Structural Connections for Massive Timber Plate Elements in Hybrid Structures

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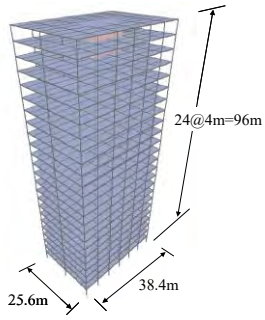
Summary

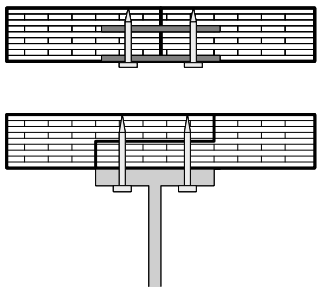
Discussion centres on connections between massive Cross-Laminated-Timber (XLam) floor slabs and steel skeletons of hybrid structures. Using the example of a 24-storey building, it is shown that such connections can be made using simple fasteners like large screws to enforce composite action in the critical case of XLam slabs acting as diaphragms during seismic or wind loading events.
Keywords: Connections, cross-laminated-timber (XLam), hybrid structures, steel, tall buildings.

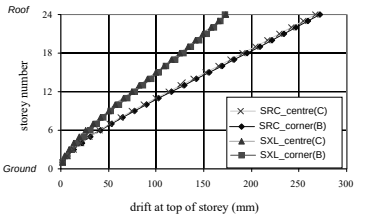
1. Introduction

Using hybrid systems allows engineers to combine best attributes of different materials to improve performance, constructability and economics of structures relative to what is possible using only one material. Previously the authors have discussed the general concepts of using massive timber (XLam) plates as replacements for RC floor and roof slabs of medium-rise and tall buildings [1, 2]. Here they provide some further details of the idea with emphasis on methods for interconnecting the XLam and steel.

2. Analysis of 24-storey building







SRC = steel frame with RC slabs
SXL = steel frame with XLam slabs
B = slab location at corner of building
C = slab location next to RC core of building

(a) 3D view of structure *(b) XLam connections* *(c)Drift response comparison*

Fig. 1: 24-storey building used to illustrate XLam slab and steel frame hybrid systems

Fig. 1a shows the arrangement of a 24-storey hybrid building containing XLam slab elements attached to the steel skeleton as shown in Fig. 1b. That system was analysed using the commercial SAP2000 finite element software, to determine typical demands on fasteners in potentially critical slab-to-frame connections for load combinations involving wind, seismic and gravity forces. As illustrated by Fig. 1c, it is generally the case that the structural response of a system with XLam slabs is superior to a similar system with conventional RC slabs, because the massive timber slabs have about 1/3 the mass of mechanically equivalent RC slabs. Both lateral sway and stress demand on the steelwork are much lower. Peak forces carried by fasteners attaching the XLam to the framework were shearing horizontal forces in the order of 20 kN per meter of connection around

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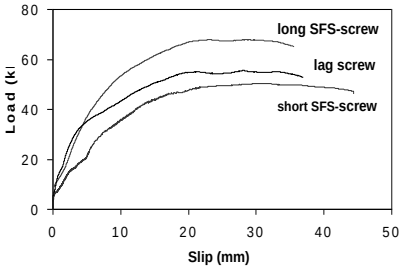
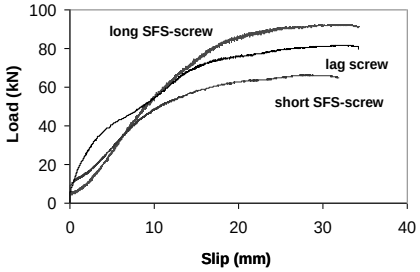
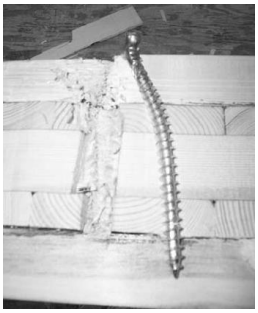
the perimeters of slab elements. That largest forces on the fasteners occurred under load combinations involving seismic excitation of the 6th floor slab.

3. XLam-to-steel connection tests

Because of the potential simplicity of using such fasteners, XLam-to-steel connections made with three alternative types of screws (already in widespread use in timber construction) were investigated. The fasteners were two sizes of proprietary fastener made by SFS Intec (127 and 89 mm long by 10 mm diameter), and 127 mm long by 9.5 mm diameter generic lag screws. Figs. 2a and 2b shows slip versus load relationships for four-fastener shear connections in which the screws loaded XLam parallel or perpendicular to that materials major axis (it is an orthotropic material at the engineering materials scale). Fig 2c shows a typical ductile failure involving creation of plastic hinges in screws and crushing of timber beneath them.







(a) Load parallel to major axis *(b) Load perp.to major axis* *(c) Typical failure*

Fig. 2: Typical results from tests on XLam-to-steel connections made with screws

By comparing the connection strength range obtained from the tests with the shear connection forces obtained from analysis of the 24-storey building it can deduced that the connections would be sufficiently strong if fasteners of any of the types tested were placed at 200 mm on centre. However from the perspective of deformation control smaller spacing is appropriate if SFS screws are used (e.g. 130 mm for the long SFS screws). In general, although minimum fastener requirements would differ from project to project and may not approximate the levels discussed here, it is clear that the idea of using screw type fasteners to secure XLam slabs to steel frameworks is highly viable.

4. Conclusion

It is highly feasible to substitute XLam as slab elements in lieu of conventional RC slabs in hybrid structures with steel skeletons. XLam slabs can be made rigid without need for complex connections joining slab elements together or for attaching them to steel. The lightweight of XLam greatly reduces the total mass of complete structural systems and thereby decreases stress demands on steel members and moderates lateral sway during potentially critical seismic or wind events.

References

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