Mechanical behavior of connections in timber gridshells structure

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ABSTRACT

This study focuses on the mechanical behaviour and performance of connections in the timber gridshells. Two different forms of timber beams are used, the first was consisting of timber beam of gridshells without connection, and the second was with steel connection that was fabricated by the Quaternion company in France. These two forms of timber beams are those most widely used as a main beams in gridshells structures. In this paper, an experimental investigation of large-scale timber beam of the gridshells with dimensions (2.8m length) are used. The timber beams were tested under four-points flexural test at the laboratory of LMDC in Toulouse. Also, the total rigidity of the connection was investigated experimentally.

Keywords: Timber gridshells, Flexural tests, Steel connection, Rigidity of connection

I. INTRODUCTION

Shell structures are versatile in the variety of forms they can offer. Timber material has been used throughout many years and is still until now a very prominent material nowadays as a structural element in building and construction. Gridshells are structures that get strength and stiffness through their double curvature form[1]. These structures are comprised of numerous straight elements each inclined with different angels joined by specific assemblies. An example is the roof over the great court in the British Museum [2] and the courtyard roof in the Museum of Hamburg History [3]. In addition, a number of bending inactive timber gridshells have been constructed such as the University of Exeter Forum [4] and Centre Pompidou Metz [3], using members created by machining smaller curved timber sections out of initially straight glulam timber of large cross section. In contrast, bending active gridshells is not common, however, a number of these have been constructed such as the Multihalle in Mannheim [5]. As matters currently stand in relation to active Timber Gridshells, capable to be assembled and disassembled several times remaining in elastic range of mechanical behavior, it is obvious that there is a lack of knowledge and a need for further experimental studies of elements of the gridshells – practically beams under flexural loads and the performance of the connection with the beam. For this purpose, this research highlights the parameters that could play a main role in the structural behavior of the assembly.

II. FLEXURAL TESTS OF WOODEN BEAMS

Two groups of wooden beams were prepared for four-points flexural testing in order to investigate the mechanical behavior of the connection in beams of gridshells. The first group consisted of wooden beams without connection and the second group consisted of wooden beams with steel connection at the middle of the beam. The total length of the entire beam is around 2.4 m. The end supports were fixed with clamps in order to allow rotation and prevent the displacement in the horizontal direction. Manual weights were applied gradually at the middle of another beam which is connected with two stirrups to represent two concentrated force on the tested beam as illustrated in Figure 2. Three laser devices (L_1, L_2, L_3) were installed to measure the deflection at three points on one side of the beam, assuming the symmetry beam's geometry.

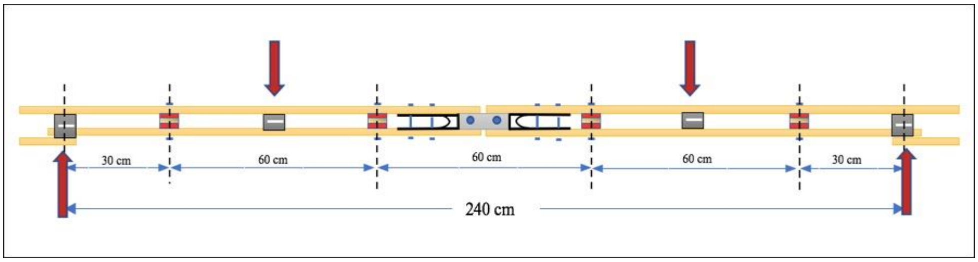

FIGURE 1. Four points flexural test of the entire wooden beam.

FIGURE 2. Beam without connection in test.

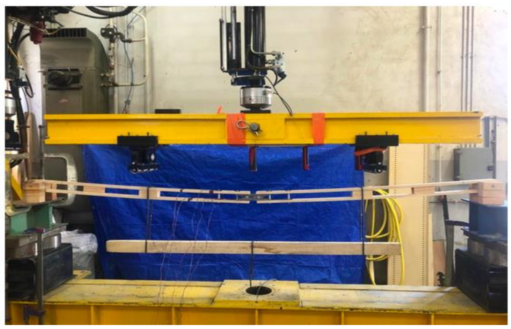

FIGURE 3. Beam with steel connection in test.

III. BEAM RIGIDITY

In order to characterize the total rigidity of the entire beam with connection, it was necessary to identify the rigidity of each part of the beam experimentally. The entire beam consists of three main parts, shear wedges (K_1), wood-steel connection (K_2) and steel-steel connection (K_3). In the loaded state of the beam, the shear wedges will be under the shear forces transmitted between the two wooden lattes. Steel-steel connection at the middle of the beam will be under flexural rotation. Wood-steel connection will be under shear effect. In order to identify experimentally the rigidity of each part, small samples of each part were prepared.

IV. RESULTS AND DISCUSSION

The results in Figure 4 for tests no. 1 and 2 represent the force displacement of wooden beams without connection and tests 3 and 4 represent the force displacement of wooden beams with steel connection. It was obvious that the wooden beams without connection have approximately the same behavior at the beginning of the test (20 mm of deflection). The results show also that beams with steel connection have different behavior due to the fabrication of steel connections.

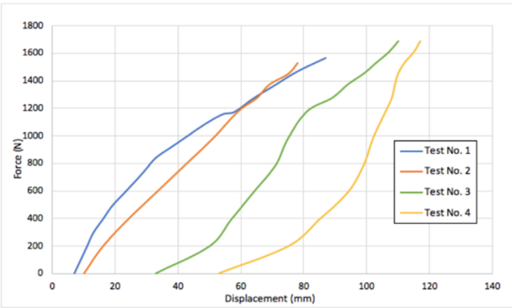

FIGURE 4. Flexural test of wooden beams with and without connection.

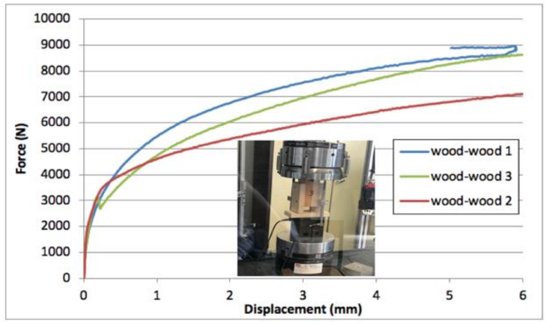

FIGURE 5. Force-displacement diagram of wood to wood connection.

Figure 6 shows the force displacement of the wood to wood connection and the average rigidity as K_{exp} = 6256 kN/m. The average rigidity of wood to steel connection was calculated experimentally (Fig. 6) and the average value was K_{exp} = 10659kN/m. The steel to steel connection was tested under the four point flexural test as illustrated in Figure 8. The moment rotation diagram was calculated from the force displacement diagram of the test. Figure 8 illustrates that the elastic behavior of samples start after 0.4mm and 0.7 mm for samples 1 and 2 respectively. The average rigidity of the complete connection in rotation as around 23386 kN.mm. The tilting rigidity of the shear wedges was considered in order to estimate the total rigidity of the complete beam.

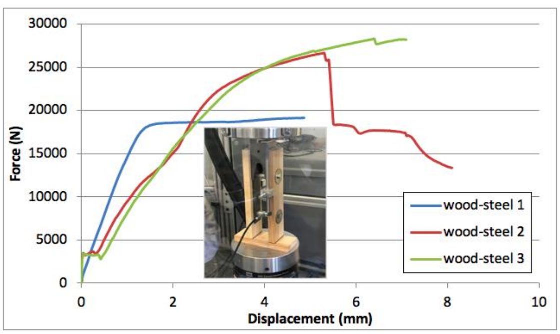

FIGURE 6. Force displacement diagram of wood to steel connection.

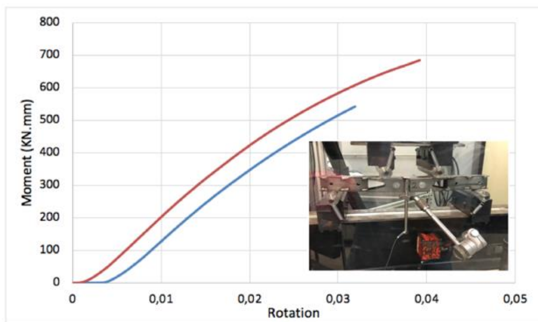

FIGURE 7. Moment rotation diagram of steel to steel connection.

This estimation can be calculated using the formula (1)

$$K_{u,E,bascule} = \frac{s.E_{mean}.b.e^3}{hc^2.\left(\frac{s}{2}-\frac{Lc}{2}\right).\left(s-\frac{Lc}{2}\right)} \quad (1)$$

$$K_{u,Bascul,CI} = \left[\frac{1}{\frac{1}{K_{u,0,top,CI}}+\frac{1}{2.K_{u,BASC,CI}}} = \frac{1}{\frac{1}{K_{u,0,bottom,CI}}+\frac{1}{2.K_{u,BASC,CI}}} \right] \quad (2)$$

Where s is the distance between shear wedges centre to centre, L_c and h_c are the length and height of shear wedges, b is length of lame and e is the thickness of the latte. The estimation of tiling of the tested beam was $k_{u,E,bascule}$ =10266kN/m. The combination of the rigidity of all parts of the beam can be express as the formula (2). The total rigidity of connection in the entire beam was 21318kN/m.

V. CONCLUSION

The mechanical behavior of wooden beam with connection was studied in order to verify the global behavior of the beam in the gridshells structures. Each part of the connection as identified to calculate each rigidity and a complete prediction of the entire beam was investigated in this study.

VI. ACKNOWLEDGMENTS

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