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TIMBER COMPOSITE FLOOR BEAMS UNDER 2 YEARS LONG-TERM LOAD

M. Hailu*
School of Civil and Environment, University of Technology, Sydney
PO Box 123, Broadway NSW 2007, Australia. Mulugheta.Hailu@uts.edu.au (Corresponding Author)

R. Shrestha
School of Civil and Environmental Engineering, University of Technology, Sydney
PO Box 123, Broadway NSW 2007, Australia. Rijun.Shrestha-1@uts.edu.au

K. Crews
Faculty of Engineering and Information Technology, University of Technology, Sydney
PO Box 123, Broadway NSW 2007, Australia. Keith.Crews@uts.edu.au

ABSTRACT

The long-term behaviour of composite beams is characterised by the response of its component parts (flanges and webs) to load, moisture content, temperature and relative humidity of the environment. This paper reports the results of a two years long-term test on two 6 m span composite floor beams made of laminated veneer lumber (LVL) under service load performed in an indoor, semi-controlled, and unheated environment. The environmental conditions were characterized by artificially induced cyclic air humidity with quasi-constant temperature. These conditions can be characterized as reasonably severe and presumably close to service class 3 according to Eurocode 5. During the test, the mid-span deflection, moisture content and air humidity were monitored. The paper recommends a creep factor for design of timber composite beams in severe environmental conditions.

KEYWORDS

Timber composite beam, Creep, Mechano-sorptive creep, Creep factor.

INTRODUCTION

Design of timber composite systems requires verification of serviceability and ultimate limit states. With the increasing trend in long span and light weight constructions, design of these floors may be governed by serviceability limit states, and deflection under long-term load is one of the serviceability criteria that need to be addressed. The long-term behavior of timber composite structures depends on a number of phenomena taking place in its components such as creep, shrinkage or swelling effects in timber and in the connection. Factors such as size, surface properties, loading type, length of environmental cycle, etc. also indirectly affect the long-term behavior of composite floors.

Several researchers have found that creep increases with increasing time and with increase in the applied load. Kingston and Armstrong (1962) found that deflection increased with time, and the deflection of beams under load increases at a diminishing rate. If failure occurred during this period, the deflection continued at increasing rate (Hermon, 1964), and also was found that the larger the load applied, the faster the beam fails. Gerhards (1985) evaluated the time-dependent deflection of four Douglas-Fir beams at three different load levels for up to 220 days. He found that the ratio of total deflection to assumed elastic deflection increases with time and also increase when the level of stress increases (Bodig, 1982).

Wood is highly hygroscopic, and any variation in humidity and temperature will affect its moisture content. When subjected to moisture content changes, wood exhibits much greater deformations than under constant humidity conditions. This phenomenon is often referred to as the mechano-sorptive effect, and has been known since the late 1950s and early 1960s (Armstrong and Kingston, 1962). Extensive work has been performed by a number of researchers for more than thirty years to clarify this phenomenon; both in its nature and in its origin (Hoyle et al 1986, Fridley et al 1992, Szabo and Ifu 1977, Leicester 1971, Hunt 1988, Hoffmeyer 1989,1990, Ranta- Maunus 2000, Lu 1977, Mohager and Toratti 1993).
This paper presents and discusses the outcomes of an experimental investigation of the creep behaviour of two identical composite beams in semi controlled environmental conditions (cyclic relative humidity). The experimental investigation is ongoing; the outcomes of the last 2 years will be presented here.

EXPERIMENTAL PROGRAM

Properties of Composite Beams

Timber composite beams with a span of 6 m were fabricated using laminated veneer lumber (LVL) with different stress grades. The web and flanges were connected using gluing and screwing technique. Polyurethane glue and normal type 17 wood screws were used. The glue allowed for full composite action between the web and the flanges while the screw facilitated full contact between the web and the flanges during the setting of the glue (Zabihi 2012). Figure 1 shows a typical cross section of the composite beams.

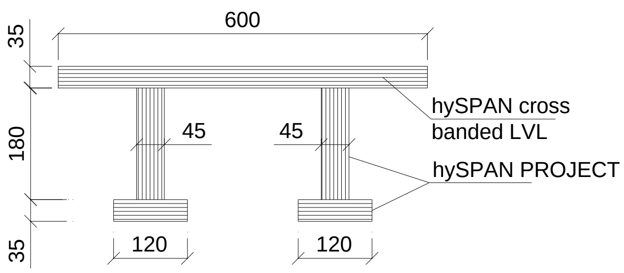

Figure 1. A typical cross section of the composite beams

Before the commencement of the long-term test, the timber beams were subjected to four-point bending test under service load up to 40% of the estimated failure load, to determine their bending stiffness's. The apparent bending stiffness's (EI) obtained from the short-term tests were 4.21 and 4.24 E+12 Nmm^2 for the first beam (referred as L6-01) and second beam (referred as L6-03), respectively and the load versus deflection curves of the composite beams showed a linear elastic behaviour. Both the beams also exhibited a strong correlation between the strain distributions over the depth of their system (about 0.99), indicating high composite behaviour (Zabihi 2012).

Test Set-up and Service Loads

The long-term test set up is shown in Figure 2 where the beams are placed on a simply supported arrangement and a long-term load was applied using lead bars evenly spaced on the top of the beams. The serviceability loads applied are equivalent to a uniformly distributed load of 2.1 kPa. This applied load is about 34 % of the short-term ultimate design load (1.2G+1.5Q) expected for the beams. The instantaneous mid span deflections after the application of the loads were 6.5 mm for L6-01 and 6.25 mm for L6-03.The slight difference between their instantaneous deflections could be either due to the variability of the wood properties or due to their differences in the stress levels (ratio of their applied load to their MOR). The bending stresses developed along the cross section of the composite beams immediately after the loads are applied are; 2.6 MPa, 2.2 MPa, 3.5 MPa and 4.6 MPa, on the top flange, top web, bottom web and bottom of the flange, respectively. These stresses range from 5 to 11 % of the design capacities of the members. In mechano-sorptive creep, the non-linearity of wood starts at about 10-20 % of the ultimate stress in compression and at about 20-30 % of the ultimate stress in tension and bending (Hunt, 1989), with generally larger the creep deformations under compression load under tension load (Bengtsson, 2001).The shrinkage and swelling due to moisture changes also indirectly affects the deformation which consequently affects the modulus of elasticity. Hunt (1988) found that the shrinkage and swelling decreases for wood loaded in tension parallel to grain while it increases for wood loaded in compression parallel to grains. Large part from the cross section of the composite beams under this investigation lies under compression and bending zones and hence, is expected to behave in similar manner to behaviours observed by wood under compression and/or bending stresses. And for LVL the creep perpendicular to the grain was found to be significantly larger than the creep parallel to grains as reported in Matthew (2008). It means that the flanges and webs will have higher creep than the webs and the stresses on the webs will also increase with time. However, no experimental measurements were conducted to verify this in this investigation.

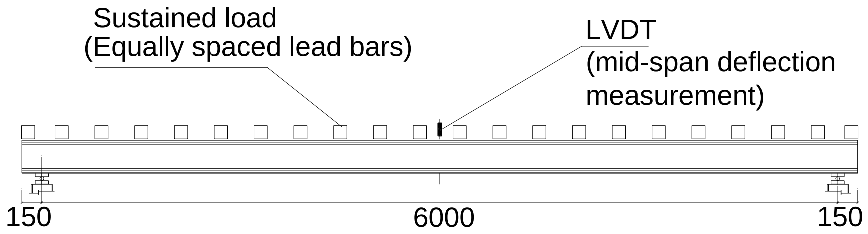

Figure 2. Long-term test set up and service loads

During the long term test, the mid-span deflection, moisture content of the timber beams and relative humidity of the air were continuously monitored. The mid-span deflection was measured every minute during loading of the specimen for the initial 24 hours and every hour for the remaining of the long term test. An air humidifier is used to increase and maintain high RH during the wet periods reaching about 100% RH.

RESULTS AND DISCUSSIONS

The relative humidity (RH) and temperature (T) of the chamber were measured regularly every hour. The changes in RH, T and timber moisture content (MC) are shown in Figure 3. The environmental conditions monitored for the last 2 years shows that the room temperature remains reasonably constant, around 20 °C (±1) while, the relative humidity varied between about (50 - 60 %) during the dry periods and saturation (100 %) during the wet periods. The length of a humidity cycle varies between six to eight weeks. The moisture content of the MC samples alternated from approx. 10 % at the end of dry periods to above 20 % at the end of wet periods. According to Eurocode 5 (2008) the environmental conditions can be assigned to equivalent to service class 3.To monitor the variation of moisture content in LVL beams, separate moisture content samples with 100x100x45 mm sizes cut from LVL were kept in the humidity chamber and the changes in the level of moisture were measured regularly.

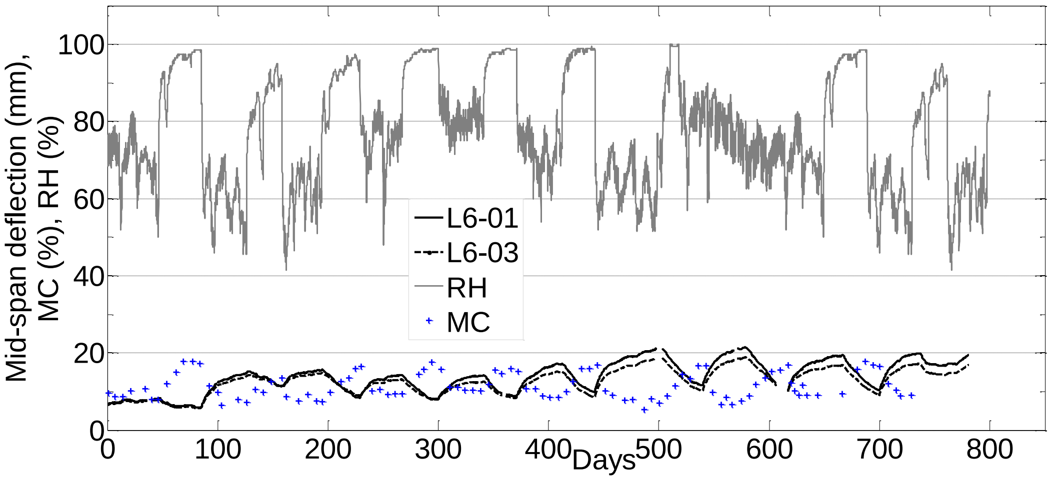

Figure 3. Mid-span deflection, relative humidity and moisture content time graph

The moisture content of the beams under load is cycled from dry to wet and back to dry again, the deformation also followed a cyclic pattern. However the recovery in each cycle is only partial and over nine cycles the total amount of creep is very large as shown in Figure 3. The amount of creep in each cycle depends on the size and length of the moisture cycle. The air humidity cycled from 50 % to 100 %, it should be noted that creep increased during drying (desorption) and decreased during the wetting cycle (adsorption) and this represents a typical creep behaviour of wood in bending. The changes in deflection during each complete cycle would have been much less if the range of change of air humidity was made narrower during moisture content cycling under load. Nevertheless, a decrease in deflection for each absorption and an increase for each desorption were still to be found for each cycle after the first cycle as was also reported by Armstrong (1965). Gerhards (1985) and Hunt and Shelton (1987) explained the apparent creep recovery during subsequent humidification (wet periods), due to the size changes caused by difference in shrinkage coefficient between the tension and compression faces of the bending test pieces. In Figure 3, the mechano-sorptive effect was increasing until the first 500 days and afterwards the rate of increase diminished with time. The overall trend looks to plateau reaching a total deflection several times the instantaneous deflection. The long-term deflection of the beams can be expressed in terms of a creep factor (K_{def}) as defined in Euro code 5.The highest value recorded for the last 2 years are 2.25 and 2.0 for beams L6-01 and L6-03, respectively.

CONCLUSIONS

This paper presents a long-term experimental investigation on timber composite beams. Even though definitive conclusions cannot be drawn yet, the cycling of the moisture seems to have induced a significant effect on the long-term deflection of the beams and the deflections also followed a cyclic pattern. Although no provisions for gross creep factor of a composite LVL beams is available in design codes, Eurocode 5 depending on the load and environment history recommends a creep factor (K_{def}) values of 2.0 for timber at 10 years. The results of this experimental result could suggest, a gross creep factor (K_{def}) more than 3 for the composite timber beams in environmental conditions categorized as equivalent to or more severe than service class 3.

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