Influence of Local Density on Concentrated Static Load Performance of Oriented Strandboard

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Abstract

Fourteen 1,220 by 2,440 by 11.1-mm commercial Oriented Strandboard (OSB) panels were X-ray scanned to obtain horizontal density matrices. Localized densities around the concentrated static load (CSL) testing points of the panels were calculated prior to the CSL test. A linear regression analysis was conducted to assess the impact of the localized density on CSL performance. The results indicated that both deflection and ultimate load were highly correlated with the local density. Deflection and ultimate load were somewhat correlated ($R^2 = 0.52$). The CSL deflection decreased and ultimate load increased significantly with increasing local density. The impact of local density on ultimate load was greater than on deflection. Horizontal density variation is inherent in OSB manufacturing processes, especially in the mat forming process. A number of factors, including evenness of strands in the metering bin, condition of picker rolls and dissolving rolls, and strand and fines surging, can affect horizontal density distribution. OSB panels with a high degree of variation in horizontal panel density may cause low density spots that increase the chance of failure in CSL test. It is therefore crucial to minimize the occurrence of very low density areas in order to reduce the odds of ultimate load failure. Reducing density variability allows OSB companies to increase the CSL properties of their products, which would otherwise need to be done by making the panel denser. Improving horizontal density uniformity allows for lowering of the average panel density, which reduces the manufacturing cost and helps improve the company's bottom line.

Oriented Strandboard (OSB) market is growing rapidly especially since the onset of the COVID-19 pandemic. A report released in 2021 by Reportlinker.com (Globenewswire 2021) projected the global OSB market to reach US$116.1 billion by 2027. The major markets including United States, China, Japan, and Canada were forecasted to grow at a double-digit compound annual growth rate over the analysis period of 2020 to 2027. A most recent report also by Reportlinker.com (Globenewswire 2023) states that the OSB market estimated at US$16.8 billion in the year 2020, is projected to reach a revised size of US$48.2 billion by 2027, growing at a CAGR of 16 percent.

The most common uses of OSB as a structural panel are sheathing in walls, flooring, and roof decking in residential construction. For floor and roof sheathing applications, OSB's ability to withstand concentrated static loads (CSL) is critical. Many production parameters including panel density, strand geometry, strand alignment, resin usage, fines content, and vertical density profile affect CSL properties. A number of modelling and simulation approaches have been attempted to predict the CSL performance of OSB (Thomas 1996, 2002; Chen et al. 2008a; Nadezhdin 2014, 2016). Limited experimental studies have been carried out to assess the impact of these parameters on CSL (Chen and Wellwood 2002, Bozo 2002, Chen et al. 2008a, Groves et al. 2020).

Numerous studies have indicated that density affects physical and mechanical properties of OSB. Chen et al. (2010a) carried out an extensive experimental study to systematically investigate the influence of panel density on major properties of OSB. Twenty-seven laboratory panels measuring 711 by 711 by 11.1 mm with nine target densities were manufactured and tested for internal bond strength, modulus of rupture, modulus of elasticity, water absorption, thickness swell, and rolling (interlaminar) shear strength. The results indicated that, in general, panel density positively affected the tested properties of the OSB panels. Horizontal panel density, especially the density around the

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concentrated load area, has also been identified as a key parameter affecting CSL performance of OSB (Chen and Wellwood 2002, Bozo 2002, Wellwood 2004, Chen et al. 2008a).

Horizontal density variability in OSB has previously been investigated (Kruse et al. 2000, Vun et al. 2003, Painter et al. 2006). Effect of horizontal density variation on CSL has been simulated in a modelling study (Dai and Yu 2008). The objective of this study was to nondestructively measure the localized density around the CSL load point and investigate the correlation between CSL performance and the localized density. Commercial OSB panels produced at the same time and under the same conditions were X-ray-scanned to calculate horizontal density distribution and the localized density prior to the CSL test. The resultant data enabled a regression analysis between CSL deflection and ultimate load and the localized density.

Materials and Methods

Eighteen 1,220 by 2,440 by 11.1-mm OSB panels were obtained from a commercial OSB mill using predominantly aspen (*Populus* sp.), of which 14 were used in this study. The panels were sampled from two consecutive master panels. The target panel density was 610 kg/m^3. Phenol formaldehyde resin (approximately 3.5%) was used for surface layers, and polymeric diphenylmethane diisocyanate (pMDI) resin (approximately 2.0%) was used for the core layer. Wax content was approximately 1.0 percent. The strand length was 4.5 inches (114.3 mm). All panels were scanned using a 50-inch (1,270-mm) -wide X-ray system to generate data and derive horizontal density matrixes based on the X-ray images and the weight and thickness of the panels. When deriving the horizontal density, the panel thickness was assumed to be constant, and the nominal thickness of 11.1 mm was used in the calculation. A detailed description of the X-ray determination of panel density was given by Chen et al. (2010b). Figure 1 is an example X-ray image of a 1,220 by 2,440 by 11.1-mm OSB panel.

Based on previous research experience and discussions with OSB mill operators, the horizontal density of an area of 1 by 1 foot (304.8 × 304.8 mm) around the CSL test point (hereafter to be referred to as ''local density'') was calculated to investigate its effect on CSL performance (Fig. 2). Each 1,220 by 2,440-mm panel was cut into two pieces of 1,220 by 1,220-mm testing specimens and tested for CSL deflection and ultimate load according to the ASTM E661 test method (ASTM 2009). Two points per specimen located diagonally were tested as illustrated in the diagram (Fig. 2), resulting in 56 data points for statistical analysis. A linear regression analysis was performed to assess the correlation between the CSL properties and the local density.

Results and Discussion

Table 1 is a summary of the regression and analysis of variance results. CSL deflection generally decreased and ultimate load generally increased with increasing local density. Deflection and ultimate load were somewhat correlated ($R^2 = 0.52$). A significant correlation ($P < 0.001$) between CSL deflection and local density was found with an R^2 of 0.69, implying that 69 percent of the variation in the measured deflection values could be explained by the local density. As shown in Figure 3, the regression predicted

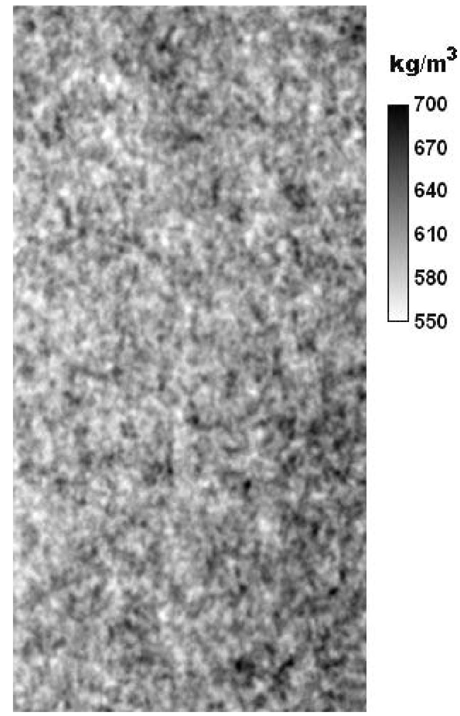

Figure 1.—An X-ray image of a 1,220 by 2,440 by 11.1-mm commercial Oriented Strandboard (OSB) panel.

deflection is equal to –0.0202 × local density + 19.648, when deflection is measured in millimeters and density in kg/m^3.

The correlation between CSL ultimate load and local density was also significant ($P < 0.001$) with an R^2 of 0.736, suggesting that about 74 percent of the variation in the measured ultimate load values could be explained by the local density. As shown in Figure 4, the predicted ultimate load is equal to 7.1531 × local density – 2,144.3, when ultimate load is measured in Newtons.

The regression coefficient of –0.02 implies that a decrease of 0.02 mm in deflection is associated with an increase in the local density by 1 kg/m^3. For ultimate load,

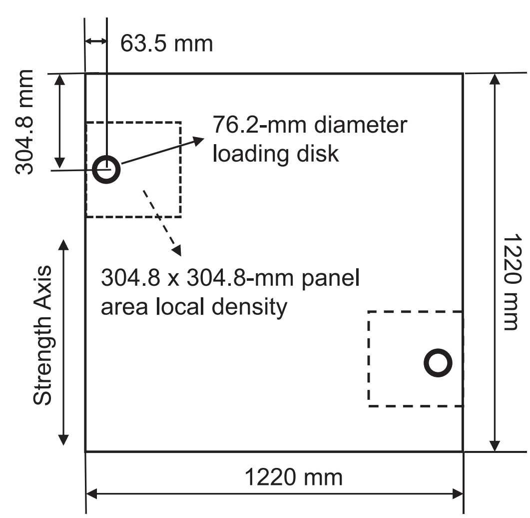

Figure 2.—Concentrated static load (CSL) testing points and the panel areas for calculation of local density.

Table 1.—Summary of regression and analysis of variance results.

Variable	R^2	Observations	Coefficient	SE of coefficient	*t* statistic	Significance (*P*)
Deflection	0.690	56	−0.0202	0.0018	−10.9748	<0.001
Ult. load	0.736	56	7.1531	0.5832	12.2661	<0.001

the regression coefficient was 7.1531, indicating that an increase of 1 kg/m^3 in local density would, on average, result in an increase of 7.1531 Newton in ultimate load. The Performance Criteria in APA PS 2-10 Performance Standard for Wood-Based Structural-Use Panels (APA 2011) specifies a maximum deflection at 0.89 kN of 12.70 mm and a minimum ultimate load of 1.78 kN for OSB sheathing with a span rating of 24 inches (609.6 mm). According to the regression equations, a 30 kg/m^3 change in the local density, which is approximately 5 percent of the target panel density of 610 kg/m^3, would result in a change of 0.61 mm in deflection and a change of 214.6 Newton in ultimate load, representing a 4.7 percent and a 12.1 percent change of the deflection and ultimate load requirements. It is obvious that the impact of local density on ultimate load is much greater than on deflection. The requirement of CSL ultimate load is generally more difficult to meet than that of deflection.

Local density variation can be very significant. For the panels used in this study, the local density varied between 524 and 722 kg/m^3, representing approximately 14 percent below and 18 percent above the target panel density. Chen et al. (2008b) reported a narrower local density range of 514 to 626 kg/m^3 for laboratory OSB panels. Horizontal density variation is inherent in OSB manufacturing processes, especially mat forming. A number of factors can affect horizontal density distribution. Large-scale density variation is often caused by uneven spread of furnish in the mat forming process. Smaller scale density variation can be a result of variability in size, shape, and other properties of the wood elements.

The structural performance criteria (NIST 2019) are based on the passing rates and average values of the testing points. The initial test set consists of 10 specimens, with 1 testing point per specimen. Let A_{10} be the average value of 10 test points, and N the number of points passing the requirement.

For deflection:

If $A_{10} \leq 12.7$ mm and $N \geq 9$, the sample passes.
If $N \leq 6$, the sample fails.
If $N = 7$ or 8, test additional 10 specimens. The combined passing points must be ≥ 17 for the sample to pass.

For ultimate load:

If $A_{10} \geq 1.78$ kN and $N = 10$, the sample passes.
If $N \leq 8$, the sample fails.
If $N = 9$, test additional 10 specimens. The combined passing points must be ≥ 19 for the sample to pass.

The requirement for the passing rates is very high; therefore, when the passing rate is met, it will almost be certain that A_{10} also meets the threshold requirement. Therefore, it is important to have a higher degree of density uniformity across the panel because a good value in deflection or ultimate load resulting from high local density could not compensate for failure in another point caused by low local density. In this study, all 56 test points met the deflection requirement. However, 6 points with low local density (<590 kg/m^3) failed the ultimate load test (Fig. 5). In addition, a few points at the lower density range were close to touching the 1,780-Newton threshold line. It is therefore crucial to minimize the occurrence of very low density areas in order to reduce the odds of ultimate load failure.

This study took a 1 by 1-foot (304.8 × 304.8-mm) panel area around the CSL testing point for the calculation of local density. The optimal size of the area may vary depending on the strand length and other production parameters. Groves et al. (2020) used a 10 by 10-inch (254 × 254-mm) area to calculate local density. Bozo (2002) found that the optimal size for deflection was different from that for ultimate load. In the authors' earlier work in a number of proprietary projects, it was found that the degree of correlation between CSL and local density varied from project to project. The R^2 value fluctuated depending on the size and shape of panel area used for the calculation of local density. However, fluctuations in R^2 were relatively small within the range of 8 by 8-inch to 12 by 12-inch (203.2 × 203.2-mm to 254 × 254-mm) local density areas, and the highest R^2 value was usually found within this range. The authors also observed that CSL deflection failure did not happen often as opposed to ultimate load.

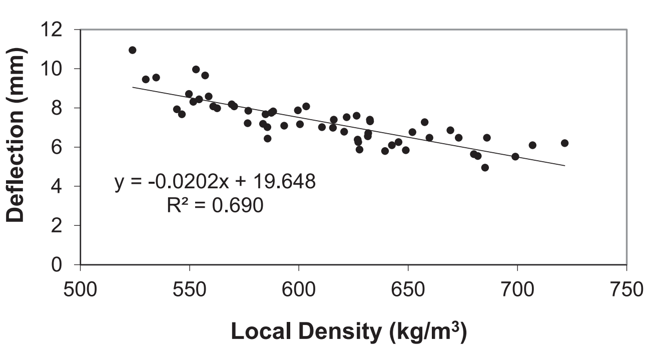

Figure 3.—Effect of local density on concentrated static load (CSL) deflection.

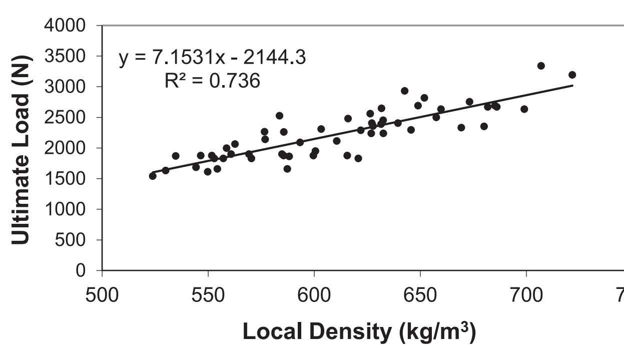

Figure 4.—Effect of local density on concentrated static load (CSL) ultimate load.

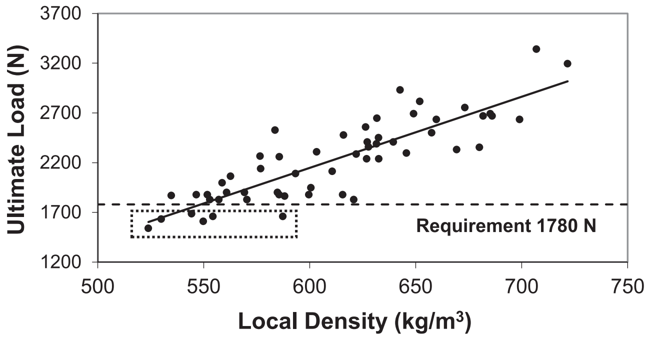

Figure 5.—Low values of local density may result in failure in concentrated static load (CSL) ultimate load. The 6 data points in the dotted box are below the requirement of 1,780 Newtons.

Conclusions

As a structural panel, one of the important performance criteria of OSB is its ability to withstand concentrated static load, a load acting on a relatively small area, such as construction worker's foot on the roof or a piano leg on the floor. Compared with other panel properties, CSL deflection and ultimate load values are intricate to predict, and the requirement is more difficult to meet. The results of this study showed that local density significantly influenced the CSL behavior of OSB panels, especially ultimate load. Panels with a high degree of variation in horizontal panel density may result in low density spots that increase the chance of failure in CSL test. It is important to increase horizontal density uniformity by tracing the sources of variability in the manufacturing processes and taking actions to correct any errors found. Reducing density variability allows OSB companies to increase the CSL properties of their products, which would otherwise need to be done by making the panel denser. Lowering the average density of panels will reduce the manufacturing cost and help improve the company's bottom line. Future research should consider quantifying the potential benefit of minimizing the occurrence of very low density areas in OSB panels.

Acknowledgments

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