Creep of Timber during Eight Years in Natural Environments

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ABSTRACT

An experimental study on the creep of timber under low load levels, typical of long duration loads in structures was made under both naturally varying sheltered and heated environments. The aim of the research was to gather information valid for code writers and to verify whether creep can be counteracted by surface coating. The results available for seven to eight years duration of experiments show continuous but slow tendency to creep (except creosoted specimens), and a clear dependency on surface coating. There is no practical difference in creep in heated room and in a sheltered space. Creep deformation, relative to elastic deformation, ranges from 0.3 to 1 after seven years load duration. For non-treated solid timber under lowest load levels the relative creep equals to 0.6. The lowest creep is observed with creosote impregnated specimens.

INTRODUCTION

The creep behaviour of wood under long-term loading depends on many factors, such as, stress level, moisture content and temperature. Under sufficiently low levels of stress, moisture content and temperature, wood behaves in a linear manner. At high levels of stress and in variable environmental conditions, the behaviour of wood becomes distinctly non-linear in character (Morlier and Palka, 1994).

The majority of creep tests are carried out at bending stress levels ranging from 5 to 15 MPa (Ranta-Maunus, 1991). However, stress levels caused by permanent and long term loads in structures are often lower: 2 to 5 MPa. In addition, the cold temperature in Nordic Countries during winter season may also reduce the creep of wood. Therefore a study was initiated to find out whether the creep factors in codes are justified for actual conditions in load bearing structures.

The test was initiated in early summer 1992 and continues partly in the beginning of 2000. Experiment in heated room started a year earlier. Materials and methods as well as the creep results after first 3 to 4 years have been reported earlier (Ranta-Maunus et al 1996, Gowda et al 1996). This paper reports the later results of the experiments which have been continued until 2000. The reason why some measurements have been interrupted is that the lateral displacements of specimens have been growing unreasonably big.

MATERIALS AND METHODS

<u>Test specimens</u>

The types of wood material used in this long term creep experiments in sheltered environment include the following: pine (Pinus sylvestris) specimens as non-treated, and coated with alkyd paint or with an alkyd-acrylate emulsion paint as well as creosote and salt impregnated. Spruce (Picea abies) was used as non-treated sawn timber and as glulam and Kerto-LVL. The third type was an I-beam with hardboard web (Masonite type, height 200 mm). Length of all beams was at least 5 meters, and 4 beams were tested in each case. In heated environment experiments consisted of glulam beams each loaded separately. Eight glulam beams (90x270x9400 mm) coated with a water-borne lacquer were made of spruce. Summary of specimen dimensions, load levels and results is shown in Table 1.

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Figure 1. Photograph of test set-up and loading arrangements in sheltered environment.

<u>Loading set-up</u>

In sheltered environment a total of forty specimens were used in this test program. The specimens are divided into five groups. Group 1 consists of 12 pine specimens and are grouped into six couplets. Each couplet was nailed together with a vertical piece of wood between them at one meter apart. The wood pieces serve as spacers and provide room for the circulation of air between the beams. The loading of beams was done in such a way that in each group the maximum bending stress is practically the same. This was achieved by placing steel bars and weights at required positions. The length of the beams was selected in such a way that there is sufficient allowance for elastic deflection in the middle of the specimens. The measurement of deflection of beams was done manually at regular monthly intervals during the first 3 years, and bimonthly later on.

In heated environment beams were loaded separately. The loading and supporting system is as shown in Figure 2. Four beams were loaded to a stress level of 2 MPa, while the other four had a stress level of 4 MPa.

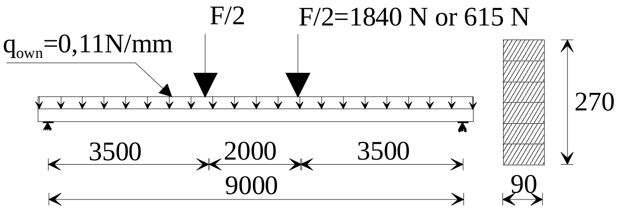

Figure 2. Loading and supporting systems for glulam beams in heated room.

<u>Humidity and temperature</u>

Sheltered environment-experiments were made in an old brick building in Southern Finland without any heating. The experiment started in summer 1992. A continuous measurement of relative humidity and temperature has been recorded. Most of the time temperature has been between +20 and -10°C. Relative humidity ranges from minimum of 50% during summer to maximum of 90% during winter. Also, separate wooden specimens were weighted monthly (bimonthly since 1995) to monitor the average moisture content of small pieces. The average moisture content of 3 untreated boards (16 to 22 mm thick) from June 1992 to November 1999 is shown in Figure 3. In the beginning of experiment the average moisture content of different specimens ranged from 8 to 14%. The annual minimum and maximum values later on are between 14 and 20%.

In heated environment all the eight glulam beams were housed in a heated and ventilated laboratory room inside the rock, where the relative humidity and temperature variation in the room was measured regularly. Temperature was fairly constant 20°C. Humidity variation depends on the seasons, being normally between 20% (min. of winter) and 70% (max. of summer).

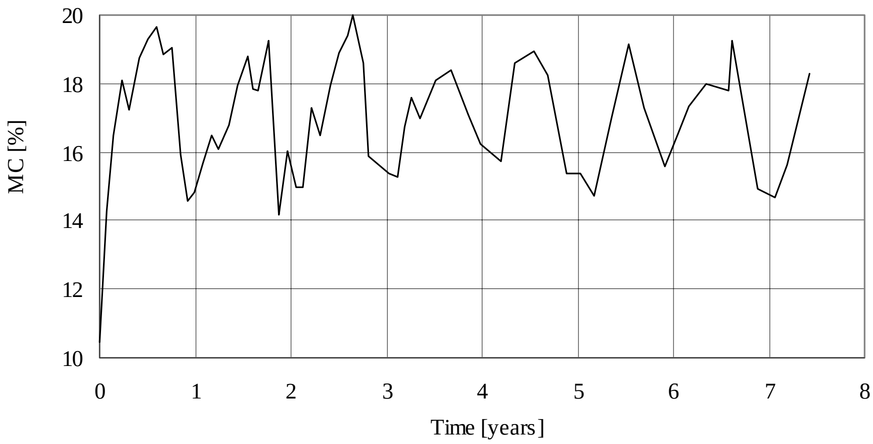

Figure 3. Mean moisture content of 3 end-sealed, untreated 16 to 22 mm thick boards in sheltered environment.

CREEP RESULTS

Creep curves, as compared to the elastic deflection after one minute loading, show the effects of heated vs. unheated environment, surface coating, impregnation, and stress level. The values given are based on the mid-point deflection of the beams.

The creep curves for painted and non-painted pine under 7 MPa maximum bending stress in sheltered environment are shown in Figure 4. The figure indicates that in 7 years the creep deflection of the untreated pine beams is as big as the elastic deflection. Surface coating appears to have an effect on creep: a dense paint film can decrease creep by 50%. On the other hand, it is obvious that all paints are not equally good. Creosote impregnated specimens had the smallest creep deformation, less than 0.3 in 7 years. Obviously this gives an indication of the viscoelastic creep under constant humidity conditions in this temperature range is less than 0.3 in 7 years.

Creep experiments at lower stress level (2 MPa) were made with spruce timber, glulam, LVL and I-beams with hard fibreboard web. Results in Figure 5 show that spruce and glulam have smaller creep than LVL or I-beam. When comparing spruce in this figure to pine in Figure 4, we observe that spruce at 2 MPa stress has 40% less creep than pine under 7 MPa stress. This indicates nonlinearity under so low stresses. However, spruce and pine may have different creep behaviour, and the number of specimens is to small to make any statistically solid conclusions.

To study the long term effect of creep on glue-laminated beams, tests on eight varnished specimens (90x270x9400 mm) were carried out in heated environment. Before the beginning of the tests, all the beams were kept for few months in the test room so that their moisture content was conditioned to the surrounding humidity. The modulus of elasticity was determined by measuring the deflection of the beams before and after the loading. After the start of the test, the vertical displacement of the upper surface of the beam in the middle and at the supports were measured regularly every month with a dial gauge. Maximum bending stress of 4 beams was 2 MPa and 4 MPa for remaining 4 beams. Mean creep results are compared in Figure 5 with the mean creep values of non-treated samples housed in sheltered environment including glulam and spruce (2 MPa). The relative creep deformation seems to be practically identical in the two cases. Furthermore, the relative creep deformation in heated room is also the same at the two load levels, 2 and 4 MPa, which is not shown in the Figures but can be seen in Table 1.

The measurements of individual beams, which are not reported here, show regular annual cycling of deflection. This is probably caused by moisture induced deformations of beams and changes of self weight of the beams, in addition to the mechano-sorptive creep behaviour.

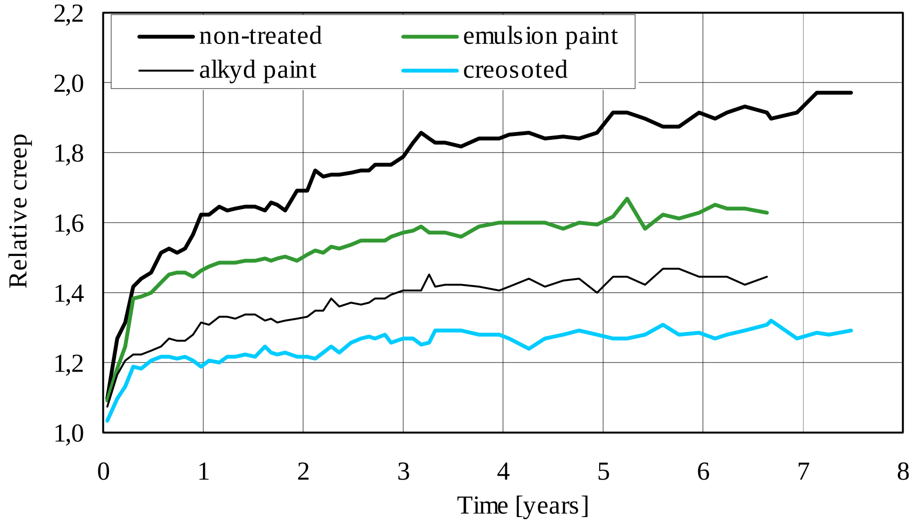

Figure 4. Average relative creep in sheltered environment for different surface coatings and treatments (pine, 7 MPa).

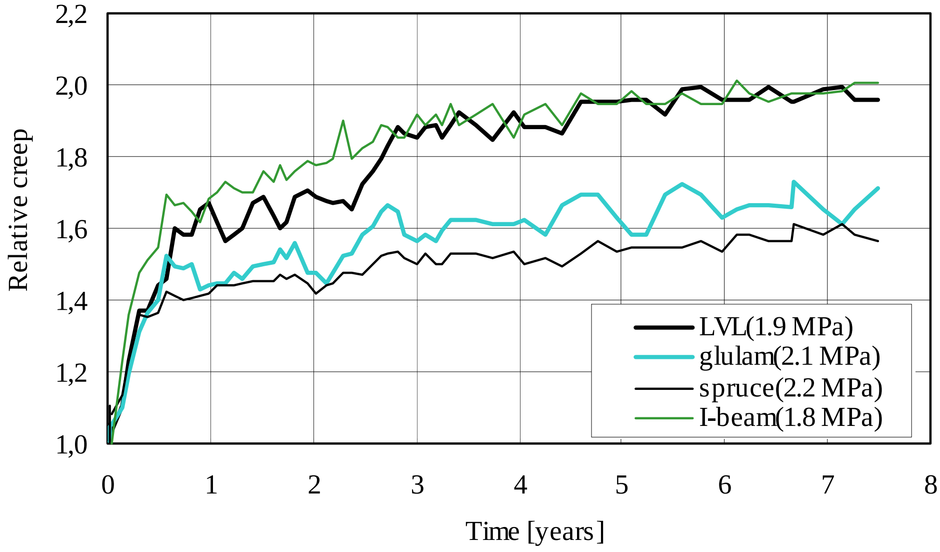

Figure 5. Average relative creep in sheltered environment: LVL, glulam, spruce, I-beam (2 MPa).

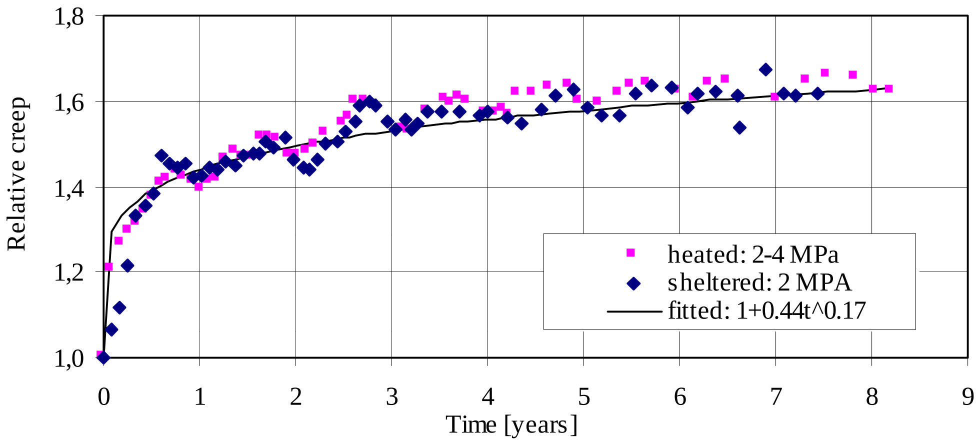

Figure 5. Comparison of average relative creep versus time at lowest load levels (means of 8 glulam beams in heated room and 4 glulam + 4 sawn spruce specimens in sheltered room).

DISCUSSION

Creep of wood is dependent on seasons: moisture variation causes fluctuation in creep curves. In the measured curves there is more fluctuation caused by moisture movements in beams. Also the load is slightly changing depending on season, because part of the load is the weight of the hanging beams. Accordingly, when focusing on long term creep behaviour, we should concentrate on values observed the same time of the year, when the moisture content of the beams is practically the same. Therefore creep values after full years of loading are summarised in Table 1.

A simple curve fitting to values observed after full years of loading is made by the use of equation:

$$\frac{\varepsilon_{creep}}{\varepsilon_{elastic}} = at^b \qquad (1)$$

where a and b are constants and t time in years. In Figure 5 a result of curve fitting is also shown (a=0.44, b=0.17). It seems to give a good fit for solid timber at low load levels both in heated and sheltered unheated environment. If this equation is used for prediction, we obtain 0.67 creep in 10 years and 0.89 in 50 years in natural environment in northern climate.

CONCLUSIONS

To study the long term effect of creep on wood material, structural size samples from pine, spruce, Kerto-LVL and I-profile were used. Experiments were made under naturally changing conditions and low load levels were used. The average values of four specimens was used to plot the relative creep versus time. Surface coating and creosote preservative treatment seem to have a clear effect in decreasing creep because the treatment acts as an effective barrier against moisture (vapour) transport. When moisture variation is prevented due to creosote preservation, the relative creep is small: in three years it reaches the level of 0.27 and seems to stop at that level. The second lowest creep values were obtained for beams coated twice with an alkyd paint (0.51 in 7 years). Other types of treatments seem less effective. Small sample size and variability in E-modulus make it difficult to draw more detailed conclusions.

The average relative creep for non-treated solid spruce timber, sawn or glued laminated, after 7 years is found to be 0.61 when loaded in Nordic sheltered or heated environment at lowest load levels. Considerable part of the creep takes place during the first 6 months. It will take at least 10 years to double the 6 months creep deformation. The prediction for relative creep deformation for 10 years is 0.67.

Table 1. Summary of relative creep deformation of specimens under long term loading. All values are averages of 4 structural size beams.

Relative creep of specimens											
Test material	Dimension [mm]	Surface treatment	max stress MPa	Time (years)							
				1	2	3	4	5	6	7	8
Pine	50x150x5000	non treated	7	0.62	0.69	0.79	0.84	0.90	0.91	0.97	
		emulsion	7	0.46	0.52	0.57	0.60	0.62	0.64		
		alkyd	7	0.31	0.35	0.40	0.41	0.45	0.45		
		creosoted	7	0.19	0.22	0.27	0.28	0.27	0.27	0.28	
		salt impr	7	0.58	0.64						
Spruce	50x150x5000	non treated	7	0.66	0.76						
			2	0.42	0.44	0.50	0.52	0.55	0.58	0.60	
Glulam	90x180x6500	non treated	2	0.44	0.48	0.57	0.61	0.62	0.65	0.65	
Kerto-LVL	51x200x6500	non treated	2	0.67	0.69	0.85	0.90	0.96	0.96	0.99	
I – beam	45x45 flange 6,5 web	non treated	3	0.68	0.78	0.92	0.95	0.98	0.98	0.98	
Glulam*	90x270x9400	varnish	2	0.40	0.45	0.51	0.56	0.58	0.59	0.60	0.61
			4	0.41	0.50	0.55	0.59	0.60	0.61	0.63	0.64

***** in heated room

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