FPInnovations
FORINTEK

Simple Progress Report
Canadian Forest Service No. 4
March 2009

Load Duration Test Protocols For Engineered Wood Products

Project Leader:	Ciprian Pirvu, Building Systems, Wood Engineering Group, Vancouver Laboratory		
Program Area:	Building Systems	Start Date:	April 2008
Program Goal:	BS	Completion Date:	March 2011
Project No.:	6252	Date of Last Update:	March 24, 2009
Project Liaison(s):	Michel Charron, Canadian Forest Service; Paul Jaehrlich, CertiWood Technical Centre; Dan Price, Tolko Industries Ltd.; Terry Courchene, West Fraser LVL; Pedro da Silva, Boise Wood Products.; Bruno Di Lenardo, CCMC; Pierre Audet, OpenJoist 2000 Inc.		

Long Term Goals / Strategies

To develop/improve practical, reliable and internationally recognized methods for assessing/pre-screening the long-term structural performance of engineered wood products used in residential and non-residential applications.

Key Objectives

- Improve/rationalize current load duration and creep standards to ensure that engineered wood products and lumber are treated fairly.
- Assess alternate methodologies for pre-screening and evaluating long-term structural performance of engineered wood products.
- Develop design recommendations that are simple to use by designers (e.g., load duration and time effect factors are different in US Codes and that makes design complicated).
- Provide research information to support: (1) harmonization of North American and European standards on quantifying the effect of duration of load on engineered wood products; and (2) development of a new ISO standard.

Key Actions and Deliverables

Deliverables	Expected Delivery Date (Completed Item ✓)
Report on the state-of-the-art information regarding load duration and creep performance of engineered wood products Report on preliminary testing (Phase I) that includes: (a) standard duration of load tests on several structural composite products†; and (b) small-scale tests for development of alternate methodologies for pre-screening. Summarize test results and conduct statistical analysis on preliminary data. Draft recommendations for code committees (if any).	March 2009 ✓
Report on Phase II of testing that includes: (a) evaluation of selected "established" engineered wood products under long-term loading according to the current North American, European and Japanese standards; and (b) continue development of alternate technologies for pre-screening. Provide a set of data and analysis resulting from Phase II of testing. Draft recommendations for national and international code committees.	March 2010

Draft an ISO standard on duration of load test protocols for wood-based products. Produce a final report summarizing project findings and suggested improvements to the current load duration and creep standard ASTM D 6815.	March 2011
Present research findings at appropriate national and international conferences, seminars and forums. Publish technical papers in recognized journals.	Ongoing

† Duration of load tests in accordance with current standards will be conducted on products that show promise during the pre-screening tests, which started in the fourth quarter of the first year. The duration of load tests in accordance to current standards will begin in the second year of the project.

Partners

FPInnovations – Paprican Division
UBC – Department of Statistics
Alberta Research Council (ARC)
Canadian Construction Materials Centre (CCMC) at NRC-IRC
The Advanced Engineered Wood Composite Centre (AEWC) at the University of Maine, USA

Collaborations

US Forest Products Laboratory
APA – The Engineered Wood Association
Finnish Forest Research Institute (Dr. Tomi Torotti)
Building Research Institute, Japan (Dr. N. Kawai)

Rationale and Potential Impact

A practical and reliable method for assessing the long-term performance of engineered wood products is critical for product development. In North America, a standard (ASTM D 6815) covering the evaluation of duration of load and creep effects for wood and wood-based products was published in 2002 based primarily on testing conducted at FPInnovations Forintek, and the US Forest Products Laboratory. Forintek's research work under the DOL Research Program was funded by Natural Resources Canada.

ASTM D 6815 in its current form has certain limitations such as restricting its use to testing of the product in the dry state. The Canadian Construction Materials Centre at NRC-IRC includes a water-soak treatment of binder-based engineered wood products prior to testing under ASTM D 6815 to compensate for this limitation. Another constraint of ASTM D 6815 is the absence of provisions for dealing with products that fail the requirements of the standard. One purpose of this project is to address these limitations and improve the standard.

The evaluation of load duration and creep requires extensive experimental testing. For example a minimum 90-day constant load period in bending is required in the current ASTM D 6815 standard, and 6 months in the European standard for panel products. A more rapid method for pre-screening that can generate a quick qualitative assessment of engineered wood products in a matter or hours or days is needed. Forintek developed such a pre-screening method to evaluate panel products; however, the method needs to be further refined to assess engineered wood products. This project aims to improve and extend the Forintek pre-screening method beyond panels, and develop alternate methodologies for rapid load duration assessment of wood products.

North America, Europe and Japan have different methods for evaluating load duration and creep, and consequently Canada/United States, Europe and Japan have different standards on this topic. China is interested in having a standard in this area and is currently using ASTM D 6815 as a seed document, while ISO will likely develop a standard using one of the existing standards as a starting point. Canada, United States and Japan have been discussing the duration of load topic under the Japan Agricultural Standards Technical

Committee / Building Experts Committee forum, but additional comparison data is necessary to come up with a resolution, and this project is designed to assist in that process.

During the course of the project, recommendations for improving the standard will be submitted to the ASTM D07 Technical Committee, related Japanese and European Committees and ISO for consideration.

Work Completed This Fiscal Year

1. State-of-the-art of load duration and creep performance of engineered wood products

Creep is defined as a slow "flow" of a material in time under constant loading. The slow "flow" of material translates into an increase in deformation over time. Wood is considered to be a viscoelastic material and, as such, generally passes through three phases of deformation when subjected to constant loading:

- An initial deformation characterized by a decrease of the speed of deformation (primary creep).
- A secondary deformation characterized by constant speed of deformation (secondary creep). The magnitude of deformation and duration of this phase are primarily dependent on the load level applied.
- A third phase characterized by a large speed of deformation that increases as the deformation becomes larger until failure occurs. This phase is called tertiary creep.

The main factors affecting creep of solid wood products include the magnitude, type and duration of load, moisture content, and temperature. Under steady environmental conditions, creep deformation increases with load duration. The magnitude of deformation depends on load level, which must be maintained lower when the duration of load is extended to ensure an acceptable deformation limit of the structure over time. All wood-based products are sensitive to humidity which affects creep significantly beyond certain limits. Creep increases with moisture content. The effect of temperature up to about 50ºC on creep is negligible and masked by the effect of moisture content. Generally, the higher the temperature, the higher the creep deformation. The same is true for stress level: the higher the stress, the higher the rate of creep and the shorter the time to failure.

Another factor affecting creep is the grain orientation relative to the direction of loading. For wood strand-based products, additional manufacturing parameters such as strand size and quality, amount of fines, and binder type and content augment the complexity of rheological behaviour of such products. Due to the additional factors influencing creep of wood-based materials, it is generally considered that, under the same conditions, creep is higher for these types of materials.

The failure or creep rupture of a product under sustained load is attributed to the duration of load (DOL) effect. A wealth of information is available on creep rupture and DOL effect on lumber, panel products and glulam, and LVL. OSB and OSL type products may have different creep and creep-rupture behaviour than solid lumber or veneer-based products, and changes to the composition or manufacturing parameters can easily change a product that has similar DOL and creep effects as solid lumber to one that does not.

A literature review on load duration and creep performance of engineered wood products and particularly structural composite lumber was undertaken. While a significant amount of literature is available for duration of load and creep effects of lumber, relatively less information is available on structural composite lumber products due to their proprietary nature. Some of the literature review findings were:

- While some structural composite lumber products, such as PSL and LVL, have consistently demonstrated engineering equivalence to the duration of load of solid sawn lumber, such equivalence is more difficult to demonstrate for other structural composite lumber products, such as LSL and OSL, and further tests are necessary to define their creep and creep-rupture behaviour. (Yeh and Williamson, 2007)

- Hoffmeyer and Sørensen (2007) reported a significant mechano-sorptive effect in terms of increased creep and shortened time to failure for structural timber subjected to bending under constant load conditions and different moisture conditions (constant at MC = 11% and 20%, and variable MC = 11~20%). The effect of long-term loading, expressed as the stress level to cause failure after 50 years of loading, was 0.60 for MC = 11%, 0.50 for MC = 20%, and 0.44 for MC = 11~20%.

- Capability of non-destructive techniques to predict modulus of rupture (MOR) varied considerably depending on the types of the density profiles of the wood-based materials tested. The best correlation between the actual MOR and predicted MOR (r^2 = 0.41~0.89) was obtained for the materials with a type I density profile (density gradually changing from the centre to surface layers), followed by the materials with a type II density profile (similar density throughout the thickness) and type III density profile (irregular density across the thickness) with r^2 = 0.33~0.59. The worst correlation was obtained for materials with a type IV density profile (similar to type III but not dominated by wood). (Fan et al., 2006)

- Test methods for determination of DOL in bending in Europe, the US and Canada are similar, and the results on DOL in bending published internationally are consistent, suggesting that it may be possible to reach an international agreement on DOL protocols for bending. However, further work on the effects of loading modes may be required before a tension or compression test protocol can be attained. (Barrett, 1996)

- Soltis et al. (1989) compared load duration factors for bending, tension and compression for one species, one grade, and one size of lumber (2x4 Douglas-fir No.2). The preliminary results indicated that load duration factors for tension and compression differ from the load duration factor based on bending by about 15% for the 2-month DOL factor and by about 25% for the 10-year DOL factor.

- The effect of load duration of lumber loaded in tension and compression was higher than that of lumber tested in bending. (Karacabeyli and Soltis, 1991)

- Leichti et al. (2007) noticed that while ASTM D 6815 requires deflection measurements after 1 min, 30 days, 60 days, and 90 days from loading application, experience showed that more frequent measurements are good practice.

- Sobue (2001) studied creep and wood fracture of Sugi (Japanese cedar) specimens tested in accordance with ASTM E 399 in ambient and cyclic humidity environments. The duration of secondary creep accounted for about 70% of the specimens' lifetime. Also, the minimum creep speed during the secondary creep phase was highly dependent on stress level and very useful in predicting the lifetime of the specimen.

- Acoustic emissions were used to asses load duration behaviour in wood-based panels during creep testing. (Beall, 1996)

- Creep tests (i.e., loading at 25% of average strength of the side-matched controls for 6 months) indicated that plywood, OSB and waferboard, in that order, were more affected by environmental conditions (constant 50% RH, constant 85% RH, and variable 50 to 85% RH) than lumber, during the cooperative research program between the US Forest Products Laboratory and Forintek. (Laufenberg et al., 1999)

- The DOL performance parameters used as criteria in ASTM D 6815 are: stress levels for avoiding creep-rupture, decreasing creep rate and fractional deflection limit. Karacabeyli (2001) further describes additional parameters (residual strength and stiffness, creep recovery) that were not implemented in the standard.

1.1 North American Approach for Evaluation of DOL and Creep Effects

The current ASTM standard for the evaluation of DOL and creep effects is a pass/fail procedure and does not provide a procedure for calculation of duration of load and/or creep factors. The Canadian standard on Engineering Design in Wood takes into account duration of load classes (that allow for the dependence of wood on duration of applied load); however, it does not take into account service classes (that allow for sensitivity of wood to moisture content variations and its consequent effect on creep). Further details about these standards are given in the following sections.

1.1.1 Current State of ASTM D 6815 Standard

In North America, structural composite lumber products are evaluated in accordance with ASTM D 5456 which references ASTM D 6815 for the evaluation of DOL and creep effects. One of the requirements for qualification of structural composite lumber products is demonstrating “engineering equivalence” to the DOL and creep effects of solid lumber so that the same design values can be used.

ASTM D 6815 requires two sets of matched specimens, out of which one set is used for determination of the short-term (static) bending stress and the second set is used for the long-term creep tests. The minimum creep bending stress (f_b) used for the long-term tests is calculated as follows:

f_b = 0.55 x (5% PE)

where,

f_b - minimum applied creep bending stress;
5% PE - the lower 5% point estimate of the bending strength as determined form the short-term bending tests.

The tests are conducted in an environmentally controlled space for at least 90 days. The ASTM D 6815 standard relies on extrapolation of the test results obtained during the 90-day constant loading to a much longer period (i.e., 10 years) assuming the product will behave over the years similarly to its behaviour during the test.

ASTM D 6815 has limitations such as restricting its use to testing of the product in the dry state, and absence of provisions for products that do not pass the standard. Under the current standard, a product that does not show “engineering equivalence” to lumber has no option (i.e., cannot use the lumber DOL factors specified in the Design Codes).

1.1.2 Proposed Revisions to ASTM D6815 Standard

FPInnovations – Forintek worked closely with the ASTM Task Group to outline, propose and monitor development of ASTM D 6815 including an alternate method to accommodate products that do not meet the requirements of the current standard. The initial proposed revisions to the standard included additional acceptance criteria and an alternate method for products that fail the standard. The additional criteria consisted of: limited average and minimum fractional deflection, minimum average creep recovery, and adequate residual strength and stiffness. The alternate procedure for products that do not meet the acceptance criteria included a re-test at a reduced load level that translates into reduced allowable design properties for such products.

At the latest committee meeting of the ASTM Task Group in fall 2008, an updated flow chart incorporating changes to the current and alternate procedures for product assessment under the revised ASTM D 6815 was discussed. The Task Group members recognized the importance of more test data and statistical support to the standard, and further Task Group discussion on the alternate procedure was proposed. Providing a statistical basis for the sampling and data analysis procedures in the standard will increase confidence in the standard and provide guidance on how best to improve its robustness and reliability. Steps are being taken to involve a team of statisticians to provide statistical support to the load duration area.

1.1.3 Additional testing (CCMC)

The Canadian Construction Materials Centre at NRC-IRC includes a water-soak treatment for binder-based engineered wood products prior to testing under ASTM D 6815. This is an accelerated aging treatment to further assess durability of a product. The water-soak treatment includes a 14-day soak in water followed by conditioning that can be accomplished by air-drying, kiln-drying, or oven-drying. Such a test may also compensate for the standard's limited dry use only.

1.1.4 Load duration factors in Canadian Codes

In North America, the load duration factors used in design codes are based on bending tests. In Canada, the CSA O86-01, Engineering Design in Wood, provides design values for structural members made of wood or wood-based products. The specified strengths in CSA O86-01 are for standard load duration (e.g., snow loads and live loads), and they can be modified to account for loads applied over a shorter or longer period than normal by using a load duration factor, K_D. The load duration factor is provided in CSA O86-01 for three load duration classes: short-term (less than 7 days throughout the life of the structure), standard term (more than short-term loading and less than permanent loading), and permanent (more or less continuously throughout the life of the structure).

1.2 European Approach for Evaluation of DOL and Creep Effects

The current European approach takes into account the DOL and creep effects by introducing duration of load and creep factors associated with different types of loading. The duration of load and creep factors take into account duration of load classes and service classes. Further details about these standards are given in the following sections.

1.2.1 European Standard for Determination of DOL and Creep Factors

The European Standard ENV 1156, Wood-based panels – Determination of duration of load and creep effects, provides a method of determining duration of load factors for wood-based panels subjected to bending under constant environmental conditions. The load duration factor is explained as the loss in strength with time under load, while the creep factor is the ratio of increase in deflection with time to the initial elastic deflection. Specimens are tested in four-point bending with a distance between the load application points of 150 mm.

Testing for determination of the DOL factors includes a series of tests at 55%, 60%, 65%, 70%, 75%, and 80% of the maximum load obtained for short-term bending tests, when environmental conditions are 20ºC and 65% RH. For humidity of 85% or 95% the standard recommends lower stress levels. The tests are conducted at least until 7 pieces per stress level have failed. The DOL factor for a wood-based product is determined by plotting the level of stress versus $\log_{10}$ time to failure, calculating the mean time to failure for each stress level, and computing the linear regression line. The stress level (SL) is extrapolated for a particular product "life" and provided by the following equation:

$SL = e - f \log_{10}T = k_{d, T, SC}$

$e = c/m$
$f = 1/m$

where,

SL: stress level (%)
c: the intercept on the vertical axis
m: slope
T: time to failure (min)
$k_{d, T, SC}$: duration of load factor calculated for T years that applies to service class SC (the service class is assigned based on the conditions during the duration of load testing).

Testing for determination of the creep factor includes 10 tests at a stress level of 25% (assuming linear viscoelastic behaviour up to at least 40% of the maximum load obtained for short-term bending tests), for at least 26 weeks (preferably 54 weeks). Deflection (a_T) as a function of time (T) is recorded after 5, 10, 50, 100 and 500 min, following by measurements at 24 h intervals. The creep factor ($k_{c, T, SC}$) for a certain amount of time (T) is provided by the following expression:

$k_{c, T, SC} = (a_T - a_1) / (a_1 - a_0)$

where,

a_T: total deflection at time T (mm)
a_1: deflection after 1 min (mm)
a_0: deflection of unloaded test piece positioned in the creep test jig (mm)
$a_1 - a_0$: initial elastic deflection measured after 1 min of load application (mm)
$k_{c, T, SC}$: creep factor predicted for T years that applies to service class SC (the service class is assigned based on the conditions during the duration of load testing)

To determine the creep factor for one stress level, the mean value of $k_{c, T, SC}$ for the 10 tests at each period of time is calculated, then the $\log_{10}$ of the mean $k_{c, T, SC}$ value is plotted against $\log_{10}$ time for each time period T, and a regression line is fitted through these points and projected to the time span required.

1.2.2 DOL and Creep Effects in European Design Codes

The main factors affecting creep of solid wood products include the magnitude, type and duration of load, moisture content and temperature. Interactions occur among all factors, but only the combined effects of load duration and moisture content are taken into account in the design rules specified in Eurocode 5 (EC5), Design of Timber Structures, which provides load duration classes and modification factors for service classes that are used in the design of structures.

The EC5 defines five load duration classes: permanent class (corresponding to more than 10 years of loading), long-term class (6 months to 10 years), medium-term class (1 week to 6 months), short-term class (less than 1 week), and instantaneous class. The creep value for a given class is taken as constant.

The EC5 distinguishes three service classes for structures, corresponding to three different moisture contents of wood. The service class system is meant to assign design values under defined environmental conditions. The three service classes are:

- Service class 1: moisture content of wood when exposed to a temperature of 20ºC and RH exceeding 65% for a few weeks per year.
- Service class 2: moisture content of wood when exposed to a temperature of 20ºC and RH exceeding 85% for a few weeks per year.
- Service class 3: climatic conditions resulting in higher moisture contents than in service class 2.

Modification factors for solid lumber, glulam and wood-based materials (OSB, plywood, particleboard and fibreboard) are provided for each of the three service classes and each of the five DOL classes.

According to EC5, calculation of final deformation (u_{fin}) takes into account the combined effect of load duration and moisture content, which is quantified by the factor k_{def}. This factor is tabulated for the service classes and durations of load classes indicated above.

$$u_{fin} = u_{inst} + k_{def}\ u_{inst}$$

The value of creep deformation in the expression above is equal to $k_{def} \times u_{inst}$, where u_{inst} represents the instantaneous deformation. The final deformation calculated for each member and joint in a timber structure is summed to obtain the total deformation.

1.3 Japanese Standard for Evaluation of DOL and Creep Effects

The current Japanese approach takes into account the DOL and creep effects by introducing DOL and creep factors associated with different types of loading, in a similar manner to the European approach. Further details about these standards are given in the following sections.

1.3.1 Japanese Test Method for Evaluation of Creep in Wood and Wood-based Panel Products

The JIS Z 2101, Methods of Test for Woods, provides specifications for evaluation of creep in wood subjected to bending, compression and tension loading. Specimens with square cross-section (sides of 10 to 30 mm) and a length of 17 times the width/depth plus 200 mm are loaded in four-point bending, and deformation at mid-span is recorded for the duration of the test. The standard specifies four mandatory stress levels that are calculated as 2/4, 3/4, 4/4, and 5/4 of the stress at yield point (i.e., elastic limit). Constant loading at mandatory stress levels is maintained for a minimum of 200 hours. The tests at the four stress levels may be run concomitantly or non-concomitantly if conducted under constant environmental conditions; however, if conducted in an ambient environment the tests at the four stress levels must be run concomitantly. Specimens that survived the test are tested to failure to assess their residual strength. The report includes: displacement versus time relationship, number of failures during the test, sample size, species, density, direction of loading and stress level, and environmental conditions.

The JIS A 1414, Methods of Performance Test of Panels for Building Construction, provides a test method for determination of creep in bending for structural panels. Specimens are loaded at loads equivalent to the long-term design load for 5 to 6 months and deflection is measured at mid-span at certain time intervals. Tests are conducted in a constant environment maintained at 20±2ºC and 65±5% RH. The report includes: load-displacement relationship, displacement versus number of days of loading relationship, and rate-of-deflection versus time of loading relationship. The rate of deflection (φ) is calculated as:

$\varphi = \delta p / \delta' e$ (long-term increment of deflection)

where,

δp: plastic deflection
$\delta' e$: elastic displacement including displacement due to self mass.

1.3.2 DOL and Creep Effects in Japanese Design Codes

Technical criteria for code acceptance of wood and wood-based products with respect to the Japanese Industrial Standards or Japanese Agricultural Standards are specified in Notification No. 1446 of the Ministry of Construction and published in the Building Standard Law of Japan. The methods of determination the load duration and creep factors (coefficients) for flexural strength, shear strength and partial compressive strength of wood-based glued axial materials are given in the Annexed Table 2 of the Notification.

The methodology for determination of the load duration factor for flexural, shear and compressive strength consists of: (1) loading the specimens to three stress levels corresponding to values up to 1 and multiplied with the average load obtained for short-term tests; (2) maintaining the load for at least 6 months (at least half of the specimens must survive the test for minimum one of the three stress levels); (3) plotting the logarithm of time against the stress value for each stress level; and (4) fitting a regression line through these points and projecting to a time span of 50 years.

The methodology for determination of the creep factor for flexural MOE and shear MOE consists of: (1) loading the specimens under loads calculated as the average short-term strength (of the side-matched specimens) x moisture content factor x load duration factor x 2/3; (2) recording displacements after 1 min, 5 min, 10 min, 100 min, 500 min from application of the load, and at 24 hour intervals for at least 5 weeks thereafter; (3) calculating the creep deformation ratio for each specimen as the ratio of deformation measured after 1 min of loading to the deformation measured every hour; (4) plotting the relationship between the logarithm of creep deformation ratio corresponding to each time (except 1 and 5 min) and the logarithms of times; and (5) fitting a regression line through these points and projecting to a time span of 50 years.

2. Preliminary testing: Standard duration of load tests on several structural composite products

The main intent of this project is to update the North American load duration test protocol by addressing its current limitations. Section 1.1.2 of this report describes the work on revising ASTM D6815 that is currently ongoing in the ASTM D7 committee. This work is primarily focused on providing alternative methodologies for products that do not pass the standard. More revisions will likely become necessary with the completion of this project. Once the updates are implemented into the North American standard, steps will be taken to harmonize the major protocols for determination of load duration of wood-based products available worldwide and develop an ISO standard.

One of the challenges associated with the development of requirements for standards is establishing a performance baseline in such a way as to include products that perform well and exclude poor performers. This may be accomplished by testing the products (good performers as well as poor performers), and using the results to develop an acceptance criteria for the standard (i.e., the minimum requirements that have to be met by a product to pass the standard). Sourcing consistently produced poor performers is difficult. An efficient approach is to consistently produce a fictitious product with known poor performance in the laboratory. Testing such a product will indicate a performance level that must be exceeded by an established product (i.e., good performer).

Development of a fictitious product with poor creep performance in a consistent fashion is challenging. In this case, by poor creep performance we understand good short-term strength but poor long-term performance. As part of this exercise, a few structural composite lumber products were developed by varying the amount of resin in the mix, and/or by altering the pressing conditions so that the material would exhibit a strong vertical density profile (i.e., high face density and low core density). Additional OSL products, which were developed in a separate study, were also made available for testing and their creep and creep-rupture behaviour will be compared with that of commercially available products.

The specimens for assessing creep and creep-rupture were conditioned to equilibrium moisture content in an environmental chamber at 20ºC and 65% RH prior to testing. For the preliminary testing, the specimens will be pre-screened using the in-house test method developed by Les Palka (Bach and Karacabeyli, 1997). The pre-screening method involves two sets of matched specimens loaded in bending in one minute and ten hours time to failure. The Palka Model uses the results of the two sets of tests and provides a quick qualitative assessment of their creep behaviour based on the ratio of plastic displacement to elastic displacement. The products that exhibit the desired creep and creep-rupture behaviour (acceptable or unacceptable) will then be selected for further testing in accordance with current North American, and possibly the European and Japanese protocols.

The testing program proposed includes a component that aims at evaluation of the effect of creep on product microstructure in different phases of creep (i.e., primary, secondary, and tertiary) in dry, wet, and wet and re-dried states. This component of the project will investigate changes at the micro-structural level due to creep and creep-rupture. The analysis will look at initial deflection, fractional deflection, creep recovery, and residual strength and stiffness, which are important parameters for assessing creep and creep-rupture behaviour of wood and wood-based products.

The DOL data acquisition system (DAS) has been upgraded to modern off-the-shelf hardware and custom software to replace the original DOL DAS built over twenty years ago, with software upgrades ten years ago. The new DOL DAS duplicates the ability to monitor DOL specimens in three distinct locations in our facility, namely the Wood Engineering Lab, the Lab conditioning chambers and the Shed conditioning chambers. Each remote location also has a local touch panel screen with software that allows the technologists to monitor specimens under test, but more importantly facilitates the coordination and ease of communication required when loading and unloading specimens, and calibrating sensors. This solved the coordination problem of how to communicate timing and calibration readings from the remote conditioning chamber sites to the main computer location where the data was entered.

3. Preliminary testing: Small-scale tests for development of alternate methodologies for pre-screening

Development of alternate technologies for pre-screening are seen as quick qualitative product assessment tests that provide an indication about the long-term creep behaviour of wood-based products. Such alternate technologies are especially important to product manufacturers as effective tools for development of new structural products. One component of this study is to improve the current (in-house) methodology for rapid assessment of wood-based products (i.e., based on one minute and ten hours ramp tests). Forintek initiated a collaborative study with the Advanced Engineered Wood Composites (AEWC) Centre at the University of Maine, for development of a methodology for embedding fibre optic sensors into structural composite products to monitor their creep behaviour.

The first phase of the study will investigate the ability to successfully incorporate fragile fibre optic sensors into strand-based wood beams during manufacturing. The objective is to determine whether the sensors survive the harsh conditions of hydraulic hot-pressing (temperatures up to 400°F and localized pressures up to 1,000 psi) and provide satisfactory output. Given the exploratory nature of this study, OSB was proposed rather than LSL/OSL as the conditions experienced by the sensor should be similar and OSB will be significantly less expensive to produce. Following pressing, specimens cut from the mats will be loaded in bending and the fibre optic sensor output recorded for several hours. If this phase is successful, the plan is to continue the study with a second phase where several LSL billets with embedded fibre optic sensors will be fabricated, producing test specimens for tension, bending and creep.

References

ASTM D 6815, 2002. Standard Specification for Evaluation of Duration of Load and Creep Effects in Wood and Wood-Based Products. ASTM International, West Conshohocken, USA.

ASTM E 399, Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{IC} of Metallic Materials. ASTM International, West Conshohocken, USA.

Bach, L. and Karacabeyli, E., 1997. Conversion of short-term to long-term responses of OSB by Palka Model. Report submitted for the Structural Board Association. Forintek Canada Corp., Vancouver BC (Project No. 1156)

Barrett, J.D., 1996. Duration of Load – The Past, Present and Future. International COST 508 Wood Mechanics Conference, Stuttgart, Germany.

Beall, F.C., 1996. The use of acoustic emission to assess duration of load behaviour in oriented strandboard. In: Proceedings, 10th symposium on non-destructive testing of wood. Lausanne, Switzerland.

CSA O86-01: 2003, Engineering Design in Wood. Canadian Standards Association. Ontario, Canada L4W 5N6.

Eurocode 5, DD ENV 1995-1-1: 1994, Design of timber structures. Part 1.1 General rules and rules for buildings. European Committee for Standardization. Brussels, EU.

European Standard ENV 1156: 1999, Wood-based panels – Determination of duration of load and creep factors. European Committee for Standardization. Brussels, EU.

Fan, M., Bonfield, P., Kearley, V. and Rochester, I., 2006. Long term performance of wood based panels. Part I: Non-destructive system for stress determination for creep loading. Journal of the Institute of Wood Science, volume 17, No. 3 (Issue 99).

Hoffmeyer, P. and Sørensen D. John, 2007. Duration of load revisited. Wood Sci Technol (2007) 41:687-711.

JIS A 1414, Methods of Performance Test of Panels for Building Construction. Japanese Standards Association, Tokyo, Japan.

JIS Z 2101, 1994. Methods of test for woods. Japanese Standards Association, Tokyo, Japan.

Karacabeyli, E. 2001. Wood: creep and creep rupture. Reprint: 5p. Encyclopedia of Materials: Science and Technology: 9616-9620. Edited by Frank Beall. Elsevier Science Limited. Oxford, England.

Karacabeyli, E. and Soltis L.A., 1991. State-of-the-art report on duration of load research for lumber in North America. In: Proceedings 1991 International Timber Engineering Conference, London. 4:141-155.

Laufenberg, T.L., Palka, L.C. and McNatt, J.D., 1999. Creep and creep-rupture behaviour of wood-based structural panels. Res. Pap. FLP-RP-574. Madison, WI: US Dept. of Agriculture, Forest Service, FPL.

Leichti, R., Clauson, M. and Cheney, D., 2007. Flexural creep apparatus and testing for structural composite lumber. Technical Note. Journal of Testing and Evaluation, Vol. 35, No. 5. Paper ID JTE14102.

Sobue, N., 2001. Application of fracture mechanics approach to creep of wood having a crack. Proceedings of the First International Conference of the European Society for Wood Mechanics, Lausanne, Switzerland.

Soltis, L.A., Nelson, W. and Hillis, J.L., 1989. Effect of Loading Mode on Duration-of-Load Factors. (http://www.fpl.fs.fed.us/documnts/pdf1989/solti89b.pdf)

The Building Standard Law of Japan, 2004. The Building Center of Japan. Tokyo, Japan.

Yeh, B. and Williamson, T.G., 2007. Creep and creep-rupture behaviour of structural composite lumber evaluated in accordance with ASTM D 6815. International Council for Research and Innovation in Building and Construction. Working Commission W18 – Timber Structures. Meeting 40, Bled, Slovenia.