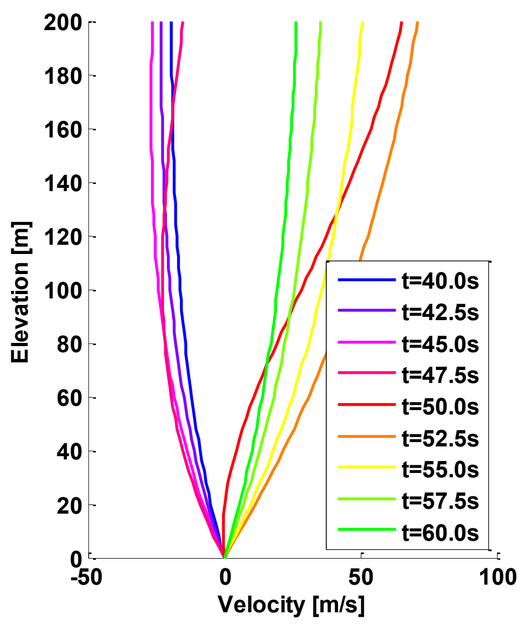


Figure 4: Profile of wind velocities at different times

Development of a 2D Model

The analytical models were tested to evaluate their accuracy in predicting:

- The restoring moment provided for each outrigger
- The natural frequency of the system
- The response of the structure under a dynamic loading

2 models were compared to each other to test the importance of including outrigger flexibility terms. The results of the dynamic response are given by Figure 5.

ACKNOWLEDGEMENTS

Many thanks to Dr Louca for his help throughout this project

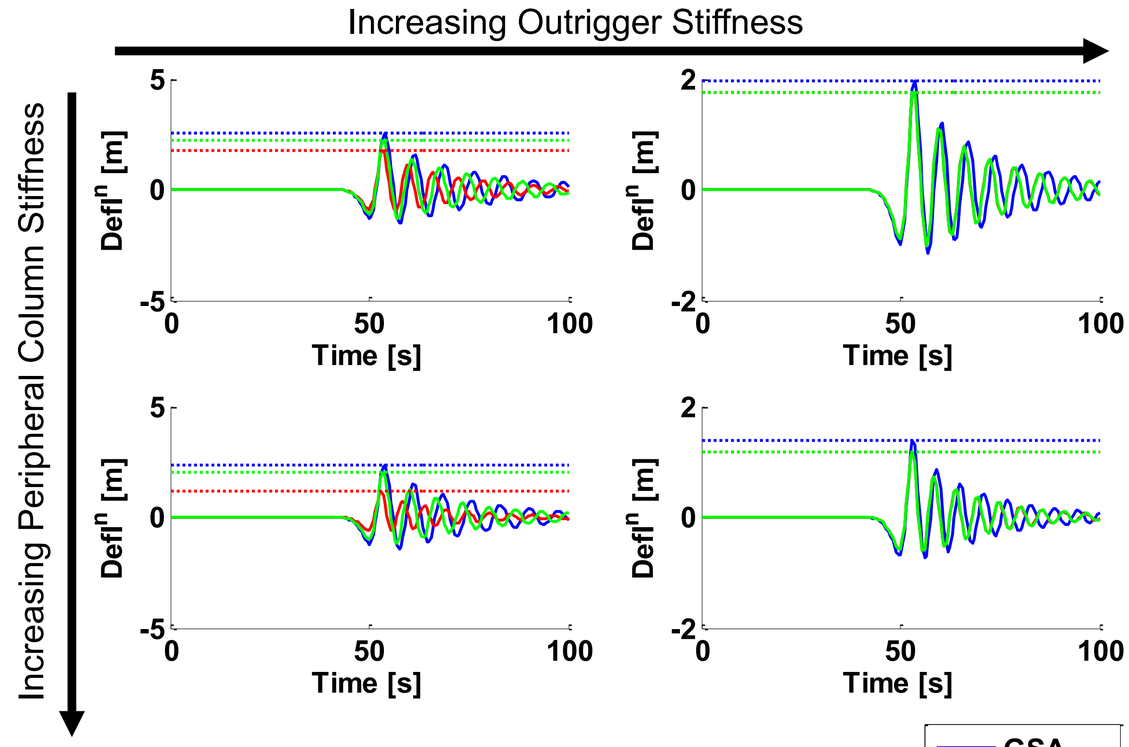


Figure 5: Time-History of deflections for a 200m tall structure with 1 Outrigger.

The results show that at low levels of outrigger stiffness the rigid model is poor. The flexible model provides better agreement to the GSA model, although it is still un-conservative.

Progression to a 3D Model

3 methods were developed for creating predictions in 3D. These are:

- Method 1 – Each bay of the structure is assumed to work in parallel to reduce deflections
- Method 2 – One core bay is assumed to act independently to reduce deflections. These deflections are assumed to be representative of the entire structure
- Method 3 – An attempt has been made to account for the flexibility and interactions of the outriggers and belt-truss

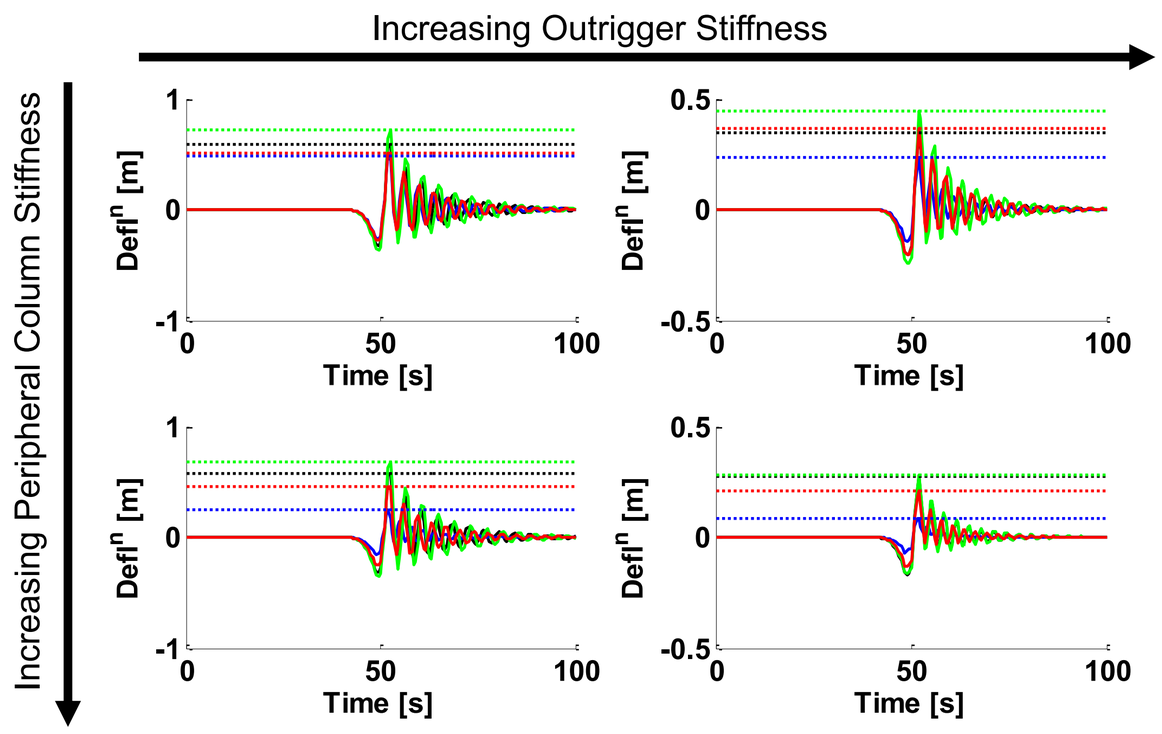


Figure 6: Time-History of deflections for a 200m tall structure with 1 Outrigger in 3D

Conclusion

The analysis of the 2D models found that it can be extremely un-conservative to assume that the outriggers cannot flex. In order to make the assumption that the bays work in parallel, it is implicit in Method 1 in 3D that the outriggers between bays are rigid – therefore this method is poor.

Used in conjunction Methods 2 and 3 can be used to give an upper and lower bound to the displacements respectively. The analytical models have an advantage over the FE model in that they are much easier to adapt the model to a change in parameters.