

# INVESTIGATION OF FLEXURAL CREEP OF KRAFT PAPER HONEYCOMB CORE SANDWICH PANELS USING THE FINITE ELEMENT METHOD

*Zheng Chen*

Postdoctoral Research Fellow  
E-mail: cxc620@yahoo.ca

*Ning Yan*<sup>\*†</sup>

Associate Professor  
Faculty of Forestry  
University of Toronto  
33 Willcocks Street  
Toronto, Ontario, M5S 3B3 Canada  
E-mail: ning.yan@utoronto.ca

*Greg Smith*

Associate Professor  
Department of Wood Science  
University of British Columbia  
2935-2424 Main Mall  
Vancouver, BC, V6T 1Z4 Canada  
E-mail: greg.smith@ubc.ca

*James Deng*

Senior Research Scientist  
Composite Products  
FPInnovations Forintek  
319 rue Franquet  
Quebec, QC, G1P 4R4, Canada  
E-mail: james.deng@fpinnovations.ca

(Received February 2012)

**Abstract.** Finite element (FE) models for the flexural creep of the sandwich panels with various Kraft paper honeycomb cores and wood composite skins were established. The creep constants of these FE models' core and skin were determined by simulating the experimental results of the flexural creep of the corresponding skin layer and sandwich panels individually. The influence of the core orientation, core shape, core and skin thickness, and core cell size was studied using these established FE models. The results indicated that the panel's flexural creep in the primary stage was smaller when the panel was thinner, longer, and wider as well as when the shelling ratio (thickness ratio between panel's core layer and skin layer) was smaller. The panel that had a higher stiffness skin layer, or the core's ribbon direction was parallel to the panel span, or was loaded at a lower level had a smaller flexural creep. However, there was no observed influence of honeycomb core's cell size on the flexural creep behavior of the sandwich panels.

**Keywords:** Finite element model, primary creep, honeycomb, sandwich.

## INTRODUCTION

The ready-to-assemble furniture industry is using hollow core panels that utilize the high-density and stiff materials as the skins and low-density paper-based honeycomb as the cores to

---

\* Corresponding author  
† SWST member

make light, stiff structures suitable for shelves and tables. The skin materials are typically wood-based composites such as medium-density fiberboard (MDF), particleboard, or hardboard (HB). Furniture made from these hollow core panels is much lighter and uses less raw materials than that made from its solid slob counterparts. As wood-based materials are viscoelastic in nature, the time-dependent behavior of such panels, ie creep, is important for practical applications.

The viscoelastic behavior of materials, such as wood, concrete, plastic, and metal, has been widely studied over the years (Holzer et al 1989). Generally, there are two types of approaches used to describe the creep behavior: power models (empirical models) and mechanical models (Schniewind 1968; Bodig and Jayne 1982; Taylor et al 1997). In mechanical models, springs and dashpots are used to simulate the creep of the materials. The power model is obtained by fitting a mathematical function to experimental data and has been used to describe the deflection creep behavior of sandwich with wood, polymer, and metal as the skin. The power model is based on the Baily-Newton law (Eq 1) (Krause 1980) and has been used widely by researchers to describe the primary and secondary creep behavior due to its simplicity.

$$\epsilon^C = C_1 \sigma^{C_2} t^{C_3} e^{(-C_4/T)} \quad (1)$$

Some researchers have obtained experimental results for the creep strain rates of honeycombs and other hollow cellular materials made from polymer, ceramic, and aluminum (Goretta et al 1990; Huang and Gibson 1991; Andrews et al 1999; Oruganti and Ghosh 2002; Xiang et al 2008). The theoretical expressions for predicting the creep rate of honeycomb and foam were developed using mechanical properties of the cell wall and related density as input (Andrews et al 1999; Lin and Huang 2005). However, neither the power model nor the theoretical expressions for the creep rate considered the effect of cell shape and extensive long-term stress redistribution caused by prolonged loading on the creep response of the honeycomb and foam structures. Recently it was reported that the elastic-plastic finite element method could be employed to

study the creep deformation of nickle honeycomb structures containing different cell shapes (Oruganti and Ghosh 2008).

There is little published work on the creep behavior of honeycomb core sandwich panels. Bitzer (1997) summarized that creep deflection of a honeycomb core sandwich panel depended on temperature, skin and core mechanical properties, panel dimension, core cell size, core ribbon orientation, properties of the adhesive used to bind the skin to the core, and the initial stress distribution. Since many factors can affect creep, it is difficult to predict creep behavior a priori. Meanwhile, there is a lack of study on creep behavior of sandwich panels containing Kraft paper honeycomb core and wood composite skins in the literature.

In one earlier study (Chen et al 2011a), a series of flexural creep tests were conducted to investigate the influence of Kraft paper honeycomb sandwich structural parameters, including different paper honeycomb core types and different wood composite skins. Although that study has shed some light on the effect of some panel structural parameters on creep, due to practical constraints, it was not possible to isolate the effects of these structural parameters independently (eg all types of the sandwich panel had the same geometric dimensions but different thickness ratios of core to skin). It is impractical to produce large numbers of iterations of sandwich test panels by varying one structural parameter at a time. To better understand the influence of individual components of the sandwich panel structure on its flexural creep step by step, a series of finite element (FE) models were developed in this study. Material properties such as modulus of elasticity (MOE), shear modulus, and Poisson's ratio for Kraft paper honeycomb core layers and wood composite skins were obtained previously (Tables 1 and 2) (Chen et al 2011b). The flexural creep constants for the wood

Table 1. Properties used in the finite element models for the skin materials (Chen et al 2010b).

Material	MOE (MPa)	Shear modulus (MPa)	Poisson's ratio
HB	3410	341.0	0.2
MDF	2064	206.4	0.2

MOE, modulus of elasticity; HB, hardboard; MDF, medium-density fiberboard.

Table 2. Properties used in the finite element models for the core materials (Chen et al 2010b).

Core type*	Cell size (mm)	MOE (MPa)	Shear modulus (MPa)	Poisson's ratio	Core web thickness (mm)
Expanded x	31.8	19.9	7.9	0.4	0.13
Expanded y	31.8	19.3	3.8	0.4	0.13
Expanded y	15.9	20.7	3.0	0.4	0.23
Corrugated x	19.1	52.2	10.0	0.4	0.13
Corrugated y	19.1	18.8	1.1	0.4	0.13

\* x and y indicated the ribbon direction of core was parallel with or perpendicular to the long edge of the sample.  
MOE, modulus of elasticity.

composite skins and Kraft paper honeycomb core were determined by simulating the measured flexural creep test data for these components respectively. The FE models were then used to carry out parametric studies to predict the influence of various structural parameters on the panel flexural creep response.

MATERIALS AND METHODS

Modeling

Based on prior experimental work (Chen et al 2011a), the following types of panels were selected for the FE model development and creep simulation: 2.8-mm thick HB solid panel; 32-mm thick sandwich panel (with 3-mm thick HB skins and 26-mm thick Kraft paper expanded honeycomb core); 32-mm thick sandwich panel (with 3-mm thick HB skins and 26-mm thick Kraft paper corrugated honeycomb core); and 32-mm thick sandwich panel (with 3-mm thick MDF skins and 26-mm thick Kraft paper expanded honeycomb core [Table 2]). Figure 1(a) indicated the core type we used for this study.

These laboratory-made test panels were constructed at the University of British Columbia in Canada. The honeycomb cores were supplied by Casewell Products Co. in Vancouver, British Columbia, Canada, and Pregis Co. in Deerfield, IL. The flexural creep testing of the HB and sandwich panels was carried out at the Material and Product Evaluation Laboratory in FPIInnovations in Quebec City, Quebec, Canada, according to ASTM standard C480 (ASTM 2005). The sample's width and span for the 2.8-mm thick HB

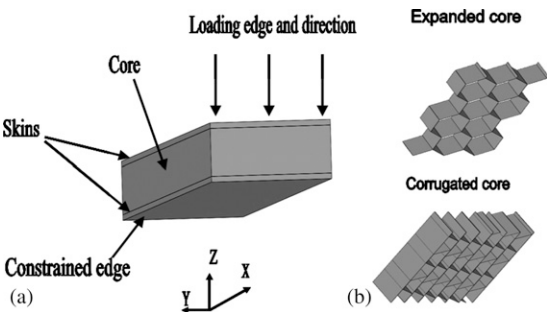


Figure 1. (a) Schematic of a sandwich panel showing the skin and core layers and constraint conditions for the finite element (FE) model under flexural creep test. Each type of honeycomb core layer was assumed as a uniform entity. (b) Type of core represented by the uniform entity.

sample were 50 mm and 76.8 mm, respectively. The constant loading level for flexural creep test of the HB was 37 N. The widths of all sandwich panels were 75 mm. The span of sandwich panel samples was between 465 mm and 864 mm. The constant loading level for flexural creep of sandwich panels was between 33.25 N and 70.19 N (Chen et al 2011a). The testing temperature was controlled at between 20°C and 22°C, and the RH of the testing environment was controlled at between 68% and 72%. The creep test of each type of panel was replicated twice (Chen et al 2011a).

Finite Element Model Construction

The FE models for simulating flexural creep of honeycomb panels were assembled by combining the FE models of the two components, ie Kraft paper honeycomb core layer and wood composite skin. To simplify the calculation, each type of honeycomb core layer was assumed as a uniform entity as shown in Fig 1(b), and the following assumptions were made for modeling the assembled panel:

- 1. The bond between the core and skin is perfect and does not contribute to any additional stiffness or flexibility to the panel.
- 2. All honeycomb cells are identical in size and of the same shape and are symmetrical to longitudinal and transversal central line.

COSMOSWork 2008 Advanced Professional (COSMOSWork 2008a) was used to generate the FE models for simulating and predicting flexural creep behavior using the nonlinear method and material creep effect module, which is based on the Bailey-Newton law (Eq 1). Ten-node parabolic solid element was selected for these FE models. The Voronoi-Delaunary meshing scheme for subsequent meshing operations was used. Element size was controlled to be between 7.8 mm and 12.2 mm. The tolerance for element size was between 0.4 mm and 0.6 mm. The iterative method used for the nonlinear analysis was the modified Newton-Raphson (NR) scheme which is illustrated in Fig 2 (COSMOSWork 2008b), whereby the tangential stiffness matrix  $K$  was formed and decomposed at the beginning of each step and used throughout the iteration. This approach simplifies the forming and decomposing process of the original NR iterative method at each iteration. From Fig 2,

$${}^{t+\Delta t}\{R\} - {}^{t+\Delta t}\{F\} = 0 \quad (2)$$

$$\{\Delta R\}^{(i-1)} = {}^{t+\Delta t}\{R\} - {}^{t+\Delta t}\{F\}^{(i-1)} \quad (3)$$

$${}^{t+\Delta t}\{U\}^{(i)} = {}^{t+\Delta t}\{U\}^{(i-1)} - {}^{t+\Delta t}\{\Delta U\}^{(i)} \quad (4)$$

$${}^{t+\Delta t}[K]^{(i-1)}\{\Delta U\}^{(i)} = \{\Delta R\}^{(i-1)} \quad (5)$$

$${}^{t+\Delta t}\{U\}^{(0)} = {}^t\{U\} \quad (6)$$

$${}^{t+\Delta t}\{F\}^{(0)} = {}^t\{F\} \quad (7)$$

The incremental load control method was devised to perform the nonlinear analysis. The equilibrium iteration was done for every step. The maximum number of equilibrium iterations was set at 20. The relative displacement tolerance used for equilibrium convergence and the tolerance for strain increment was between 0.9 and 0.97, respectively. To assist with the convergence in solution, the stiffness singularity elimination factor was set between 0 and 0.5, and the direct sparse solver of COSMOSWork was used.

The values of the constants of Bailey-Newton law,  $C_1$ ,  $C_2$ , and  $C_3$ , in the material creep effect module

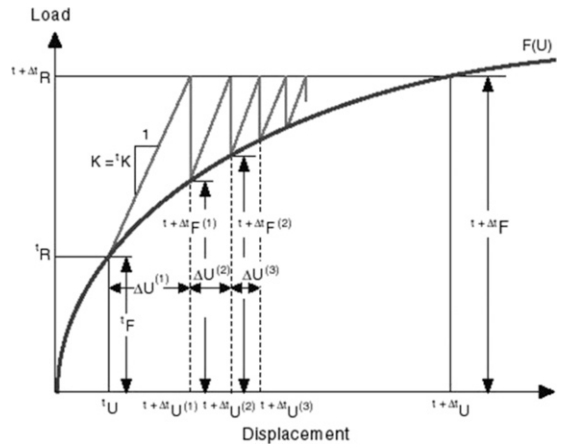


Figure 2. Illustration of modified Newton-Raphson iteration, where the tangent stiffness matrix is formed and decomposed at the beginning of each step and used throughout the iterations.

of the FE model for the HB skin component were determined when FE model predictions of creep deflection for HB fitted well with the measured creep deflection data for the HB specimen with the correlation coefficient ( $R^2$ ) between the two creep deflection values reached maximum. Using the obtained  $C_1$ ,  $C_2$ , and  $C_3$  values for HB,  $C_1$ ,  $C_2$ , and  $C_3$  for Kraft paper expanded honeycomb core were determined when the FE model predicted creep deflection values for sandwich panels consisted of the Kraft paper expanded core and HB skins correlated best with the measured data for these sandwich panels with a highest  $R^2$  value between the two sets of the creep deflection values. Similarly,  $C_1$ ,  $C_2$ , and  $C_3$  for Kraft paper corrugated honeycomb core and MDF skin components were deduced according to previous measured creep test data using the same approach (Chen et al 2011a). In the FE models, the core and skin thicknesses of the sandwich panels were 26 mm and 3 mm, respectively. Since the influence of temperature on creep was not evaluated in this study,  $C_4$  for all materials was assumed to be zero.

The stiffness data for wood composite skin and Kraft paper honeycomb core layer obtained by an earlier study (Chen et al 2011b) were used in the FE models which was shown in Tables 1 and 2.

Table 3. Creep constants for various core layers and skins obtained by the finite element simulation.

Model type*	C1	C2	C3
HB skin	$2.00 \times 10^{-16}$	1.2097	0.8247
MDF skin	$7.00 \times 10^{-12}$	0.5000	0.7000
Expanded x core layer	$2.06 \times 10^{-15}$	1.9000	0.8020
Expanded y core layer	$2.06 \times 10^{-15}$	2.0000	0.7800
Corrugated x core layer	$7.80 \times 10^{-15}$	2.0160	0.5300
Corrugated y core layer	$6.40 \times 10^{-15}$	2.0600	0.6000

\* x and y indicated the core ribbon direction was parallel with or perpendicular to the long edge of the sample.  
HB, hardboard; MDF, medium-density fiberboard.

The relative flexural deflection was used to compare the flexural creep of sandwich panels with different types of cores and skins. The relative flexural deflection was defined as:

$$\delta_{rt} = (\delta_t - \delta_e) / \delta_e \tag{8}$$

Since the loading condition in flexure is symmetric along the panel’s width, FE models were established in half symmetry for simplicity. The boundary conditions for each FE model were set according to ASTM standard C480 (ASTM 2005). The constraint condition for the restrained edge was:  $U_Y = U_Z = 0$ . The constraint condition for the restrained faces was:  $U_X = U_Y = 0$ .

RESULTS

The Flexural Creep Constants of Sandwich Core and Skin Components

Shown in Table 3,  $C_1$ ,  $C_2$ , and  $C_3$  of the FE models for flexural creep of 2.8-mm thick HB under 37 N constant flexural loading (corresponding to the loading used in the testing) were determined as  $2 \times 10^{-16}$ , 1.2097, and 0.8247, respectively, obtained by fitting the FE model to the test data as Fig 3 indicated. Using these creep constants and based on the creep test data for the corresponding sandwich panels,  $C_1$ ,  $C_2$ , and  $C_3$  for the expanded core and corrugated core in both core ribbon direction parallel and perpendicular to the samples’ span (wrt to the ribbon direction) were deduced. Using the deduced creep constants for the expanded core in core ribbon direction perpendicular to the sample’s span and the test data for the sandwich panels containing this type of core and MDF skins (Fig 3), the creep constants,  $C_1$ ,  $C_2$ , and  $C_3$ , for MDF skins were obtained. The constant flexural loading values for all sandwich panel tests and corresponding models were set as 54.25 N.

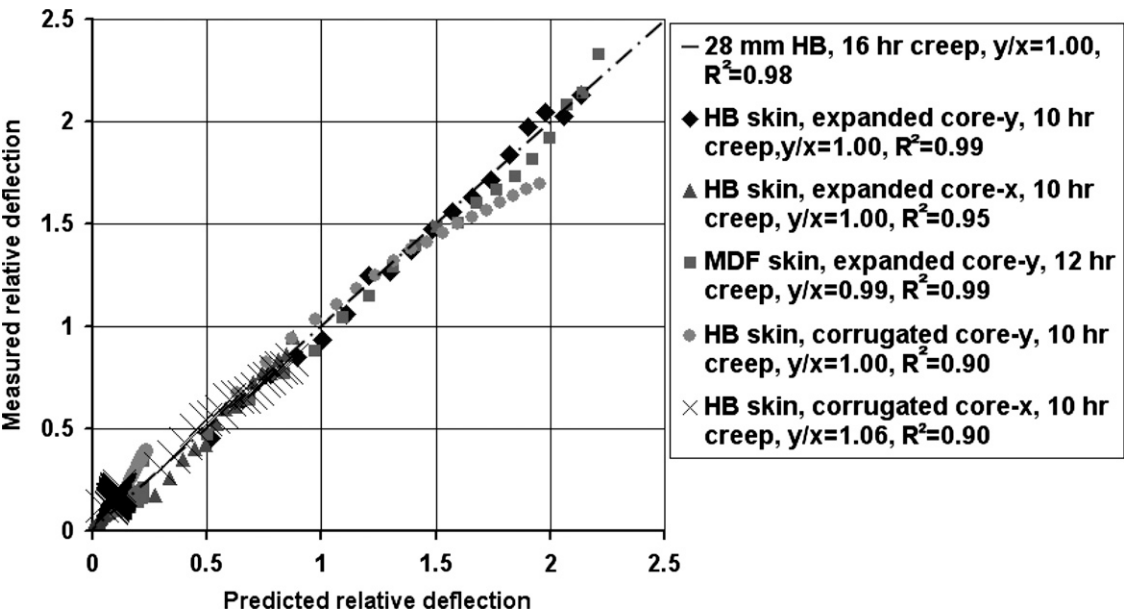


Figure 3. Comparison of the relative flexural deflection in primary creep predicted by the finite element (FE) models with the experimental data where y/x is the average creep ratio of the experimental data to prediction.



### Influence of Panel Size and Load Level

It is known that different geometric size and load level can affect creep behavior (Bodig and Jayne 1982). Here FE models for sandwich panels containing Kraft paper expanded honeycomb core and MDF skins were established with two levels of span, width, panel thickness, and load, respectively. All models' shelling ratios (thickness ratio of core to skin) were set as 8.67. Table 4 gives the predicted flexural creep rate and deflection at 5 hours within the primary creep stage of these models. It indicates that the specimens with longer span, greater width, smaller thickness, or lower load level had the smaller creep rates and deflections in the primary creep stage for the panels studied.

### Influence of Shelling Ratio, Skin Type, Core Orientation, Cell Shape, and Size

To study these parameters without the influence of panel's dimension and load level, all panels in these FE simulations were fixed at the same size of 372 mm × 75 mm × 32 mm (length × width × thickness) and loaded constantly at 54.25 N.

**Shelling ratio.** The FE predicted curves for creep deflection vs. time for sandwich panels containing MDF skins and expanded honeycomb core with different shelling ratios in the primary creep stage are plotted in Fig 4. It indicated that a higher shelling ratio reduced creep deflection. This response was opposite to what was observed when the panel was under instantaneous static load whereby the panel with a higher shelling ratio had a lower stiffness (Chen and Yan 2012).

**Cell size.** The predicted relative deflection as a function of time for panels with different core cell

Table 4. Relative deflection and creep rate at 5 h within primary stage creep.

Sample span (mm)	Sample thickness (mm)	Sample width (mm)	Load level (N)	Relative deflection	Creep rate ( $s^{-1}$ )
744	32	40	54.25	3.96	$2.20 \times 10^{-4}$
744	32	75	20.00	1.00	$5.57 \times 10^{-5}$
744	32	75	54.25	1.52	$8.44 \times 10^{-5}$
744	20	75	54.25	0.84	$4.67 \times 10^{-5}$
1488	32	75	54.25	0.56	$3.11 \times 10^{-5}$

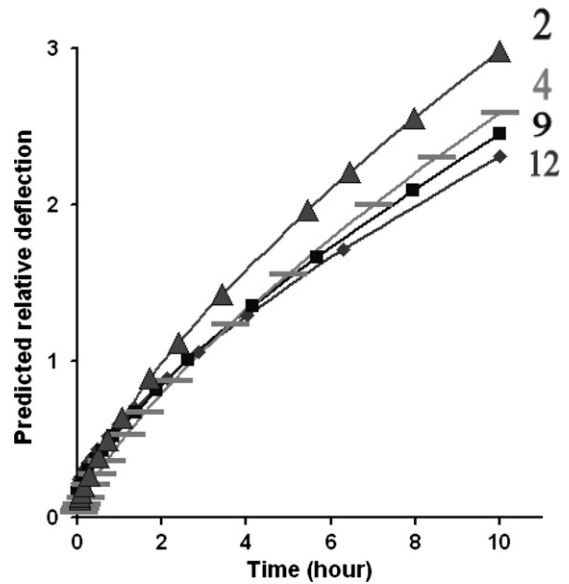


Figure 4. Finite element (FE) model predicted relative flexural deflection as a function of time for sandwich panels with shelling ratio of 2, 4, 9, and 12.

sizes is plotted in Fig 5. This is for sandwich panels that contained 3-mm thick HB skins and 26-mm thick expanded honeycomb core. The other geometric size of the panel, test span, and load level were the same as it has been mentioned before. The results showed that although

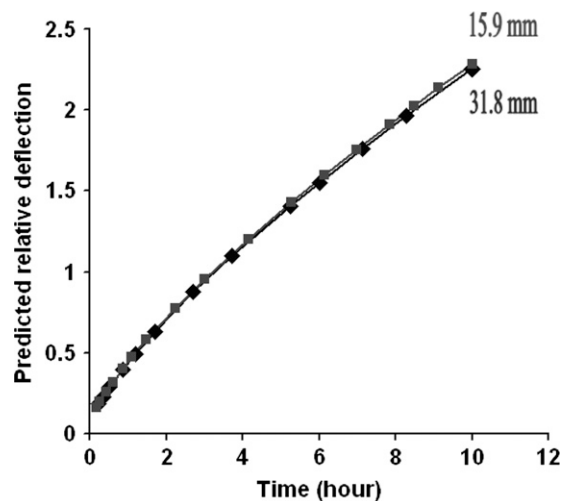


Figure 5. Finite element (FE) model predicted relative flexural deflection as a function of time for sandwich panels with 15.9- and 31.8-mm cell size core.

the web thickness of the honeycomb core with 15.9-mm size cell was 0.23 mm, which was 0.10 mm thicker than the web of the core with 31.8-mm size cell, predicted flexural creep behaviors of these two types of sandwich panels were almost the same.

#### **Honeycomb core shape and the orientation.**

Figure 6 shows the creep deflection as a function of time for panels containing 3-mm thick HB skins and different shapes of 26-mm thick honeycomb cores with core ribbon oriented (x direction) either parallel or perpendicular to the long edge of the sample. The sandwich panels containing 31.75-mm cell size expanded core showed higher flexural creep than the panels containing 19.05-mm cell size corrugated core in the corresponding core orientation. In addition, the panels with the core ribbons oriented perpendicular to their span (y direction) showed higher flexural creep in the primary stage than the panels with the core ribbons parallel to their span.

**Types of skin material.** Predicted flexural creep of sandwich panels containing MDF skins or HB skins are shown in Fig 7. Both types of sandwich panels had a 3-mm thick skin and 26-mm thick expanded honeycomb core. Panels with HB skins had slightly less flexural creep in the primary stage than those with MDF skins. Since the MOE of HB is higher than that of MDF (Table 1), the results suggested that the panels with higher stiffness skins were likely to have lower flexural creep.

#### **DISCUSSION**

It is known that the size of the sandwich panels may affect the flexural creep of the sandwich panels (Taylor 1996; Bitzer 1997). FE models can help to overcome the practical limitations of making large numbers of sandwiches with the same sizes and at the same time adjusting shelling ratio, core shapes and sizes, and skin materials.

### **Sample's span ribbon direction**

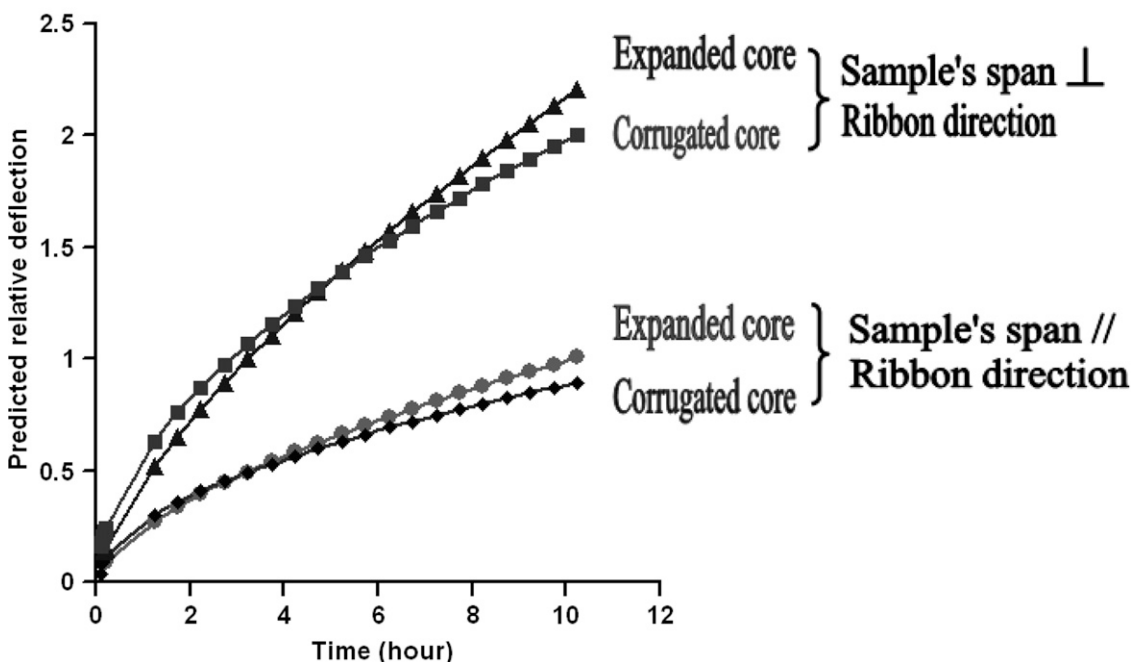


Figure 6. Finite element (FE) model predicted relative flexural deflection as a function of time for sandwich panels with different core structures.

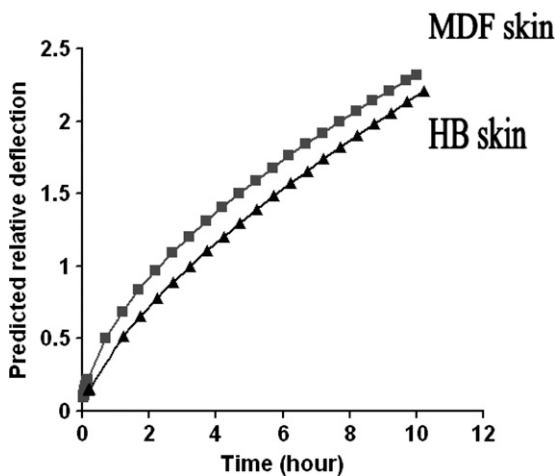


Figure 7. Finite element (FE) model predicted relative flexural deflection as a function of time for sandwich panels containing medium-density fiberboard (MDF) and hard-board (HB) skins, respectively.

Taylor (1996) reported that thicker structural insulated sandwich beams (consisting of an expanded polystyrene core [EPS] and oriented strandboard faces) had smaller flexural creep. However, Taylor did not mention if the shelling ratio of these sandwich beams was kept the same when the beams became thicker or thinner. Tabuchi et al (1997) mentioned that greater thickness of the specimen increased the creep crack rate of 1Cr-Mo-V steel specimen. According to the results from this study, both the sandwich panel thickness and the shelling ratio affected the flexural creep of the sandwich panels. In addition, Taylor reported that increasing load level from 1/3 of modulus of rupture (MOR) to 2/3 of MOR did not change the flexural creep of the EPS sandwich beams significantly. The results from this study suggested that a higher load level would result in greater flexural creep (Table 4).

Bitzer (1997) had drawn some experimental based conclusions generally. He mentioned that creep in the ribbon direction of honeycomb is less, which agreed with the predictions of the FE models in this study, which were in turn generated from empirical data. Bitzer also concluded that creep rate increases with increasing cell size. However, he did not mention whether this influence of cell size occurred in the primary creep or secondary

creep stage. Since our results showed that cell size did not affect the primary creep, perhaps it is the secondary creep that was affected by the cell size. Bitzer's conclusion on the influence of core orientation was also consistent with the findings from this study.

## CONCLUSIONS

Using the experimental results of flexural creep of HB solid panels and the sandwich panels containing Kraft honeycomb core and HB or MDF skins from an earlier study, FE models for flexural creep of these sandwich panels in the primary creep stage were developed. The FE models were used to analyze the influence of various panel parameters. The following conclusions were obtained from this study:

1. Flexural creep of sandwich panel in the primary stage was affected by panel geometric size and load level. The FE model predicted sandwich panels undergo less flexural creep if they were thinner, longer, wider, higher in shelling ratio as well as if they were under lower constant loading level. However, there was no influence of expanded honeycomb core cell size on the flexural creep behavior of the sandwich panels.
2. Flexural creep for sandwich panels containing expanded Kraft paper honeycomb core was greater than those containing corrugated honeycomb core.
3. Sandwich panels with their span parallel to their core ribbon (x direction) had lower primary flexural creep than the panels with their span perpendicular to the x direction.
4. Sandwich panels containing HB skins had slightly lower flexural creep than those containing MDF skins.

However, given the intrinsic variability in materials, applicability of these conclusions for a larger set of samples involving different materials and configurations needs to be thoroughly tested. In addition, the impact of the bonding between the skin layer and the core has to be studied further.



---

### Nomenclature

---

$\sigma$ = the total uniaxial stress at time $t$ .	${}^{t+\Delta t}\{R\}$ = vector of externally applied nodal loads
$\varepsilon^C$ = creep strain	${}^{t+\Delta t}\{F\}$ = vector of internally generated nodal force
$t$ = creep time	$\{\Delta U\}^{(i)}$ = vector of incremental nodal displacements at iteration (i)
$T$ = temperature (Kelvin)	${}^{t+\Delta t}\{U\}^{(i)}$ = vector of total displacements at iteration (i)
$C_1, C_2$ and $C_3$ = the constants of Baily-Newton law. $C_2 > 1, 0 < C_3 \leq 1$	$U_i$ = displacement in I direction
$C_4$ = a material constant defining the temperature-dependency	$\{\Delta R\}^{(i-1)}$ = the out-of-balance load vector at iteration (i)
$\delta_{rt}$ = relative deflection at time $t$	${}^{t+\Delta t}[K]^{(i-1)}$ = the tangent stiffness matrix at iteration (i)
$\delta_t$ = deflection at time $t$	${}^{t+\Delta t}\{F\}^{(i-1)}$ = vector of internally generated nodal force at iteration (i)
$\delta_e$ = deflection under instantaneous elastic load.	MOE = modulus of elasticity
$x$ = the ribbon direction of the honeycomb core, the direction of the continuous honeycomb sheets.	MOR = modulus of rupture
$y$ = the direction in which the honeycomb core is expanded (ie perpendicular direction to the ribbon direction)	RH = relative humidity
$z$ = the direction parallel to the cell openings in the honeycomb core, direction along the thickness of the sandwich panel.	

---

### ACKNOWLEDGMENTS

We acknowledge NRCan Value-to-Wood Program for the financial support of the project and Dr. Kate Semple from the University of British Columbia for her valuable contributions to sample preparations and editing of the paper.

### REFERENCES

- ASTM (2005) C480-99. Standard test methods for flexural creep of sandwich construction. American Society for Testing and Materials, West Conshohocken, PA.
- Andrews EW, Huang JS, Gibson LJ (1999) Creep behavior of a closed-cell aluminum foam. *Acta Mater* 47(10): 2927-2935.
- Bitzer T (1997) Honeycomb technology: Materials, design, manufacturing applications and testing. Chapman & Hall, London, UK.
- Bodig J, Jayne B (1982) Mechanics of wood and wood composites. Van Nostrand Reinhold Company Inc., New York, NY.
- Chen Z, Yan N (2012) Investigation of elastic moduli of Kraft paper honeycomb core sandwich panels. *Compos Part B-Eng* 43(5):2107-2114.
- Chen Z, Yan Y, Smith G, Deng J (2011a) Flexural creep of the sandwich panel with Kraft paper honeycomb core and wood composite skin. *Mater Sci Eng A* 528(16-17): 5621-5626.
- Chen Z, Yan Y, Smith G and Deng J (2011b) Parameters influence on the stiffness of Kraft honeycomb core sandwich core panel with wood composite skins. Submitted to *Journal of Sandwich Structures and Materials*.
- COSMOSWork (2008a) COSMOSWork 2008 Advanced Professional. SP2.1 (2008). SolidWorks Corporation, Concord, MA.
- COSMOSWork (2008b) COSMOSWork 2008 online user's guide. SolidWorks Corporation, Concord, MA.
- Goretta KC, Brezny R, Dam CQ, Green DJ, DeArellano-Lopez AR, Dominguez-Rodriguez A (1990) High temperature mechanical behavior of porous open-cell. *Mater Sci Eng A* 124:151-158.
- Holzer SM, Loferski JR, Dillard DA (1989) A review of creep in wood: Concepts relevant to develop long-term behavior predictions for wood structures. *Wood Fiber Sci* 21(4):376-392.

- Huang JS, Gibson LJ (1991) Creep of polymer foams. *J Mater Sci* 26:637-647.
- Krause H (1980) Creep analysis. Wiley, New York, NY.
- Lin JY, Huang JS (2005) Creep of hexagonal honeycombs with Plateau borders. *Compos Struct* 67:477-484.
- Oruganti RK, Ghosh AK (2002) Fabrication and creep studies on open cell nickel structures. Pages 211-221 *in* 3rd Global Symposium on Materials Processing and Manufacturing. Seattle, WA, February 17–21, Processing and properties of lightweight cellular metals and structures.
- Oruganti RK, Ghosh AK (2008) FEM analysis of transverse creep in honeycomb structures. *Acta Mater* 56:726-735.
- Schniewind AP (1968) Recent progress in the study of the rheology of wood. *Wood Sci Technol* 2:199-206.
- Tabuchi M, Kubo K, Yagi K (1997) Effect of specimen thickness of creep crack growth properties of 1 Cr-Mo-V steel. *Zairyo* 46(1):53-57.
- Taylor SB (1996) The flexural creep behavior of structural insulated panel (SIP) sandwich beam. PhD thesis, The Pennsylvania State University, University Park, PA.
- Taylor SB, Manbeck HB, Janowiak JJ, Hiltunen DR (1997) Modeling structural insulated panel (SIP) flexural creep deflection. *J Struct Eng* 123(12):1658-1665.
- Xiang H, Fu YM, Huang SQ (2008) Creep-buckling of general hexagonal honeycombs under biaxial compression. Pages 900-904 *in* Advances in Heterogeneous Mechanics, International Conference on Heterogeneous Material Mechanics, Huangshan, China, June 3-8.