Time-temperature effects on early-stage primary thermal creep of plywood and oriented strand board (OSB) at elevated temperatures

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Abstract. This study examined the effects of elevated temperatures on plywood and Oriented Strand Board (OSB) subjected to a constant load. Due to the short duration and the absence of a steady-state, this behavior was classified as "Early-Stage Primary Thermal Creep." Deflections at each elevated temperature, ranging from 120°C to 200°C, were analyzed to assess the thermal effects. Statistical analysis of the maximum deflections indicated the onset of thermal degradation at around 170°C for both plywood and OSB. Notably, a significant increase in deflection was observed between 180°C and 190°C for OSB, suggesting adhesive thermal decay. In addition to the statistical analysis, a numerical model was fitted to the experimental data to create temperature-dependent deflection curves, revealing an exponential trend. To understand the combined effects of temperature and time on early-stage primary thermal creep, two models were evaluated: a modified rational function model and a modified power model. The temperature-dependent power-exponential creep model provided a superior fit for both plywood and OSB, as indicated by higher R^2 values and lower root mean square errors.

Keywords: Wood sheathing, Primary creep, Elevated temperatures, Power Law Model, Thermal degradation

Introduction

According to the U.S. Fire Administration (2021), an estimated average of 230,500 fires occur annually in one-family and two-family residential buildings. Ensuring structural stability during a fire is critical to allow occupants sufficient time for safe egress. Therefore, building materials must be able to withstand not only the direct impact of fire but also the elevated temperatures associated with such events. Fires within a house typically progress through several stages before fully engulfing a structure. Once fully developed, temperatures within a room can reach up to 1200°C (Kerber 2012). In order to prevent flame spreading to flammable building materials, such as sheathing materials like plywood and OSB, fire-resistant materials, such as drywall and gypsum board, as well as insulation, are often installed over or around these vulnerable components.

When exposed to extreme temperatures, such as in the case of a fully developed fire, even if shielded from direct flames, sheathing materials like plywood and OSB can be affected by elevated temperatures. Understanding how these materials behave under such conditions is critical, as these sheathing materials are designed to provide structural support by distributing loads from floors and joists to the foundation. For example, in wall systems, the sheathing covers framing members and transfers loads to the wall studs, playing a key role in maintaining the overall stability of the structure (APA 2020).

The thermal degradation of wood products has been extensively studied due to wood's inherent flammability. Two key factors influencing this degradation are temperature severity and exposure duration. Research indicates that the breakdown of wood compounds begins at temperatures between 80°C and

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150°C (Sebio-Puñal et al. 2012; Paál et al. 2023). Additionally, prolonged exposure to lower temperatures (65°C to 70°C) can lead to significant deterioration of wood properties over 1 to 3 years in both untreated and fire-retardant-treated lumber and clear wood (Green et al. 2003; Lebow and Winandy 1999). Studies on plywood at lower elevated temperatures reveal similar degradation patterns, with both untreated and fire-retardant-treated specimens showing mechanical property loss when exposed to temperatures between 54°C and 77°C over 140 days (Winandy et al. 1991).

For solid sawn lumber, both temperature and exposure time have been widely investigated and are accounted for in building codes and guidelines. For example, the National Design Specification (NDS) includes a temperature effect factor, Ct, for temperatures between 38°C and 67°C. This factor helps engineers determine potential strength losses in lumber when designing structures exposed to elevated temperatures. However, there is a lack of comprehensive studies on the combined effects of temperature severity and exposure time on plywood and OSB, particularly when these materials are subjected to constant loads, as they would be in real-world structural applications.

Research on the long-term effects of constant loading falls under the category of thermal creep studies, which focus on how materials deform over time under constant stress. Studies examining the effects of temperature exposure typically analyze the loss of strength in materials after being subjected to various temperature conditions. However, the intersection of these two areas, prolonged loading (creep) and temperature-induced strength degradation, has been relatively unexplored for plywood and OSB. While some research has examined these effects on wood-plastic composites, comprehensive studies specifically addressing plywood and OSB under these conditions remain limited (Wei and Zhao 2023; Chang et al. 2014).

The strength of wood and wood-based composites decreases as temperature increases, a behavior well-documented in numerous studies examining both the fire performance of wood and its properties at elevated temperatures without direct flame exposure (Sinha et al. 2011; Sinha 2013, 2009; Rammer et al. 2018; Kuronen et al. 2021). Wood products used in structural applications require a fire rating, indicating the duration a product can withstand fire before reaching a set failure criterion (American Wood Council 2021). Research on plywood and OSB at elevated temperatures typically examine both the immediate and residual effects on strength (Miyamoto et al. 2024). These studies often assess strength properties, such as flexural performance, comparing the modulus of elasticity (MOE) and modulus of rupture (MOR). Findings suggest that elevated temperatures have a more significant impact on MOR than on MOE (Sinha et al. 2011; Zhong et al 2015).

Creep behavior, which is critical to understanding long-term material performance, occurs when a material is subjected to a constant load over time. This process can be broken down into three distinct phases: primary, secondary, and tertiary (Granello and Palemo 2019). The primary creep phase occurs immediately after load application, characterized by a relatively high rate of deformation that gradually decreases as the material adapts to the applied stress (Madsen 1992). The secondary creep phase follows, marked by a steady, low creep rate that forms a plateau and represents an equilibrium state. Finally, the tertiary creep phase begins when the material's structural integrity starts to deteriorate under sustained loading, leading to a rapid acceleration of deformation and eventual failure (Granello and Palemo 2019). Accurately modeling these phases, especially with temperature effects, is essential for predicting the long-term safety and performance of plywood and OSB in structural applications.

In this study, the authors investigate the effects of time and temperature on the creep behavior of plywood and OSB under a constant load to better understand their mechanical response to thermal stress. Due to the short loading duration, the full creep behavior could not be observed, and it is likely that the materials did not reach the complete primary creep phase. Therefore, the observed behavior is referred to as " Early-Stage Primary Thermal Creep." This term describes the stage where the material is subjected to a load sufficient to begin primary creep, but unloading occurs while the initial creep rate remains high, without reaching a steady-state plateau.

To simulate the behavior of these materials in a protected system during a fire scenario, they were exposed to elevated temperatures ranging from 120°C to 200°C. The objectives of this study were to:

- Compare the maximum Early-Stage Primary Thermal Creep deflections of plywood and OSB after 50 minutes of exposure to elevated temperatures,
- Analyze and compare the Early-Stage Primary Thermal Creep behavior of plywood and OSB as a function of time and temperature,
- Compare two common creep models used for wood products to predict the effects of time and temperature on these materials.

Materials

Two wood composites, oriented strand board (OSB) and plywood, were selected for testing under elevated temperatures in an environmental chamber. Both OSB and plywood are among the most commonly used sheathing materials in the United States, and the selected thicknesses represent typical sheathing dimensions (International Code Council 2018). Samples were prepared from 11.1 mm-thick Aspen OSB structural sheathing classified as Exposure 1 and 12.7 mm-thick Douglas-fir CDX plywood structural sheathing. A total of 56 specimens were prepared for each composite type, with each specimen measuring 50.8 mm in width and 508 mm in length. Prior to testing, the specimens were conditioned to approximately 10% to 12% moisture content (MC) in a controlled environment at 65% relative humidity (RH) and 20°C for four weeks.

Methods

Testing procedure

Specimens were tested at 10 different temperatures, with 25°C serving as the control and the remaining temperatures ranging from 120°C to 200°C in 10°C increments. Both plywood and OSB specimens were randomly selected for testing to ensure unbiased sampling. Additionally, six specimens of each material underwent three-point bending tests to determine the peak deflection at failure and the proportional limit. The peak deflection at failure provided a baseline for comparing creep deflections, and the proportional limit was used to define the constant load applied during testing. As shown in Figure 1, load-deflection curves for plywood and OSB illustrate the process of identifying the proportional limit. Fifty percent of the proportional limit was selected to establish the constant load applied to the specimens.

Prior to testing, the specimens were pre-heated in an oven. Two specimens were placed in the oven, one as the test specimen and the other as the thermocouple specimen. The thermocouple specimen was equipped with two thermocouples, one positioned at the center and another near the surface, to monitor the temperature, as shown in Figure 2C. Once the test specimens reached the target temperature, they were removed from the oven for testing.

Testing was conducted using a BEMCO environmental chamber integrated within an INSTRON 5589 testing frame, as shown in Figure 2A. The chamber featured openings for both the testing base (bottom) and load head (top). The test supports had a 457 mm span for the specimen and a secondary support for the thermocouple, as illustrated in Figure 2B. A 5 kN load cell was connected to a loading extension arm, allowing it to extend into the chamber without damaging any electrical components due to temperature. A high-temperature Linear Variable Differential Transformer (LVDT) was used to record the center deflection. The specimen was loaded in a 3-point bending configuration as shown in Figure 2B.

The testing procedure was comprised of three phases: loading, holding, and unloading. The entire loading protocol, including all phases, is illustrated in Figure 3, with red lines marking

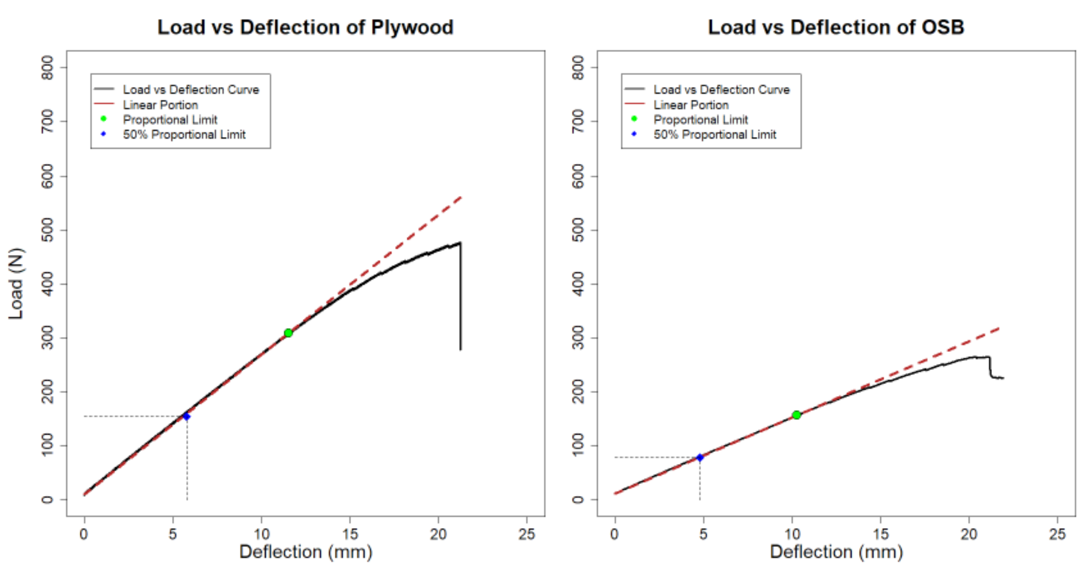

Figure 1. Load Deflection curves of OSB and Plywood Bending tests to determine the applied constant load.

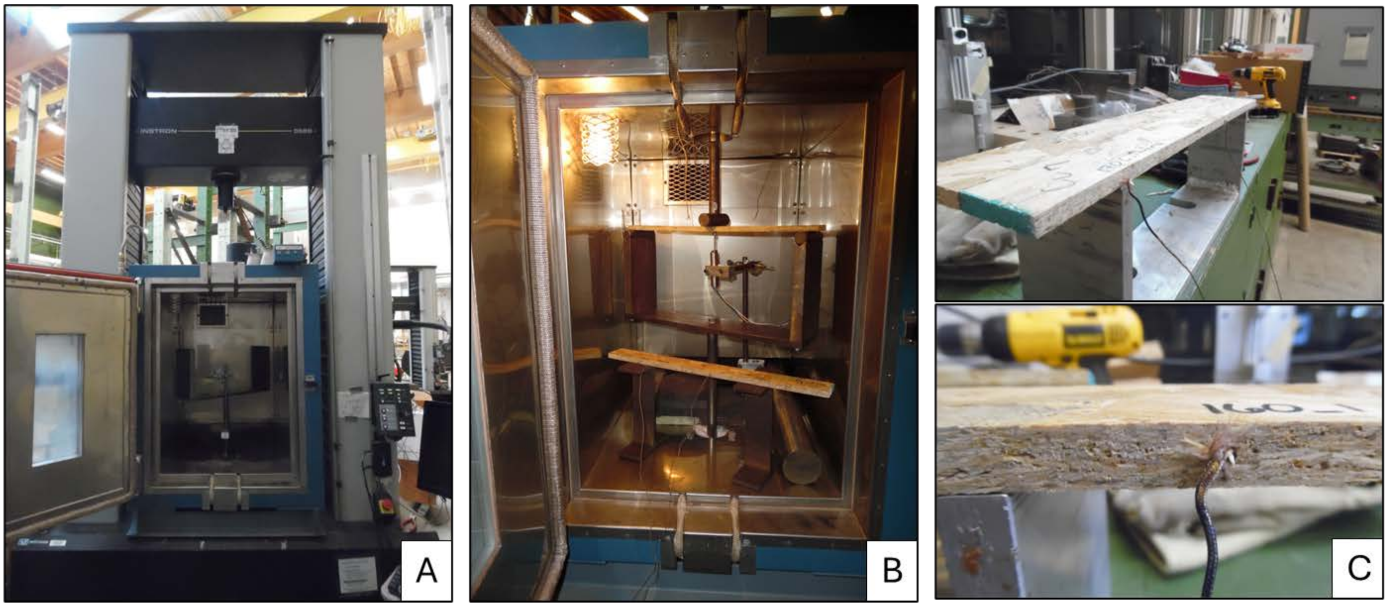

Figure 2. (A) BEMCO chamber installed within Instron 5589 Testing Frame, (B) Test setup with both testing and thermal couple specimens installed, and (C) Top: Thermal couple specimen with both thermocouples installed, Bottom: close up of installed thermocouple.

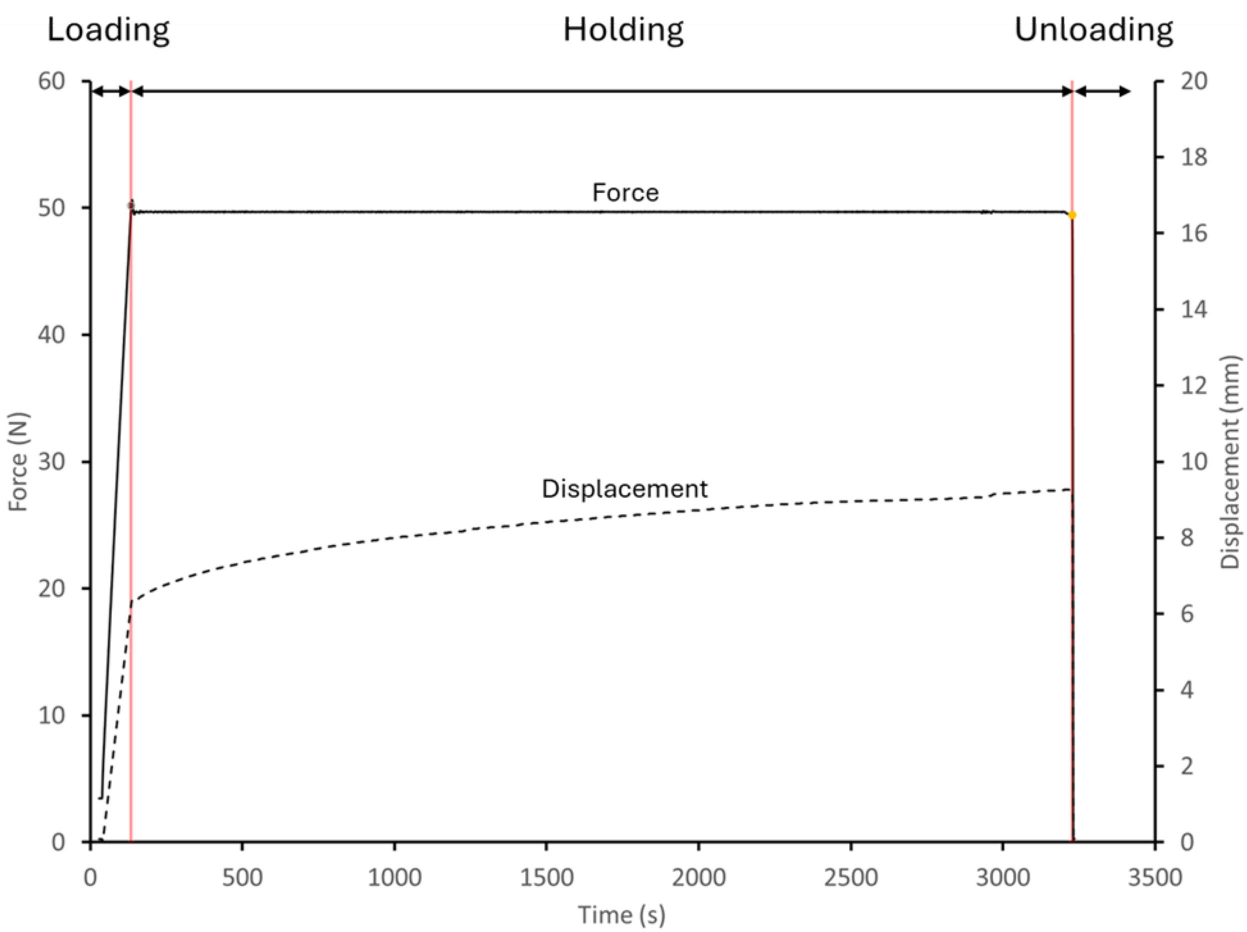

Figure 3. Testing procedure depicting applied force, and recoded displacement.

each phase. During the loading phase, the load head applied force at a rate of 6 mm/min to the center of the specimen until the target loads of 50 N for OSB and 160 N for plywood were reached, as shown in Figure 1. The time required to reach the target force ranged from 40 to 80 seconds for both plywood and OSB.

Following the initial loading, the specimen entered the holding phase, during which the load was maintained for 3,000 seconds. This duration was based on findings from a study by Kerber (2012), which investigated structural collapse times and firefighter response during house fires. The study reported that protected floor systems (e.g., gypsum board, plaster, or lath) experienced collapse times ranging from 26 to 79 minutes, while unprotected floor systems could fail as early as 18 minutes. A duration of 50 minutes was chosen for this experiment as a midpoint within the range of protected system collapse times.

After the holding phase, the specimens were unloaded and removed, along with the thermocouple specimen. To ensure the analysis focused on the creep behavior for both material, specimens that had failed before completing the holding phase were excluded from the data. By analyzing only specimens that sustained the entire loading protocol, the study provides a more accurate representation of the early stage primary creep. During testing, force (N), displacement (mm), time (s), and temperature (°C) were recorded at a frequency of 1 Hz.

To isolate material behavior during the holding phase, the initial deflection at the prescribed load for both materials was recorded and subtracted from the total deflection data for each specimen. The resulting value, referred to as creep deflection, is calculated using the formula in Equation 1.

$$D_{cr} = D_t - D_i \tag{1}$$

Where, D_{cr} is the creep deflection, D_t is the deflection at a given time, and D_i is the initial deflection after loading. Additionally, the time was adjusted to represent the starting point at the zero-deflection mark.

Statistical analysis

A statistical analysis was conducted to evaluate differences in maximum creep deflections across the tested temperatures for both plywood and OSB. The Fligner test ($\alpha = 0.05$) and the Shapiro-Wilk test ($\alpha = 0.05$) were used to assess the assumptions of equal variance and normality, respectively. A violation of the normality assumption was indicated by the Shapiro-Wilk test (p-value < 0.05), necessitating the use of the non-parametric Kruskal-Wallis test ($\alpha = 0.05$), which is more suitable for non-normally distributed data. When significant differences between temperatures were found, a post-hoc Kruskal multiple comparison test ($\alpha = 0.05$) was used to identify specific differences between individual temperatures.

Modeling

Three models were constructed to investigate the effects of temperature and time on the creep deflection properties of plywood and OSB. The first model utilized an analytical exponential approach, focusing only on the temperature effect on the two wood composites. This model followed a modified exponential equation that incorporated temperature (T) as the independent variable. The temperature-dependent deflection curve, following an exponential trend, was fitted using an equation derived from the study by Chang et al. (2023), which examined the creep behavior of wood-plastic composites at elevated temperatures. The equation is expressed as:

$$D_{cr}(T) = a * \exp\left({}^{T}\!/_{m}\right) + b \tag{2}$$

where T is the temperature in Celsius, and (a), (b), and (m) are parameters determined by fitting the model. The parameter (a) within the equation represented the scaling factor for deflection sensitivity to temperature, while parameter (m) represented the temperature scaling factor. Parameter (b) accounted for the baseline deflection, corresponding to the initial deflection observed at lower temperatures, including the control specimens.

The other two models, a rational function and a power model, were constructed to investigate the combined effects of temperature and time on the material's primary creep behavior. The rational function model, one of the earliest and simplest models, used to characterize polymers and food properties, was originally proposed by Peleg (1979) and later refined by Smulski (1987). This function is expressed as:

$$D_{cr} = \frac{t}{c + dt} \tag{3}$$

where Dcr represents the creep deflection, (t) is time in seconds, and (c) and (d) are constants. Smulski (1987) further rearranged the equation to enable linear regression by plotting t/Dcr against (t), facilitating the estimation of the constants (c) and (d) using the slope intercept form. The linearized equation is:

$$\frac{t}{D_{cr}} = c + dt \tag{4}$$

To incorporate the effect of temperature, linear relationships between the parameters (c) and (d) with temperature were introduced. These linear regressions were incorporated into the model, resulting in the function expressed as:

$$D_{cr}(t,T) = \frac{t}{(eT+f)+(gT+j)t} = \frac{1}{gT+j+\frac{eT+f}{t}} \tag{5}$$

In this equation, (c) was replaced with (eT+f) and (d) with (gT+j), reflecting the temperature dependency of these parameters. Where t is time in seconds, T is temperature in Celsius, and (e) and (g) are coefficients while *(f)* and *(j)* are constants. Both *(e)* and *(g)* are negative coefficients, with *(e)* representing the rate of change in the initial stiffness at a given temperature, and *(g)* indicating the creep rate at that temperature. The constant *(f)* characterizes the baseline creep resistance at 0°C, representing the resistance to creep when temperature effects are minimal, while *(j)* reflects the initial creep rate at 0°C, providing a baseline rate for the model.

The third model developed was the power law model or power model. This model is widely used to describe viscoelastic behavior in materials subjected to moderate loads. Both Chang et al. (2023) and Hoyle et al. (1985) used this model to determine the creed properties of wood products along with Clouser (1959), Moosavi (2016), and Hsieh and Chang (2018). The Power model is a simple model and has an exponential form, with the model shown below in equation 6:

$$D_{cr} = k * t^n \tag{6}$$

Where *(k)* is a coefficient of time-dependent displacement, (*t)* is time in seconds, and *(n)* is the exponential material constant. To incorporate the effect of temperature, the exponential function from the first model was integrated, resulting in the following combined equation:

$$D_{cr} = d * t^n * \exp\left(\frac{T}{m}\right) + j \tag{7}$$

All models were fitted to the experimental data using the Levenberg-Marquardt nonlinear algorithm in R (RStudio Team, 2023).

Results and discussion

Early-stage primary thermal creep deflection analysis

For all 100 specimens, the maximum deflections for plywood and OSB were 6.09 mm and 8.15 mm, respectively, both observed at 200°C. The average maximum creep deflection results are presented in Table 1.

Plywood exhibited lower deflections compared to the OSB tested specimens but demonstrated greater variability and a higher number of failures. For both materials, higher temperatures resulted in increased creep deflections over time. Failures in plywood occurred at three specific temperatures: 130°C, 180°C, and 200°C. At 130°C, a failure was observed after 1,300 seconds of loading, while at 180°C, failure occurred after 1,200 seconds. The two failures at 200°C happened within 1,000 seconds. Upon inspection, the specimen that failed at 130°C had an open knot near its center, whereas the others contained only minor, non-substantial defects. In contrast, OSB specimens exhibited higher deflections than plywood but showed lower variability and experienced only one failure. This failure occurred after maintaining a constant load for 1,900 seconds at 200°C. To illustrate the differences in creep deflections, the average deflection curves for each temperature were calculated and are presented in Figure 4.

A comparison of the average deflection curves for plywood and OSB reveals distinct differences in their creep behavior at each tested temperature. Plywood showed a gradual increase in creep deflection across the tested temperature range. However, OSB displayed a significant increase in creep deflection between 180°C and 190°C, where the maximum average deflection rose from 3.69 mm to 6.37 mm, nearly doubling. This pronounced increase in OSB's deflection can be attributed to differences in adhesives and wood species.

Plywood uses phenol-formaldehyde (PF) adhesive to bond the veneers, which begins to degrade around 250°C (Alonso et al. 2011, Huang et al. 2024). In contrast, OSB typically uses polymeric methylene diphenyl diisocyanate (PMDI) adhesive, which can start to degrade at approximately 185°C and above at prolonged exposure (Desai and O'Dell 1989; Yang et al. 1985). The degradation of the PMDI adhesive at these temperatures, combined with time-dependent creep behavior, likely explains the sharp deflection increase in OSB at elevated temperatures.

The results from the Kruskal multiple comparisons test are presented in Figure 5, with the fitted exponential equation (2) overlaid on the boxplots. In these boxplots, the letters above each box represent statistically significant differences between temperatures as determined by the Kruskal multiple comparisons test. Boxes labeled with the same letter(s) do not differ significantly. The red dashed line in each plot represents the fitted exponential equation, with its specific parameters incorporated and the R^2 values displayed at the top left corner of each plot.

For both plywood and OSB, the results indicate that temperatures above 170°C become significantly different from

Table 1. Table 1. Average maximum creep deflections for plywood and OSB.

Temp. (°C)	Plywood (mm)				OSB (mm)			
	Average	StaDev	COV (%)	N (#)	Average	StaDev	COV (%)	N (#)
*20	0.47	0.22	47%	5	0.45	0.15	34%	5
120	1.90	0.60	32%	5	1.28	0.50	39%	5
130	1.32	0.41	31%	4	1.71	0.82	48%	5
140	1.72	1.04	61%	5	1.59	0.53	33%	5
150	2.13	0.72	34%	5	1.79	0.63	35%	5
160	1.86	0.68	36%	5	1.90	0.89	47%	5
170	2.91	0.75	26%	5	2.98	0.66	22%	5
180	2.83	0.44	16%	4	3.69	0.90	24%	5
190	3.68	1.17	32%	5	6.37	1.30	20%	5
200	4.76	1.35	28%	3	7.57	0.49	6%	4
**Control	20.07	4.81	24%	6	21.49	3.75	17%	6

* Testing temperature was at room temperature, but categorized for plotting as 20.

** Specimens used for calculating the constant load, and used as a baseline for maximum deflection at peak load.

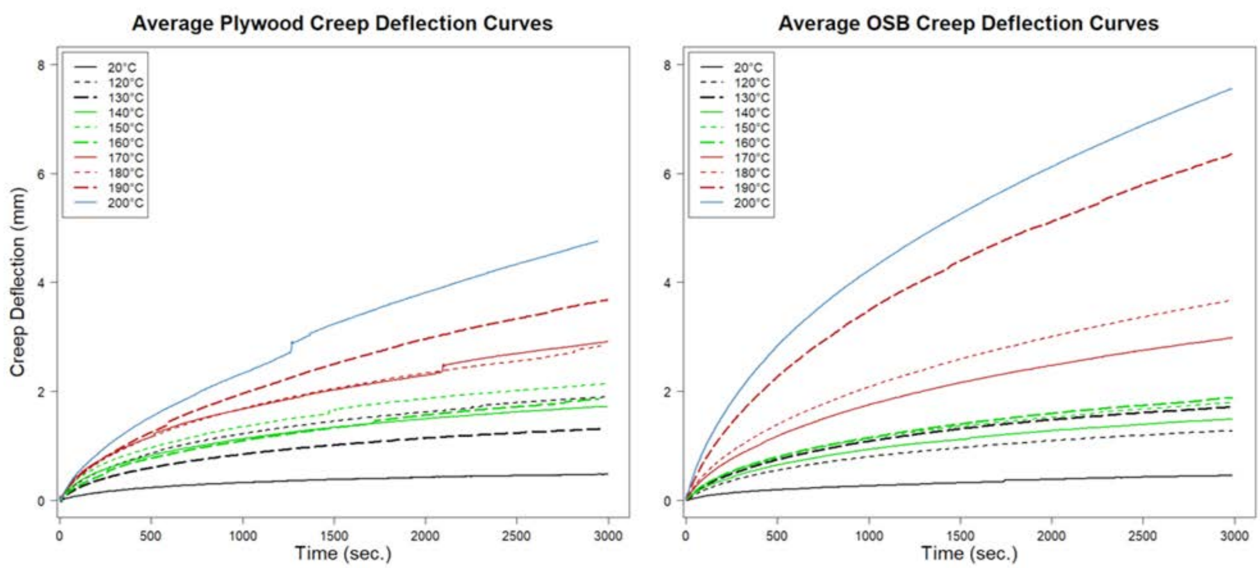

Figure 4. Average creep deflection curves for plywood and OSB at each temperature.

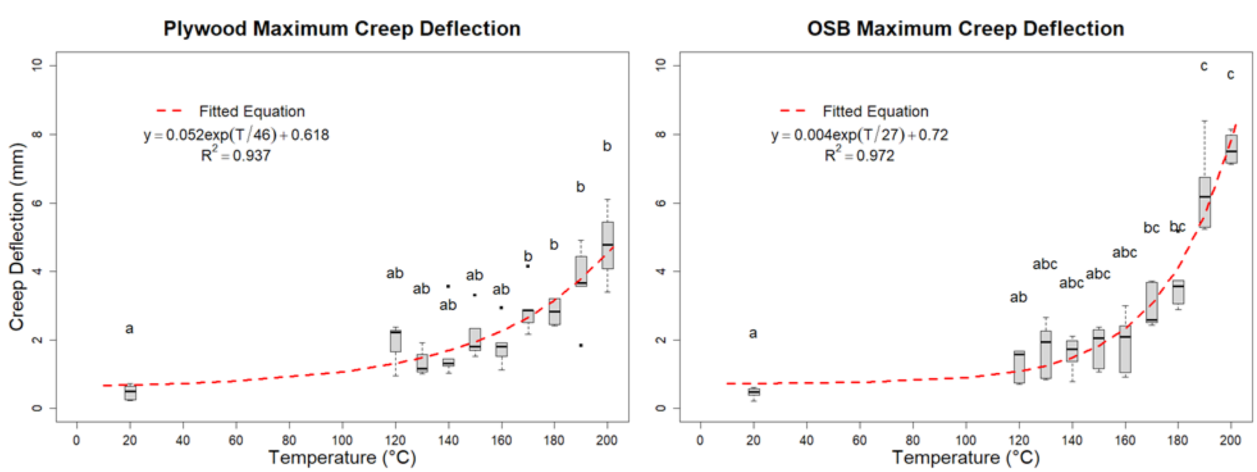

Figure 5. Boxplots for plywood (left) and OSB (right) of the creep defection indicating the results of the Kruskal multiple comparisons tests and a dashed line of the fitted equation 2.

the room temperature deflections. This aligns with findings by Miyamoto et al. (2024), who observed similar behavior in plywood, noting that temperatures around 170°C trigger chemical changes in wood. Around 150°C, wood extractives begin to decompose, and in dry conditions, lignin transitions from a hard, glassy state to a softer, rubbery state (Fengel and Wegnener 1989). As temperatures increase to approximately 180°C to 220°C, hemicellulose, the most thermally sensitive component of wood, begins to degrade (Dietenberger and Hasburgh 2016).

Because OSB is manufactured from Aspen, a hardwood with higher hemicellulose content than Douglas-fir, it shows greater deflection at elevated temperatures. The earlier degradation of the PMDI adhesive used in OSB further amplifies this deflection. Together, the combined effects of hemicellulose content and adhesive degradation explain the more pronounced creep behavior of OSB compared to plywood at high temperatures.

The exponential model provided a strong fit for both plywood and OSB data, with R^2 values of 0.937 and 0.972, respectively. These high R^2 values indicate that the exponential trend effectively captures the temperature-dependent creep behavior of both materials, demonstrating that the model used by Chang et al. (2023) is effective at predicting the initial primary thermal creep at elevated temperatures.

Effects of time and temperature on early-stage primary thermal creep

To understand and predict the early-stage primary thermal creep behavior of plywood and OSB at elevated temperatures, the rational function and power models were fitted to the data, represented by equations 3 and 6, respectively.

Temperature-dependent rational creep model

The rational function from equation 3 was rearranged to plot t/Dcr against (t) for each temperature, enabling a simple linear regression to fit the data into equation 4 and calculate the constants (c) and (d). An example of this process for plywood and OSB at 170°C is shown in Figure 6, with the calculated constants listed in Table 2.

A linear relationship between temperature and the constants (c) and (d) was identified from the values in Table 2. Simple linear regression was used to predict the values of (c) and (d) at each temperature, excluding 20°C, as it did not accurately represent the behavior of the material, as seen in Figure 7. The regression data for OSB showed stronger correlations, with R^2 values of 0.92 and 0.93, compared to plywood. The (c) constant for plywood exhibited a weaker correlation, indicated by an R^2 value of 0.48. These regression equations were incorporated into secondary regression formulas, resulting in the development of a second-order function (Equation 5).

Table 2. The calculated constant a and b for plywood and OSB.

Temperature (°C)	Plywood		OSB	
	*c	**d	*c	**d
20	1332.40	1.70	1845.00	1.69
120	378.96	0.42	604.81	0.61
130	534.72	0.60	435.46	0.45
140	380.08	0.47	510.24	0.52
150	335.01	0.37	412.50	0.44
160	465.64	0.40	415.47	0.41
170	294.09	0.26	293.56	0.25
180	297.67	0.27	258.58	0.20
190	305.91	0.18	164.63	0.11
200	266.13	0.13	129.25	0.10

* Initial creep resistance.
** Creep rate.

The function (Equation 5) was developed by incorporating the regression equations for (c) and (d) into the model. As shown in Figure 7, the regression equations for (c) are plotted in panels (I) and (II) for OSB and plywood, respectively, while the regression equations for (d) are presented in panels (III) and (IV) for the corresponding materials. These regression formulas were integrated into the model to form Equation 5, a temperature-dependent rational creep model. The combined effects of temperature and time on creep deflection are visualized in Figure 8 for both OSB and plywood. The fitted parameters, root mean square errors, and R^2 values are summarized in Table 3.

The temperature-dependent rational creep model was evaluated using statistical analysis of the Root Mean Square Error (RMSE) and R^2 values. The results indicated that the model demonstrated strong predictive potential for OSB, with an R^2 of 0.957, suggesting a high correlation between the model and the observed data. The relatively low RMSE of 0.347 for OSB indicates only a small deviation between the predicted and actual values. In contrast, the model's fit for plywood was less accurate, with an R^2 of 0.729, showing a moderate correlation. The RMSE for plywood was 0.501, indicating a higher level of prediction error. These results suggest that the temperature-dependent rational creep model is more suitable for predicting the behavior of OSB than plywood.

Temperature-dependent power-exponential creep model

The final model constructed was the power model (Equation 6), which was combined with the exponential function (Equation

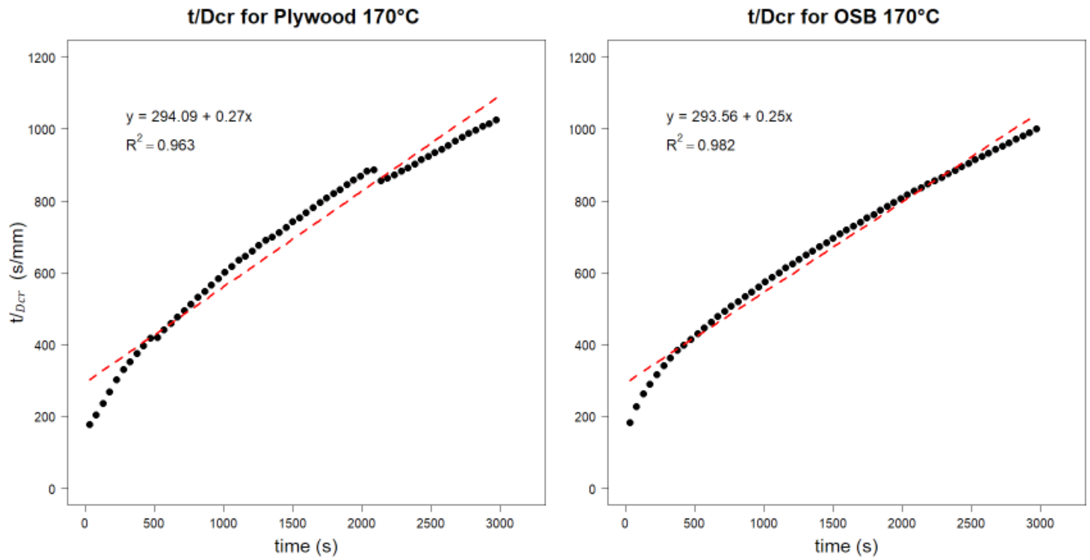

Figure 6. Example of the linear regression fit for the (time/deflection) vs time to obtain (c) and (d).

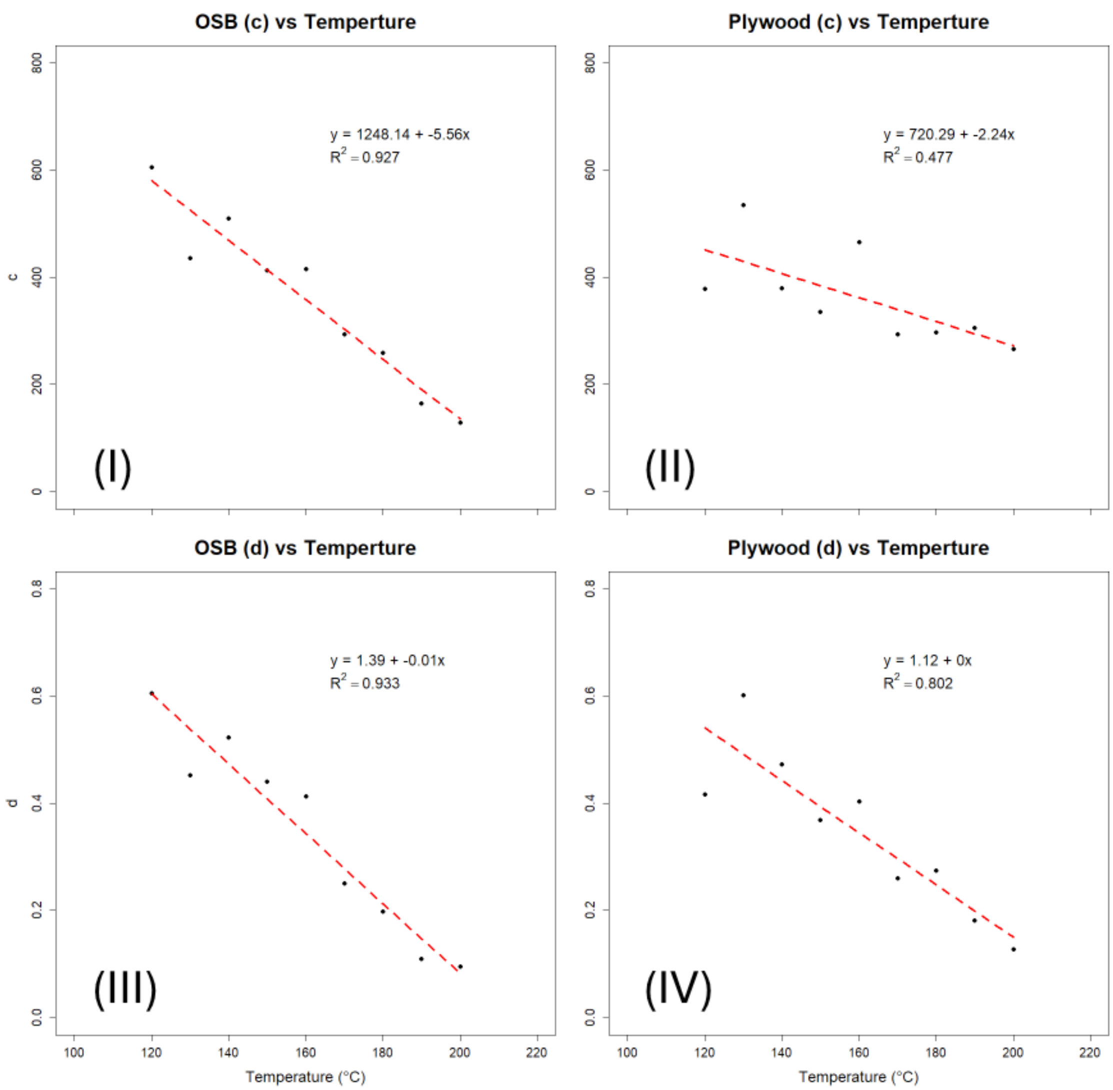

Figure 7. Calculate constants a and b plotted against temperature with a simple linear regression performed.

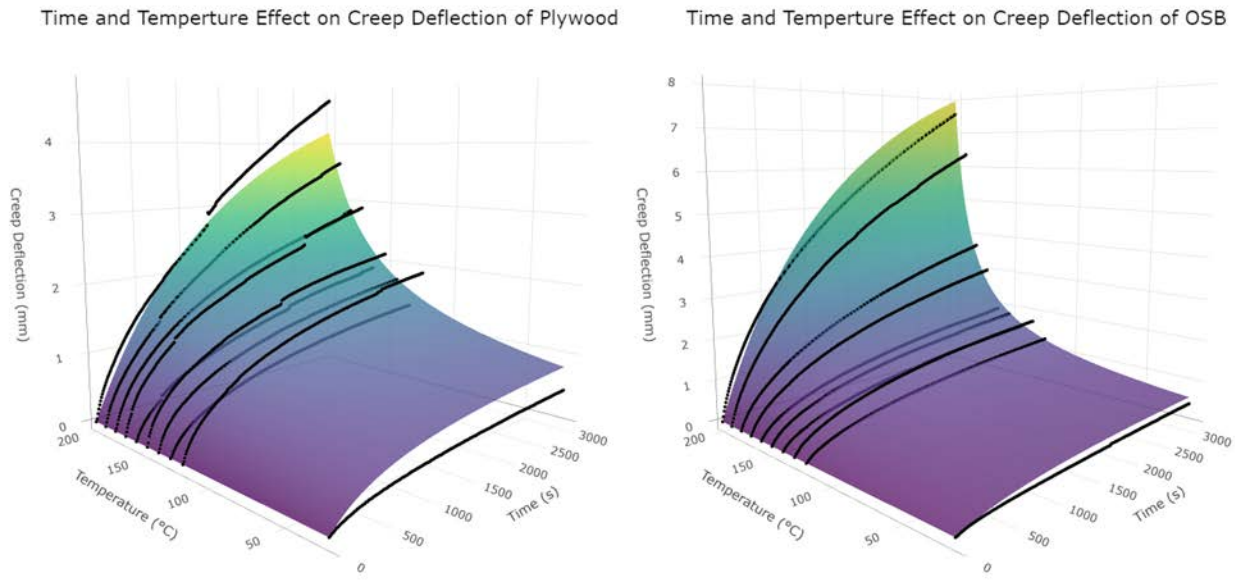

Figure 8. The fitted the temperature-dependent rational creep model from equation 5 for plywood and OSB.

Table 3. Parameters for the temperature-dependent rational creep model.

Material	Parameters				R^2	RMSE
	*e	**f	***g	****j		
Plywood	-2.24	720.29	-0.005	1.12	0.729	0.501
OSB	-5.56	1248.14	-0.010	1.39	0.957	0.347

* Rate of change of the initial stiffness at a given temperature.
** Creep rate at a given temperature.
*** Baseline creep resistance at 0°C.
**** Initial creep rate at 0°C.

Table 4. The calculated parameters (k and n) for each temperature for plywood and OSB.

Temp. (°C)	Plywood			OSB		
	*k	**n	R^2	*k	**n	R^2
20	0.016	0.427	0.986	0.008	0.508	0.997
120	0.051	0.457	0.993	0.028	0.482	0.993
130	0.036	0.453	0.993	0.040	0.474	0.993
140	0.057	0.430	0.995	0.033	0.478	0.994
150	0.057	0.456	0.996	0.043	0.470	0.994
160	0.032	0.510	0.997	0.039	0.486	0.996
170	0.046	0.518	0.997	0.046	0.523	0.997
180	0.054	0.496	0.996	0.047	0.546	0.998
190	0.032	0.596	0.999	0.064	0.576	0.998
200	0.028	0.647	0.998	0.091	0.554	0.999

* Coefficient of time-dependent displacement.
** Exponential material constant.

2) to capture both time and temperature effects on the creep behavior of plywood and OSB. This combination resulted in a unified equation (Equation 7) that reflects the interaction between time-dependent deflection and temperature-induced degradation, similar to the temperature-dependent rational creep model. Before constructing Equation 7, the parameters (k) and (n) of the power model were estimated by fitting Equation 6 to the data, ensuring that the model adequately captured the time-dependent deflection behavior. These parameter values are presented in Table 4 for all 10 tested temperatures, alongside the corresponding R^2 values, which indicate how well the model fits the observed data.

The high R^2 values indicated that the power model fitted the creep deflection data effectively across all temperatures for both plywood and OSB, suggesting that this model accurately captured the time-dependent creep behavior. Given the strong correlations observed in Equations 2 and 6, these equations can be combined to develop a comprehensive governing model. A similar modeling approach was employed by Chang et al. (2023) to predict the time-temperature behavior of wood-plastic composites at temperatures ranging from -45 to 45°C, with stress included in Chang 's model. The newly formulated combined equation 7 is referred to as the temperature-dependent power-exponential creep model.

The fitted data for both plywood and OSB can be seen in Figure 9. The parameters and correlation values for the temperature-dependent power-exponential creep model are provided in Table 5. Both plywood and OSB exhibited a high correlation between the model and the observed values, along with relatively low RMSE, indicating minimal deviation between

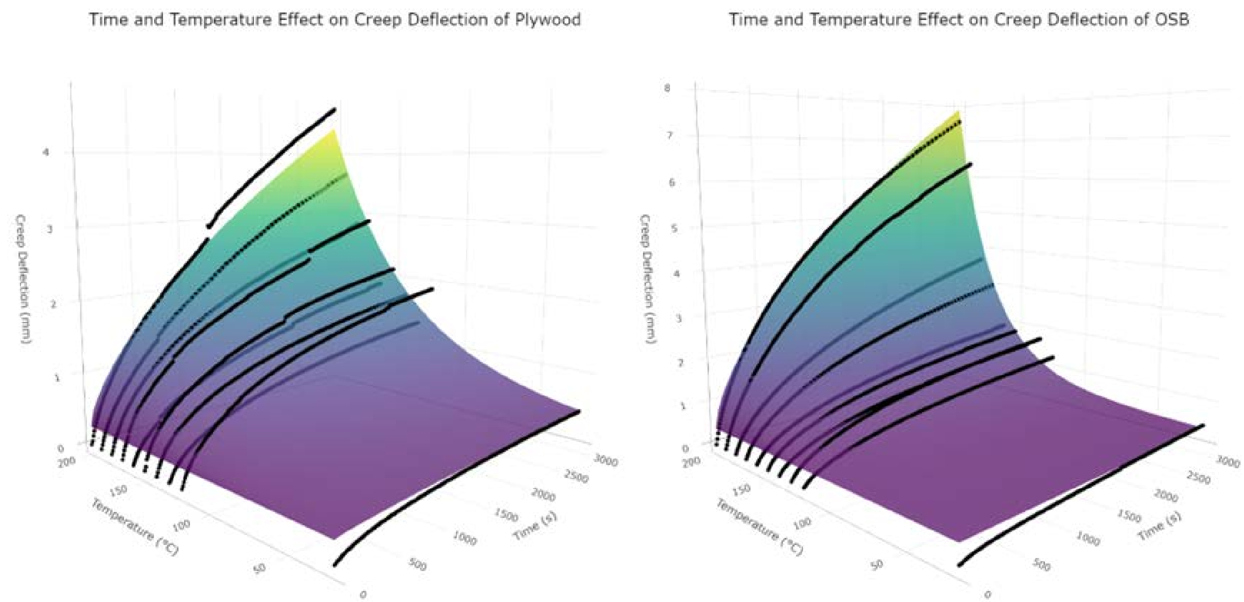

Figure 9. The fitted the temperature-dependent power-exponential creep model from equation 7 for plywood and OSB.

Table 5. Parameters for the temperature dependent power model.

Material	Parameters				R^2	RMSE
	*d	**n	***m	****j		
Plywood	0.0009	0.652	60.693	0.257	0.946	0.222
OSB	0.0003	0.635	30.232	0.380	0.972	0.281

* Coefficient of time-dependent displacement.
** Exponential material constant.
*** Temperature scaling factor .
**** Baseline deflection corresponding to the initial deflection observed at lower temperatures.

the predicted and actual values. Compared to the temperature-dependent rational creep model (5), these results suggest that the temperature-dependent power-exponential creep model (7) is best suited for describing the behavior of both plywood and OSB under constant loading at various elevated temperatures over different time durations.

Conclusion

This study investigated the early-stage primary thermal creep of two common sheathing products, plywood and OSB. Mechanical testing for flexural creep was conducted by applying a constant load at elevated temperatures ranging from 120°C to 200°C for 50 minutes. Deflections were measured continuously to generate average deflection curves for each material at each temperature. These observations revealed that OSB exhibited a substantial increase in deflection between 180°C and 190°C, potentially indicating the onset of adhesive degradation.

Analysis of the maximum deflections after 50 minutes showed that both plywood and OSB began to exhibit increased deflection around 170°C, a temperature associated with the degradation of chemical compounds in wood. An exponential function was used to model the temperature-dependent behavior, providing a good fit to the experimental data and effectively illustrating the effects of temperature on the thermal creep of plywood and OSB.

To incorporate both time and temperature effects on the creep behavior of plywood and OSB, two models were developed and compared: a time-dependent rational function integrated with temperature to create a temperature-dependent rational creep model, and a power law model combined with the exponential function to form a temperature-dependent power-exponential creep model. The temperature-dependent rational creep model worked well for OSB, with an R^2 of 0.95, but performed less effectively for plywood (R^2 of 0.75). In contrast, the temperature-dependent power-exponential creep model demonstrated the best performance for both plywood and OSB, with R^2 values of 0.94 and 0.97, respectively. The superior performance of the power model aligns with the findings of Chang et al. (2023), who validated its effectiveness for wood-plastic composites at lower temperatures.

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