Master Thesis
M.Sc. Wood Technology

Assessment of Various Structural Frame Types and their Suitability for Tall Timber Buildings

Abstract

This analysis outlines an early-stage structural design evaluation of a variety of “all wood” tall timber frame systems and is one of the first comparison analyses of multiple frame types and assessment of their viability for timber towers. Four types of tower frames were modelled in 3D finite element analysis using the software RFEM by Dlubal: braced frame, core, outrigger, and braced tube. Calculations for member ULS design, connection feasibility, deformations from wind loading, and wind-induced horizontal vibrations were carried out for all four frame types. The final results of the analysis provided estimates of maximum height for the simplest form of the four structural frames. The results of this analysis indicate that all of the frames investigated are viable for tall timber buildings: the braced frame, core, outrigger, and braced tube structural systems reached 8, 9, 14, and 24 storeys respectively. The braced tube system proved to be especially efficient, while it reached the tallest height it also has the smallest connection requirements and all member sizes remained feasible. Ensuring that structural designs are appropriate for the associated material is key to ensuring an efficient structure.

Method

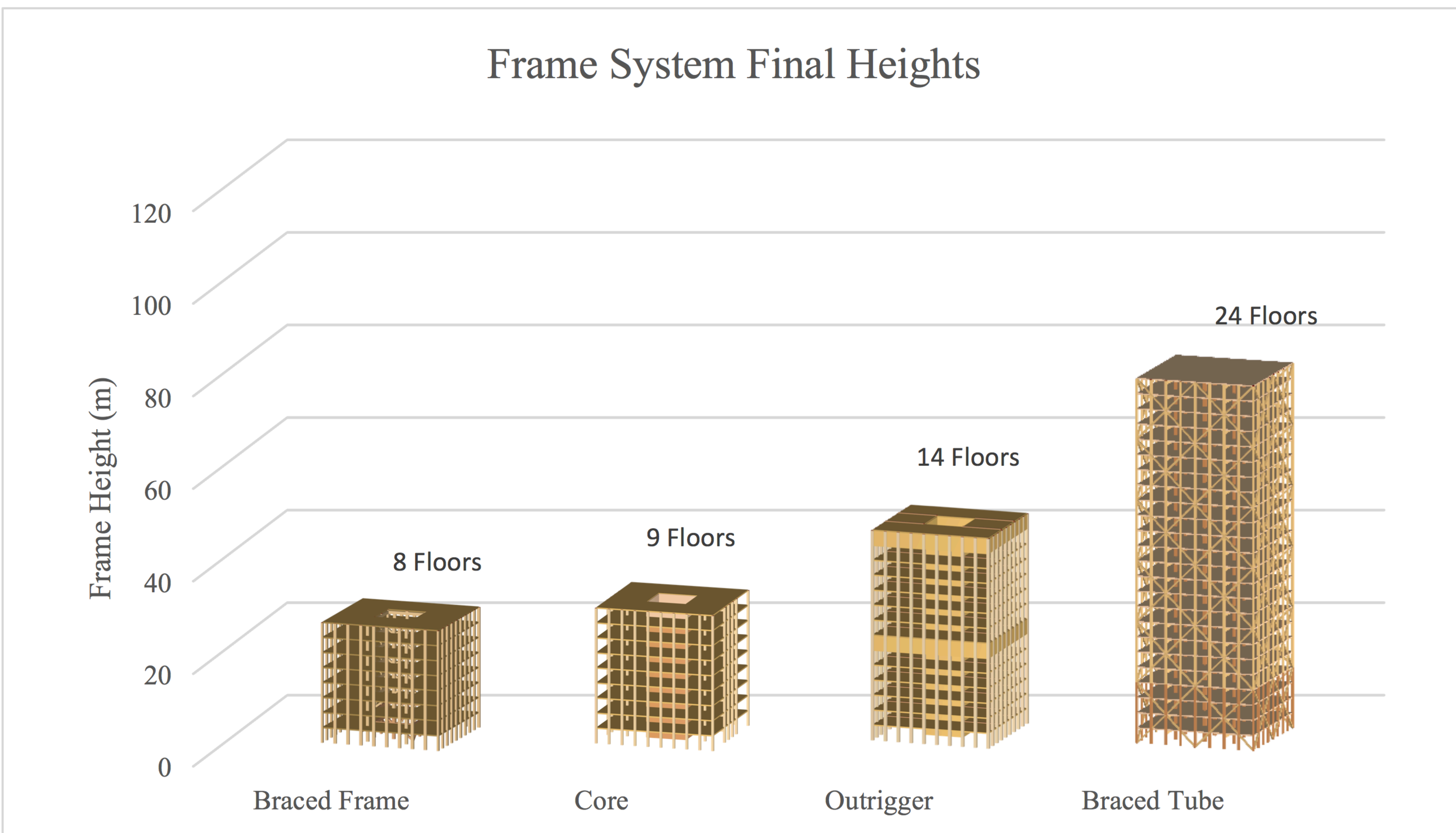
All frame models were created in the software RFEM from Dlubal (version 5.11). RFEM was selected due to its thorough integration of timber. To calculate the limit states of individual timber elements the module RF-TIMBER Pro was used. Similarly, the module RF-LAMINATE was used to calculate the stresses in CLT members and ensure appropriate sections were being used. This was also beneficial in ensuring the overall building stiffness for the dynamic calculations. To derive the natural frequency and mode shapes the module RF-DYNAM Pro was used. Finally, the module RF-JOINTS was used to ensure connections were still feasible between glulam elements where there were significant loads. The connections were kept simple to reflect current timber construction methods; typical doweled connections with steel knife plates were specified.

Results

Several limit criteria framed the results of the analysis: 1) ULS design of the elements 2) horizontal deformation from wind loading 3) connection design. 4) the horizontal accelerations of each frame. The connection design was especially important to ascertain the stiffness of the frame for dynamic analysis. Each of the 4 frames returned preliminary results of 15, 16, 21, and 32 floors for the core, braced frame, outrigger, and braced tube respectively after the static calculations. When considering the dynamic effect and occupant comfort criteria the acceptable building heights dropped to 8, 9, 13, and 24 floors for the braced frame, core, outrigger, and braced tube.

Conclusion

Based on the results of this evaluation, timber structures can stand as tall as most medium-rise buildings, which make up the majority of today's urban areas. This is perhaps the best application for tall timber frames – not to compete with the tallest of the concrete and steel towers but to provide the bulk of the housing that will be needed in urban areas. With respect to this investigation, the method provided an effective means to evaluate the frames and established a realistic early design criteria which could be used to de-sign tall timber buildings.



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