Feature

Wood Versus Steel Versus Static Versus Dynamic

Is Oriented Strand Board Reliable for Low-Slope Roofs with Mechanically Attached Components?

By Flonja Shyti, MASc, PEng; Bas A. Baskaran, F-IIBEC, PhD, PEng; and Steven (Kee Ping) Ko, MEng

WOOD IS WIDELY used as a decking material in both residential and commercial roofing systems, mainly due to its ease of installation and cost-effectiveness. Environmental factors have influenced the choice in materials, leading to the prevalent use of wood roof decks in the western regions of the country. In these areas, low-slope roof systems are typically installed over decks made from plywood or oriented strand board (OSB). Historically, built-up roofing (BUR) was a popular roof covering used over wooden decks. This combination performed well, partly due to the dark color of the BUR, which facilitated high energy absorption and mitigated condensation buildup under the membrane through self-drying cycles.[1,2] The increased use of materials with lower permeability, combined with the lack of self-drying cycles, raises concerns about condensation and moisture accumulation on wood decks, potentially hindering their performance. Multiple technical articles have highlighted that while both OSB and plywood can function effectively if kept dry, plywood demonstrates high compatibility with various roof coverings.[3,4] Meanwhile, the National Roofing Contractors Association (NRCA) reports moisture-related dimensional stability problems and its inclination towards the use of plywood with panels complying with structural plywood, product standard 1 (PS 1) over OSB and wood-based structural-use panels, product standard 2 (PS 2).[5] Additionally, the NRCA cites APA (The Engineered Wood Association) research involving ½ in. (12.7 mm) plywood and 7⁄16 in. (11.1 mm) OSB, which demonstrated that OSB exhibited 28% more linear expansion than plywood along with a thickness swell that was 3.5 times greater than that of plywood. While both plywood and OSB decks are used, Factory Mutual Insurance Company (FM) only provides guidance through *FM Property Loss Prevention Data Sheet 1-29: Roof Deck Securement and Above-Deck Roof Components* for the securement of lumber and plywood decks.[6] However, while there may be some rated systems with OSB tested under certain jurisdictions, FM does not currently have any FM-approved systems with wood as a deck on RoofNav.

In the modern mechanically attached roof systems (MARS), the deck/fastener interface is subjected to higher stress accumulation. In the MARS, wind load is distributed through a structural load path from the membrane to the fasteners and then to the deck.[7] **Figure 1** shows a representation of the stress distribution on a mechanically attached single-ply roof system with different seaming technologies.[8]

Gustin and Hughes's research highlighted that cyclic wind loading can negatively impact the fastener pullout resistance of wood decks. The dynamic standard Canadian Standards Association CSA A123.21, *Standard Test Method for Dynamic Wind Uplift Resistance of Membrane-Roofing System,* was developed by the Special Interest Group on Dynamic Evaluation of Roofing Systems (SIGDERS) and is mandated by the National Building Code of Canada.[9] For wood decks used in residential roofs, the University of Florida has developed a dynamic test protocol for wind uplift testing. After evaluating a small sample size, a 20% reduction in uplift capacity was found when compared to results from the static test.[10]

The wind loading experienced by roof systems is dynamic. Therefore, it is crucial to further investigate how wood decks perform under dynamic wind loading conditions. This article presents and discusses the performance of wood decks and steel decks at the interface level through the application of CSA A123.21. SIGDERS assessed the performance of four wood decks and two steel decks, along with two commonly used fasteners from various sources, under both static and dynamic loading conditions. By presenting the comparison of fastener pullout resistance, this article compares and quantifies which wood deck is more reliable for low-slope roof systems, while also demonstrating which deck provides greater reproducibility when evaluated under laboratory conditions.

EVALUATION OF WOOD DECK PERFORMANCE

To evaluate the performance of wood decks at the interface level, a series of small-scale evaluations were undertaken under both static and dynamic conditions. This involved assessing the interaction between various wood deck types and thicknesses with commonly used fasteners. Recently, Gustin and Hughes published an article addressing wood decks on commercial roofs.[11] It compared ½ in. (12.7 mm) OSB and ½ in. (12.7 mm) plywood. The present study expands the analysis to include the evaluation of ⅝ in. (15.9 mm) OSB and ⅝ in. (15.9 mm) plywood. In addition, two different grades of steel decks with minimum tensile strengths of 40 ksi (276 MPa) and 100 ksi (690 MPa), respectively, representing the Canadian and US markets, were included in the experimental program. The inclusion of the steel decks, which are regularly evaluated as part of a roof system under CSA A123.21, will aid in the comparison of the performance of the four types of wood decks. This expansion aims to provide a more comprehensive understanding of the performance of these materials and the impact of thickness on the performance. Furthermore, by evaluating the fastener pullout resistance from the wood and steel decks under both static and dynamic conditions, this study provides insights into the expected field performance and highlights the potential overestimation of resistance under a static condition.

This study investigated different sources for two commonly used fasteners, specifically #14 and #15, as illustrated in **Fig. 2.** The experimental program followed can be seen in **Fig. 3.** For each combination, a minimum of five specimens were evaluated to calculate the average and standard deviation. After reviewing applicable standards for small-scale testing of roofing materials, most do not specify statistical accuracy and reproducibility, but some, such as ASTM C473, *Standard Test Methods for Physical Testing of Gypsum Panel Products,* specify that during laboratory testing in a controlled environment, a variation from the average greater than 15% is not acceptable.[12] In contrast, ANSI/SPRI FX-1, *Standard Field Test Procedure for Determining the Withdrawal Resistance of Roofing Fasteners,* an in-place evaluation, stipulates that a variation from the average greater than 20% is unacceptable.[13] For the dynamic evaluation, the protocol was adapted to a small scale from CSA A123.21, which requires a variation less than the lesser of 5% or 10 lb/ft^2 (0.5 kPa).[14] Considering the above-defined acceptable variations, along with the data obtained for the wood and steel decks, and recognizing the

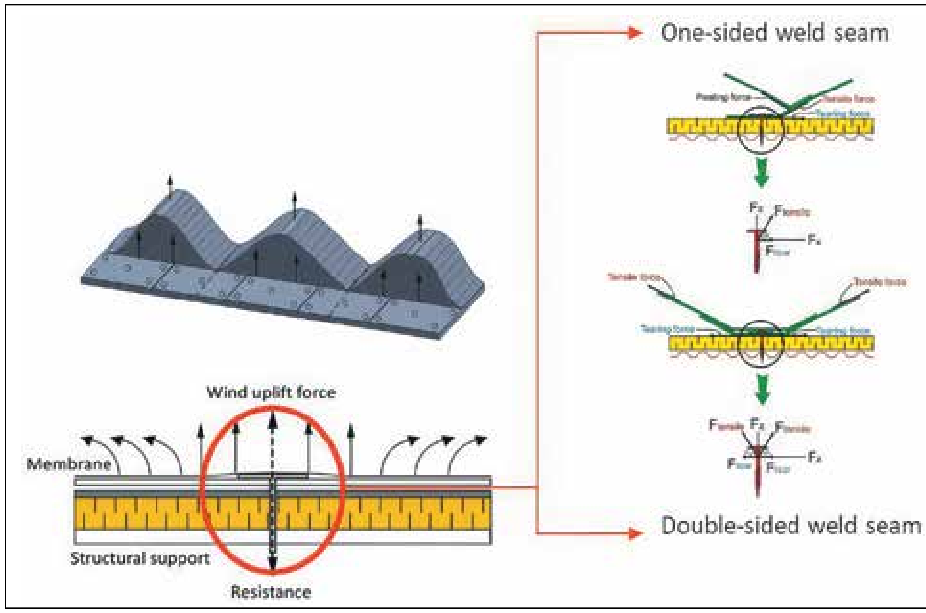


Figure 1. *Stress distribution of a mechanically attached roofing system.*[8,14]

Figure 2. *Fasteners evaluated for both static and dynamic.*

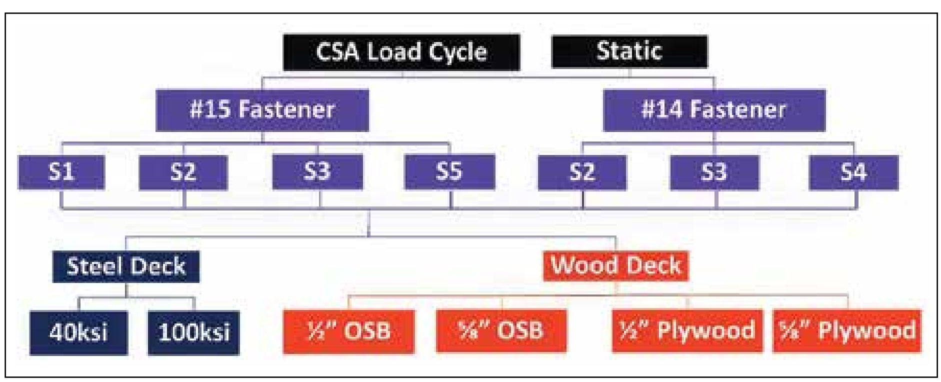


Figure 3. *Experimental program for small-scale evaluation.*

importance of reproducibility as an indicator of consistent and reliable performance in laboratory test methods, a coefficient of variability (COV) less than 10% was deemed acceptable. This allowable limit of a 10% COV was applied to both static and dynamic evaluations to ensure the statistical validity of the small-scale data.

STATIC EVALUATION

To evaluate the fastener pullout resistance of different steel and wood decks under static conditions, ANSI/SPRI FX-1 was followed.[13] As indicated in the standard, the load was applied at a rate of 2.0 ± 1.0 in./min. (51 ± 25 mm/min), and a protrusion depth of 1 in. (25 mm) was achieved in all the specimens during the test preparation. The standard was adapted to be utilized with an Instron machine, utilizing specimen sizes of 7.5 in. × 12 in. (191 mm × 305 mm), as depicted in **Fig. 4** for steel decks and **Fig. 5** for wood decks, having a fastener installed protrusion depth of 1 in. The specimens were then mounted in the Instron machine and fixed to the bottom fixture, which remained stationary during testing. The head of the fastener was gripped by the upper connection, which was moved at a gradual rate specified above. Prior to testing, the specimens were stored in laboratory conditions for a week.

The results for the static evaluation for the two types of steel and four types of wood decks are summarized, respectively, in **Fig. 6** and **7.** Each value represents the average of a minimum of five specimens. The various sources for each fastener type, #14 and #15, did not have a significant impact on the fastener pullout resistance. As a result, the specific sources of the fasteners are not identified, and the results are grouped by fastener type into #14 and #15. Apart from one case, where only one source was evaluated, typically, two or three sources were assessed.

Figure 4. *Setup for the static evaluation of the steel deck using the Instron.*

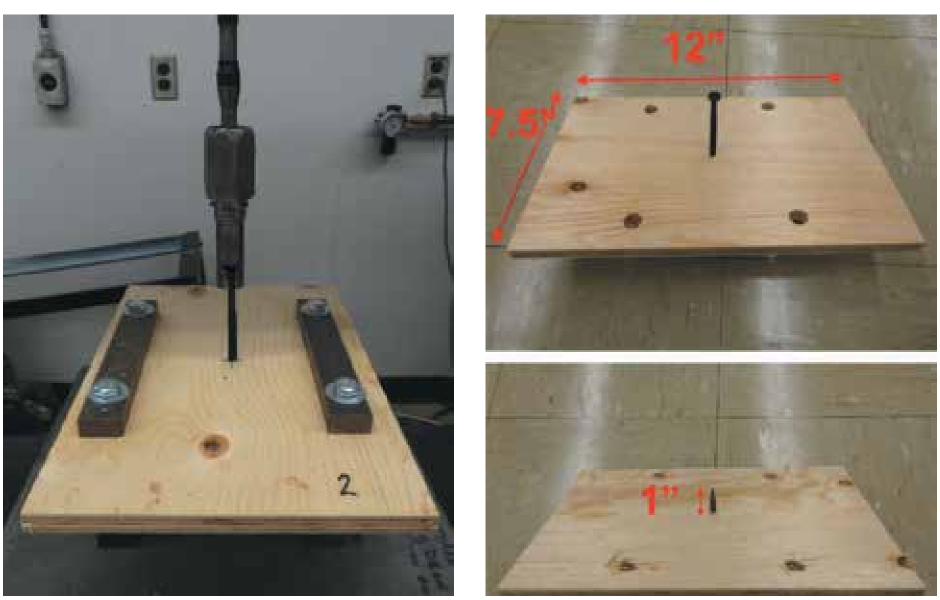


Figure 5. *Setup for the static evaluation of plywood using the Instron.*

For the steel decks, the minimum fastener pullout resistance of 454 lbf (2020 N) was recorded for the 40 ksi (276 MPa) steel deck in combination with the #14 fastener. The highest, ranging from 761 lbf (3385 N) to 774 lbf (3443 N), were recorded for the 100 ksi (690 MPa) steel deck in combination with the #15 fasteners. The combination of both types of steel decks with the #15 fastener yielded higher fastener pullout resistance values.

Both ½ in. (13 mm) and ⅝ in. (16 mm) plywood had higher fastener pullout resistances than both types of OSB. The combination of ⅝ in. (16 mm) plywood and the #15 fastener yielded the highest fastener pullout resistance, ranging from 484 lbf (2153 N) to 531 lbf (2362 N). In contrast, the lowest pullout resistance was observed in the combination of the ½ in. (13 mm) OSB combined with the #15 fastener, ranging from 166 lbf (738 N) to 167 lbf (743 N).

To accurately interpret the data, both the standard deviation and the COV are examined. For the steel deck specimens, the standard deviation varied between 15 lbf (67 N) and 38 lbf (169 N) for the 40 ksi (276MPa) grade and between 9 lbf (40 N) and 56 lbf (249 N) for the 100 ksi (690 MPa) grade. In comparison, the wood decks exhibited the following standard deviations: ½ in. (13 mm) OSB ranged from 24 lbf (107 N) to 38 lbf (169 N), ⅝ in. (16 mm) OSB from 27 lbf (120 N) to 44 lbf (196 N), ½ in. (13 mm) plywood from 19 to 42 lbf (85 to 187 N), and ⅝ in. (16 mm) plywood from 37 lbf (165 N) to 61 lbf (271 N).

The COV, expressed as a percentage of the standard deviation divided by the average for the static fastener pullout resistance, is illustrated in **Fig. 8** and **9** for steel and wood decks, respectively. Both grades of steel decks exhibited low COVs, with the highest value of 8.4%. Only the plywood decks had values within a comparable range with the steel decks, indicating consistency and reliability of the data and the plywood and steel decks. The highest values, ranging from 14.5% to 22.6%, were recorded for ½ in. (13 mm) OSB, and the lowest, ranging from 5.8% to 11.8%, were recorded for ⅝ in. (16 mm) plywood. The results obtained for plywood decks are more consistent and less variable than those for OSB, exhibiting consistency comparable to that of steel decks.

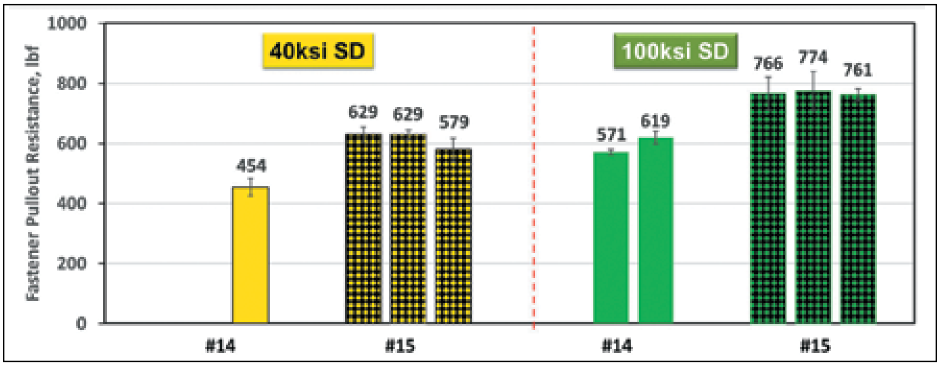


Figure 6. *Static fastener pullout resistance results for steel deck.*

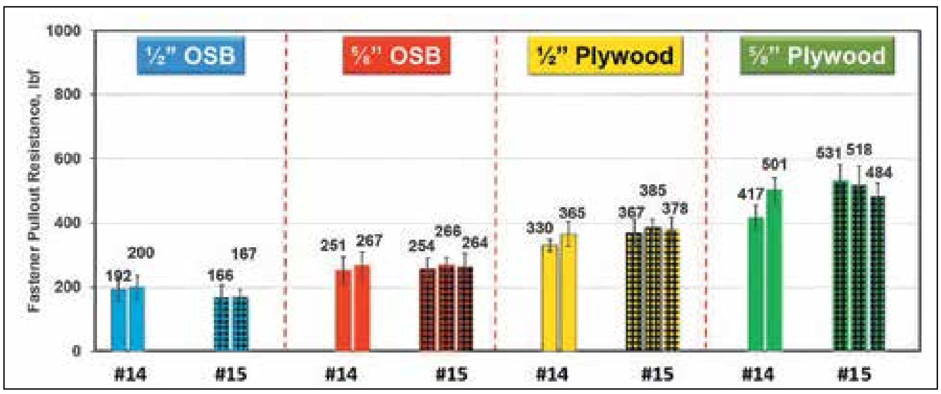


Figure 7. *Static fastener pullout resistance results for oriented strand board (OSB) and plywood decks.*

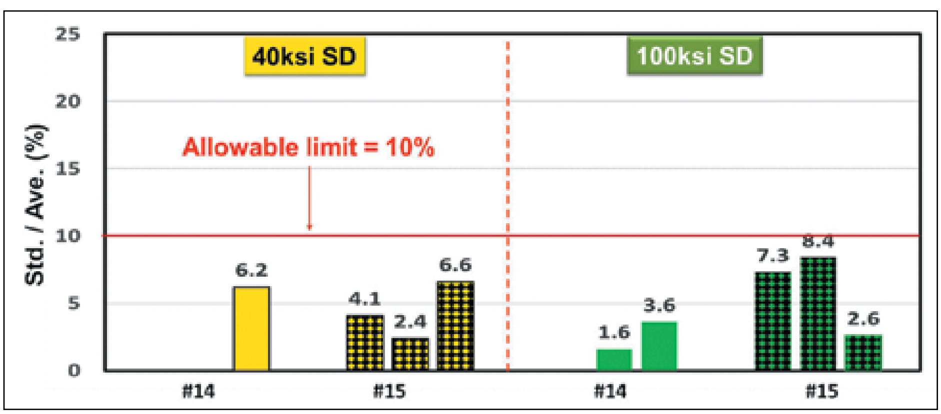


Figure 8. *Coefficient of variability for the static evaluation of steel decks.*

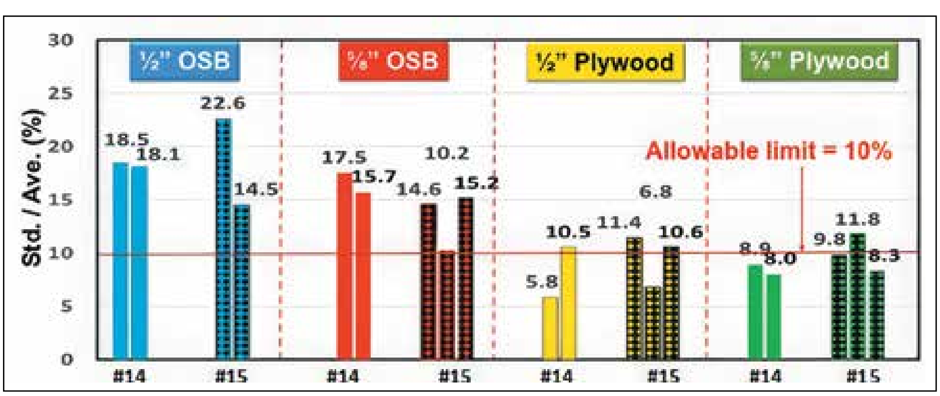


Figure 9. *Coefficient of variability for the static evaluation of the oriented strand board (OSB) and plywood decks.*

The failure mode for the steel deck involved upward cone-shaped deformation around the fastener. For the plywood wood deck, plywood splitting was observed when tested with both #14 and #15 fasteners, with the splitting area being larger for the #15 fastener. In the OSB wood decks, the failure mode was characterized by disengagement of the material surrounding the fastener shaft.

DYNAMIC EVALUATION

The CSA A123.21 dynamic protocol was applied to the small-scale testing for the fastener pullout resistance. The testing was completed using the Interface Fatigue Simulator (IFS), shown in **Fig. 10.** The evaluations were performed on specimens with a size of 16 in. × 22 in. (406 mm × 559 mm) and a fastener protrusion depth of 1 in. (25 mm) Both steel and wood deck specimens were prepared in the same manner as they were for the static evaluation with the fastener installed with a protrusion depth of 1 in. (25 mm). Two fastener pullout resistances were evaluated on the same deck with the fasteners having a distance of 6 in. (152 mm) between them. The specimens were installed in the IFS, between two steel plates, with the fastener gripped by the bottom stationary connection. The entire specimen was moved up and down in accordance with the CSA A123.21 dynamic protocol, simulating the wind gusts.

The results of the dynamic evaluation for the two types of steel and four types of wood decks are summarized in **Fig. 11** and **12,** respectively. Similarly to the static evaluation, each value represents the average of a minimum of five specimens, and the source of the fastener did not impact the fastener pullout resistance, and therefore the results are grouped by fastener type (#14 and #15).

For the steel decks, the minimum fastener pullout resistance of 231 lbf (1028 N) was recorded for the 40 ksi (276 MPa) deck with the #14 fastener. The highest fastener pullout resistance values, ranging from 395 lbf (1757 N) to 420 lbf (1868 N), were recorded for the 40 ksi (276 MPa) steel deck in combination with the #15 fasteners. The combination of both types of steel decks with the #15 fastener yielded higher fastener pullout resistance values.

The ⅝ in. (16 mm) plywood had a higher fastener pullout resistance when compared to the other wood decks, especially in combination with the #15 fastener, ranging from 361 lbf (1606 N) to 363 lbf (1615 N). The lowest pullout resistance was observed in the combination of ½ in. (13 mm)

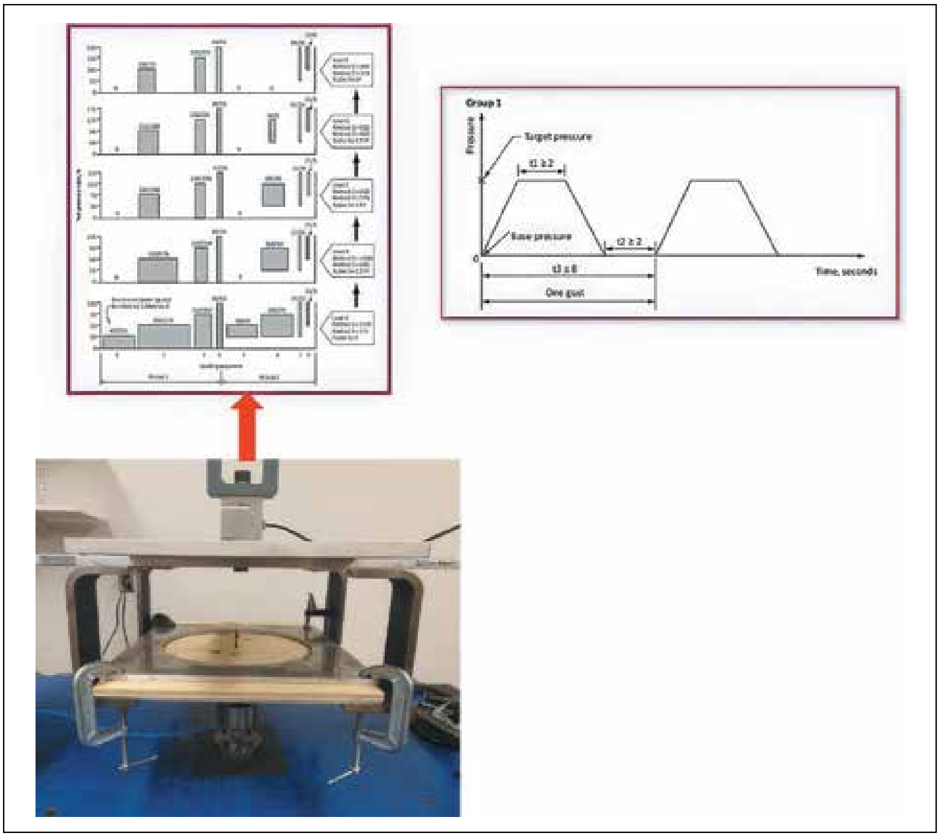


Figure 10. *Setup for the dynamic evaluation for the fastener/deck interface evaluation.*

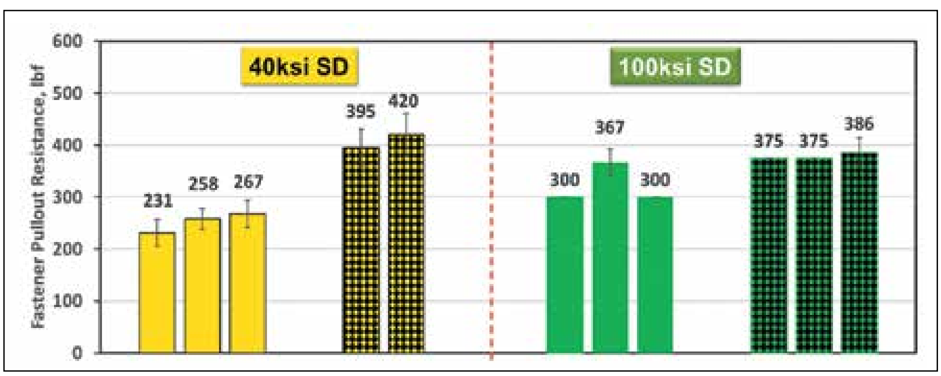


Figure 11. *Dynamic fastener pullout resistance results for steel decks.*

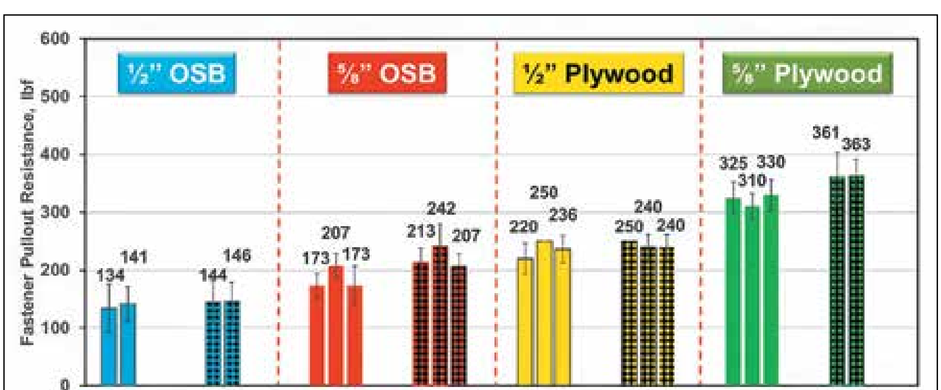


Figure 12. *Dynamic fastener pullout resistance results for oriented strand board (OSB) and plywood decks.*

OSB combined with the #14 fastener, ranging from 134 lbf (596 N) to 141 lbf (627 N).

For the steel deck specimens, the standard deviation ranged between 26 lbf (116 N) to 41 lbf (182 N) for the 40 ksi (276 MPa) grade and between 0 lbf (0 N) to 28 lbf (125 N) for the 100 ksi (690 MPa) grade. In comparison, the wood decks exhibited the following standard deviations: ½ in. (13 mm) OSB ranged from 30 lbf (133 N) to 42 lbf (187 N), ⅝ in. (16 mm) OSB from 21 lbf (93 N) to 38 lbf (169 N), ½ in. (13 mm) plywood from 0 lbf (0 N) to 27 lbf (120 N), and ⅝ in. (16 mm) plywood from 22 lbf (98 mm) to 42 lbf (188 N).

At first look, the pullout resistance values obtained for ⅝ in. (16 mm) OSB and ½ in. (13 mm) plywood might appear to be within the same range. However, once the COV is taken into account, it can be seen that the pullout resistance of the OSB has higher values of COV than the plywood.

Under dynamic loading, the COV is illustrated in **Fig. 13** and **14** for steel and wood decks, respectively. Both grades of steel exhibited low COVs, with the highest value of 11 recorded for 40 ksi (276 MPa) in combination with the #14 fastener. Similar to the conclusion reached in the static evaluation section, only plywood decks, and especially the ⅝ in. (16 mm) type, had values, of 7% to 12%, within a comparable range with the steel decks. Meanwhile, ½ in. (13 mm) OSB had a very high COV, ranging from 21.1% to 31.3%, demonstrating variable and inconsistent results. Similarly, ⅝ in. (16 mm) OSB had a COV range from 10.1% to 19.7%. There were two combinations, ½ in. (13 mm) plywood and #14 (source 3) fastener and ½ in. (13 mm) plywood and #15 (source 1) fastener, that had a zero COV. Similar to the static conclusion, this indicates that the results obtained for plywood decks are more consistent and less variable than those for OSB.

Examples of the failure modes for the steel, plywood, and OSB decks are shown in **Table 1.** The failure mode for the plywood wood deck involved the plywood splitting when tested with both #14 and #15 fasteners, with the splitting area being smaller than that observed under static loading. In the OSB wood decks, the failure mode was characterized by disengagement of the material surrounding the fastener shaft. This disengagement was smaller than that observed under static loading.

The dynamic pullout resistance values are consistently lower than the static data. So when you take into account that the dynamic values are more representative of the field data and the high variability of the OSB, the target

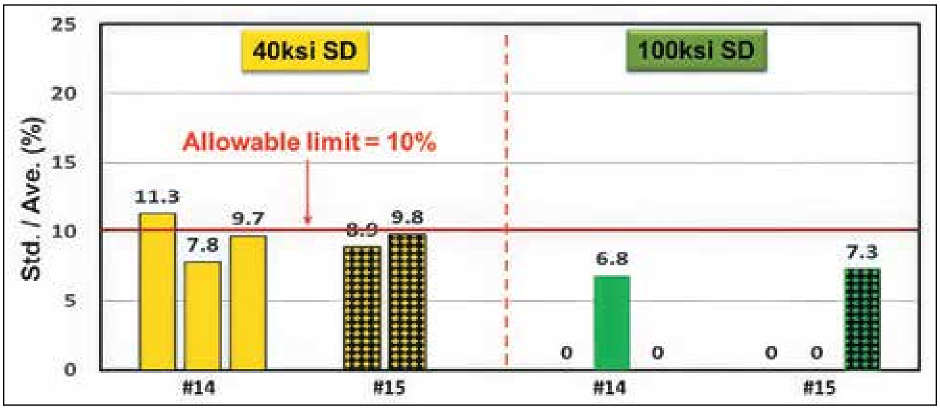


Figure 13. *Coefficient of variability for the dynamic evaluation for steel decks.*

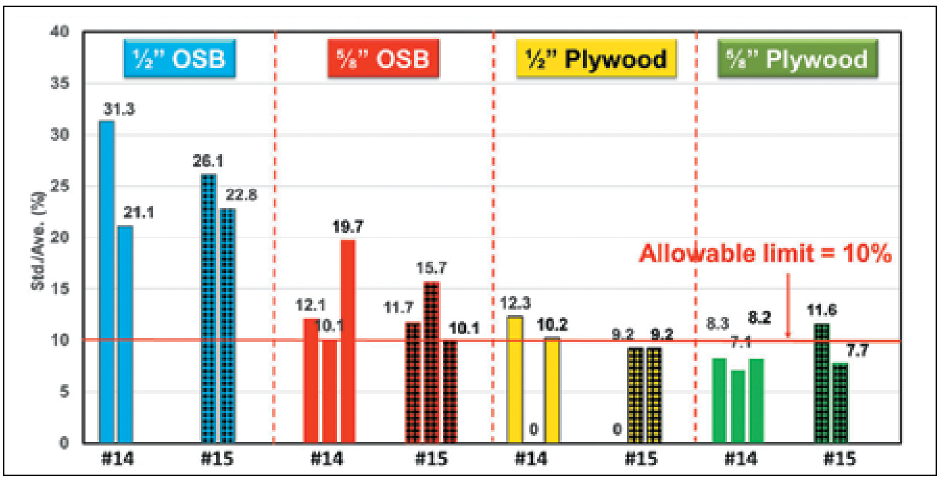


Figure 14. *Coefficient of variability for the dynamic evaluation for oriented strand board (OSB) and plywood decks.*

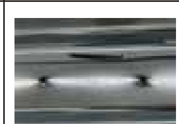
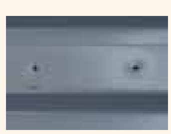
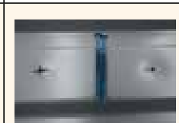
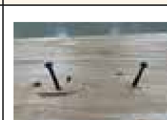
probability (sweet spot) of consistently having a fastener pullout resistance that meets a minimum value of 400 lbf (1779 N), identified in Gustin and Hughes's article as the "generally accepted minimum pullout resistance for mechanically attached membrane systems over any structural deck,"[11] decreases.

CONCLUDING REMARKS

In this article, the fastener pullout resistance of ½ in. (13 mm) and ⅝ in. (16 mm) OSB and plywood and 40 ksi (276 MPa) and 100 ksi (690 MPa) steel deck was evaluated in combination with commonly used fasteners, #14 and #15, to better understand the performance of wood decks at the interface level. The following is a summary of the findings under both static and dynamic conditions:

- Plywood consistently had higher fastener pullout values than OSB, with less variability under both static and dynamic evaluations.
- Only plywood decks had COV values within a comparable range with the steel decks, indicating consistency and reliability of the data.
- ⅝ in. (16 mm) plywood had the highest fastener pullout resistance, with a low COV, showing a superior performance irrespective of the fastener type and source.
- ½ in. (13 mm) OSB had the lowest fastener pullout resistance, with a very high COV and inconsistent results.

TABLE 1. Summary of the dynamic failure mode of steel deck, oriented strand board (OSB), and plywood.

DECK	FASTENER	
	#14	#15
40 ksi Steel Deck	 Deck cracked	 Deck deformed upwards and cone shape around fastener hole; larger deformation than #14
100 ksi Steel Deck	 Deck cracked	 Deck cracked and fastener thread chipped
Plywood	 Plywood splitting at fastener engagement area	 Plywood splitting at fastener engagement area; larger splitting than #14
OSB	 Disengagement of material surrounding the fastener shaft	 Disengagement of material surrounding the fastener shaft

- Irrespective of the deck/fastener combination, dynamic resistance values were lower than static values. For steel decks, the dynamic values averaged 50% to 70% of the static values, while for plywood decks, the dynamic values were 60% to 75% of the static values.

In the case of OSB, the dynamic pullout resistance values were consistently and significantly lower than those obtained from static testing. This, combined with the variability observed in the OSB data, leads to the conclusion that OSB is not a reliable deck option, as it presents challenges in consistently reproducing data within the defined criteria. Furthermore, the investigation concentrated on new materials; it did not account for the effects of moisture and extreme weather, which would exacerbate these issues. Consequently, OSB is not a suitable decking component for the low-slope roofs where components are mechanically fastened. Further investigation is being completed to validate the small-scale data with large-scale system testing.

ACKNOWLEDGMENTS

Special Interest Group for Dynamic Evaluation of Roofing Systems (SIGDERS) contributed to the development of this standard. SIGDERS was formed from a group of partners who were interested in roofing design. These partners included Altenloh, Brinck & Co. US Inc., Atlas Roofing Corp., Canadian Roofing Contractors' Association, Carlisle SynTec Systems, Duro-Last Inc., Element, Elevate (Holcim Solutions and Products US LLC), EXP Inc., GAF, IKO Industries Ltd., IIBEC, Johns Manville Inc., Polyglass, Roofing Contractors Association of British Columbia, Rockwool, Sika Sarnafil, Soprema Canada Inc., and Tremco Inc.

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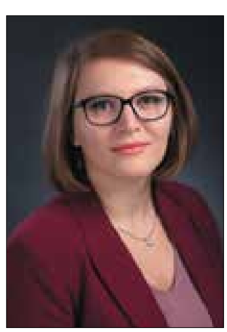

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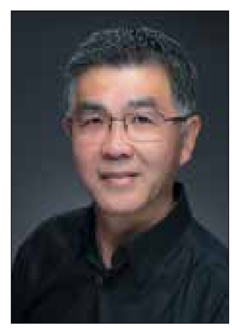

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