SIGNIFICANCE OF FACTORS AFFECTING CREEP DEVELOPMENT IN TIMBER BEAMS

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Abstract
This study is a part of an extensive research of creep development in softwood (*Pinus sylvestris*) timber beams under natural environmental conditions. Large size test data sample obtained during long-term (approximately one and half year) static loading of timber beams in a four-point bending simulating the real service conditions of roof structures for winter and non-snow period has been processed and results presented. The correlation between creep deformation and its affecting factors, such as span to height ratio of beam, percent of latewood and width of year ring (a growth ring formed during a single year), orientation of year ring segments against main axis of cross section, number of year rings in 1 cm of wood, and density of wood have been analyzed and corresponding coefficients of correlation presented. It is concluded that the most significant creep development affecting factor is density of wood. Strong relationship between creep development and width of year ring, number of year rings in 1 cm of wood and density of wood was observed during test. Orientation of year ring segments against the main axis of cross section, amount of latewood and span/depth ratio do not have noteworthy direct influence on creep development in terms of this study. Temperature can be neglected as creep affecting factor in terms of this study but in the moments of sharp raise or fall of temperature, almost immediate effect on creep development was recorded.
Key words: Duration of load (DOL), creep, bending, softwood lumber.

Introduction

Serviceability limit state of timber structures is seriously influenced by increase of deformation due to creep of material. Creep process is affected by many physical and mechanical factors that leads to time-dependent increase of deformation of structural elements that can cause inadmissible deformations and even collapse of all construction.

According to the Burger body concept on physical model of deformation of wood, the mathematical model of total strain to be expected occurring in side fibers of timber beam has been proposed and proved in previous study by Ozola and Brokans (2013). Also, it has been revealed that the changes of relative humidity of air and sub sequential variation of the moisture content of wood in long-term performance do not affect the rate of creep significantly. The increase and decrease stages of creep taking place due to moisture cycling lead to some compensation of total deformation and do not result in a significant increase of total deformation at the inspected moisture content level (Ozola & Brokans, 2014).

Materials and Methods

The aim of this study is to evaluate the significance of all other factors disclosed in this study as affecting the creep development of timber beams subjected to approximately the same stress level during 478 days when moisture content of wood varied from 8 to 14%. Correlation analysis between creep rate (CRU) and creep development affecting factors is provided as the main task to reach the aim of this study.

Data processed in this study have been selected from measurements of static tests of timber beams under long-term load in four-point bending for approximately two years limiting deflection data sample corresponding to moisture content of wood from 8 to 14%. Test samples were cut out from tree trunk so they are free from knots and damages. Two groups of timber beams were selected: sample 'KS-4' which consists of four timber beams with span L = 1500 mm and span/depth ratio 25 – 26, and sample 'KS-3' which consists of eight beams, span L = 1320 mm with span/depth ratio of 22. The bending stresses varied between 8.2 to 11.1 MPa. Timber specie is

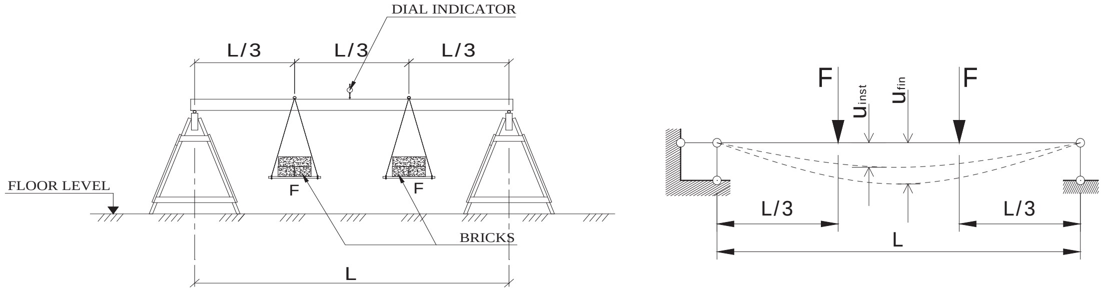

Figure 1. Long-term bending test setup and static model.

Scandinavian Pine (*Pinus Sylvestris*). Long-term test models loading schedule was described in previous publications by Ozola and Brokans (2013, 2014). Tests were carried out in an unheated building under uncontrolled climate conditions. The timber beam cross section nominal dimensions (height and width) were 60 mm and 30 mm respectively. The bending test setup and static model are given in Figure 1.

Concentrated forces were represented by clay and silicate bricks which were suspended on timber beams. The deflection measurements were made with dial indicators. Measuring precision of indicators is 0.01 mm while measuring diapason of indicators – 50 mm. The dial indicators were placed in the middle of the span on the compressed side of the beam. The environmental climatic condition parameters were recorded once during the day. Temperature (T, °C) in the room and outdoors was fixed with mercury-in-glass (Hg) type thermometers.

Results and Discussion

In the correlation analysis the relative increment of deflection, here named as creep rate (CRU) and estimated according deflection measurements of beams during time periods of relatively constant moisture content of wood (8%-14%), was defined as dependent variable:

$$CRU = \frac{u_{fin,t} - u_{init,t}}{u_{init,t}} \cdot 100\%, \tag{1}$$

where $u_{fin,t}$ is the final deflection of a beam, unit is the deflection value at the beginning of the dry period. The affecting factors measured, such as density of wood, amount of latewood, width of year ring, orientation of year ring segments against main axis of cross section, span/depth ratio and number of year rings in 1 cm of wood were defined as independent variables.

Quantity R (coefficient of linear correlation) for each relationship measures the strength and the direction of a linear relationship between CRU and affecting factors.

Results of correlation analysis present variable levels of relationships between CRU and affecting factors.

An assumption was made during test that CRU is significantly influenced by orientation of year ring segments against main axis of cross section of timber beam. This assumption was not proved and weak negative relationship with value rCRU, or = -0.245 was recorded between CRU and orientation of year ring segments against main axis of cross section. Significance level (α) for this and all other relationships in this study is defined as α=0.05. In this study moderate positive relationship between relative increment of deflection (CRU) and orientation of year ring segments against main axis of cross section has been characterized by Pearson's coefficient of linear correlation. See Figure 2. Sections of all test beams and main characteristics are showed in Figure 3. This relationship showed that orientation of year ring segments against main axis of cross section can be neglected as significant affecting factor.

It is found by Panshin and Zeeuw (1980), as well as by Cown (1992) and Dinwoodie (2000) that density is a general indicator of cell size, and it is a good predictor for strength and stiffness properties of wood. In this study moderate positive relationship between relative increment of deflection (CRU) and density of wood (r) has been found characterized by Pearson's coefficient of linear correlation rCRU, r = 0.67. See Figure 4.

Kubo and Jyodo (1996) stated that density of the wood increases directly with an amount of latewood in the growth ring, and density affects wood strength and stiffness significantly. Correlation analysis of current

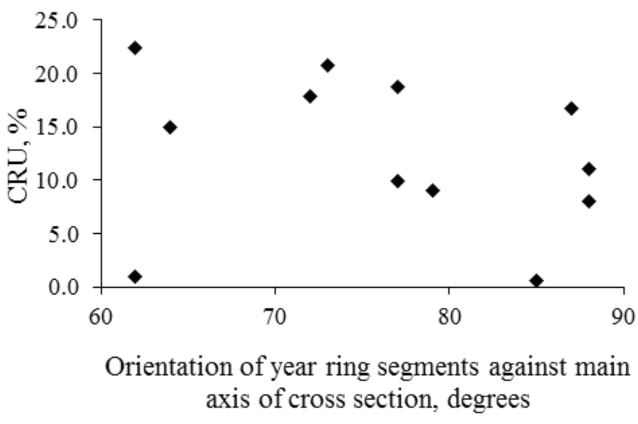

Figure 2. Relationship between CRU and orientation of year ring segments.

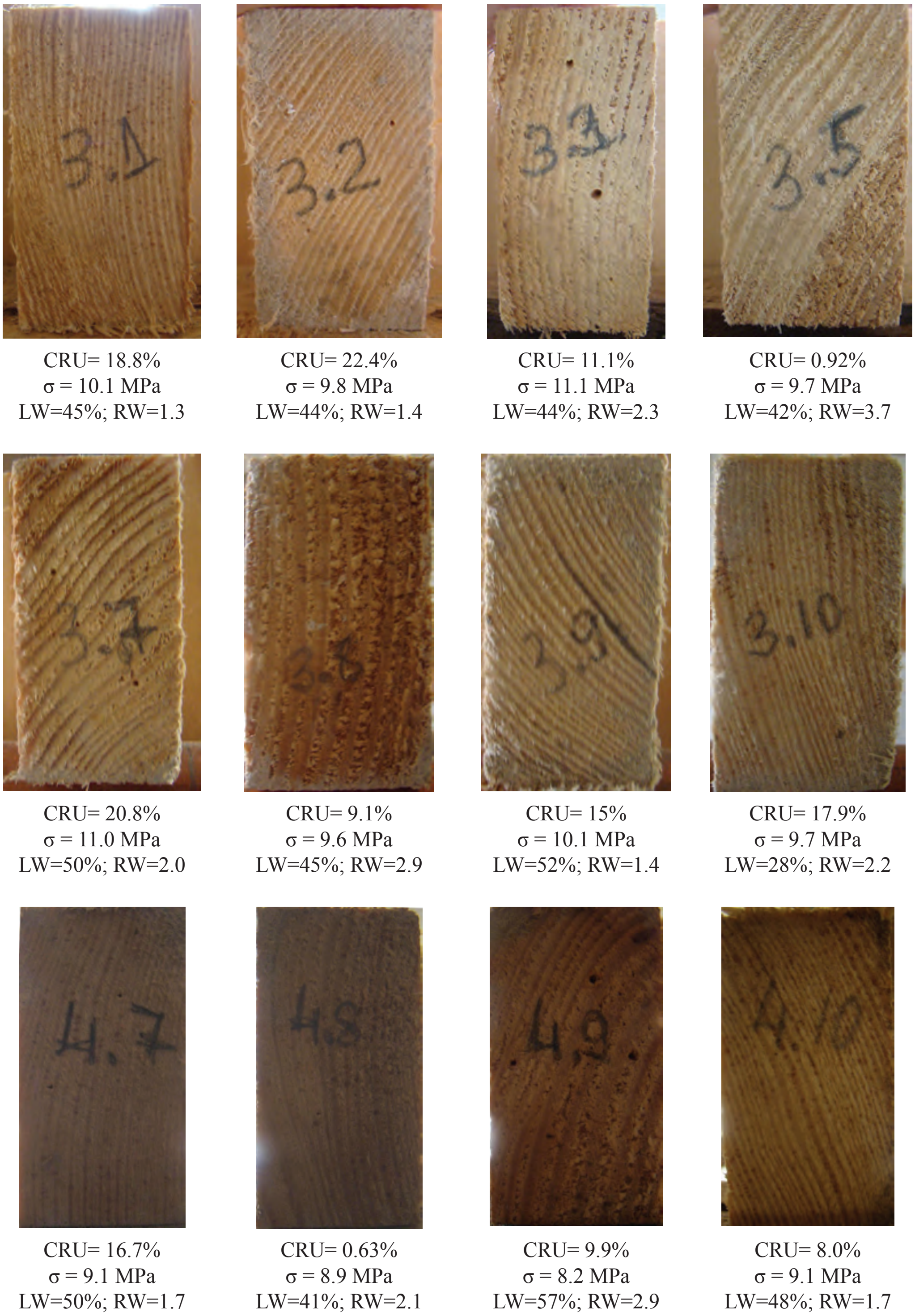

Figure 3. Sections of test beams: orientation of year ring segments and main characteristics.

data samples does not approve this relationship – there is no meaningful effect of amount of latewood in year ring (LW, %) to the relative increment of deflection CRU; moreover, dependence is negligible as revealed by coefficient of correlation rCRU, LW = 0.029. See Figure 5.

The assumption before study was made that the more year rings are in 1 cm of wood the higher is strength and stiffness of wood that leads to better behavior under long-term loading. This assumption was proved in this study by moderately good relationship (rCRU, n = 0.622) between relative

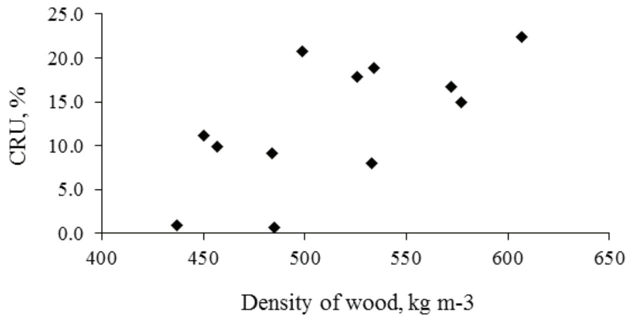

Figure 4. Relationship between relative increment of deflection and density of wood.

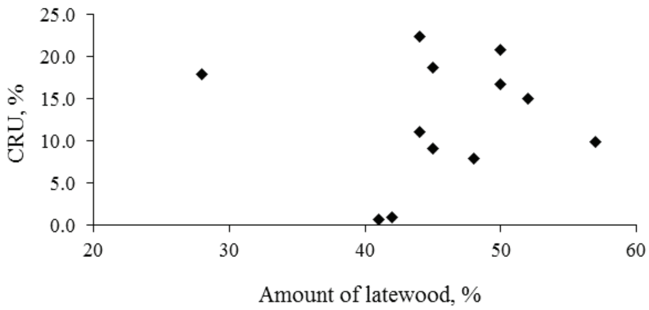

Figure 5. Relationship between relative increment of deflection and amount of latewood.

increment of deflection and number of year rings in 1 cm of wood (n). See Figure 6.

Early conjecture was made before test that span/ depth ratio could be assessed as one of the most important affecting factor in terms of this test, but this statement was rejected by results of test. Span/ depth ratio showed low negative relationship rCRU, s d^{-1} = -0.38 with relative increment of deflection. See Figure 7.

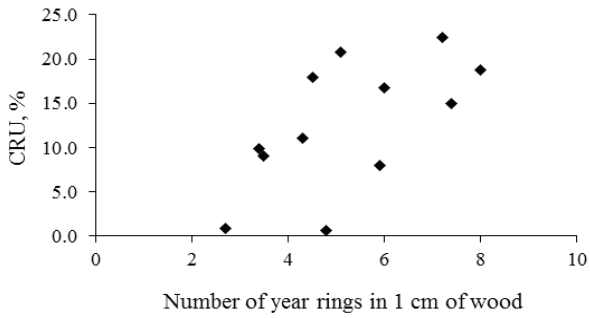

Figure 6. Relationship between relative increment of deflection and number of year rings in 1 cm of wood.

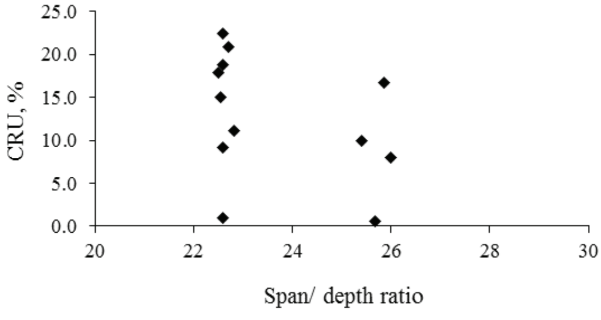

Figure 7. Relationship between relative increment of deflection and span-depth ratio.

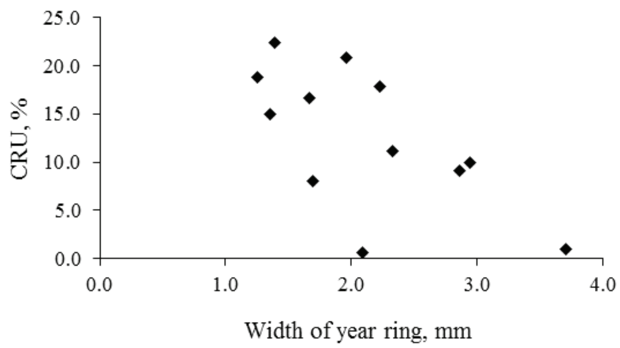

Figure 8. Relationship between relative increment of deflection and width of year ring.

Width of year rings can be used as an indicator of growth rate and good predictor of wood density which is one of the best indicators of wood quality, but there is no direct correlation witnessed. Results of this study confirm that there is moderate negative relationship (rCRU, w = -0.65) between width of year rings and relative increment of deflection. See Figure 8.

Conclusions

It was recognized during this study that width of year ring, the number of year rings in 1 cm of wood and density of wood are considered as the most significant factors affecting creep development in timber beams.

Correlation analysis present strong relationship between creep development and density of wood, width of year ring and number of year rings in 1 cm of wood. Most significant affecting factor in terms of this study is density of wood with coefficient of correlation R = 0.67.

Other above stated factors such as orientation of year ring segments against main axis of cross section, amount of latewood and span/depth ratio do not have noteworthy direct influence on creep development in terms of this study.

Temperature can be neglected as affecting factor in terms of this study with low total effect on creep development during sharp rise or fall of temperature.

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