LATERAL CONNECTION BEHAVIOR OF MOLDED CORE SANDWICH PANELS WITH SELF-TAPPING SCREWS

*Daniel Way**†
Graduate Research Assistant
248 Richardson Hall
Department of Wood Science and Engineering
Oregon State University
Corvallis, OR 97331
E-mail: daniel.way@oregonstate.edu

Tahir Akgül
Assistant Professor
Department of Civil Engineering
Sakarya University
Sakarya, Turkey
E-mail: tahirakgul@sakarya.edu.tr

Ian Morrell
Undergraduate Research Assistant
School of Engineering and Applied Science
Gonzaga University
Spokane, WA 99258
E-mail: imorrell@zagmail.gonzaga.edu

Arijit Sinha†
Assistant Professor
119 Richardson Hall
Department of Wood Science and Engineering
Oregon State University
Corvallis, OR 97331
E-mail: arijit.sinha@oregonstate.edu

(Received May 2016)

Abstract. This study investigated lateral connection behavior of a single shear connection between a molded core sandwich panel produced with wood strands and solid sawn lumber. A continuous thread self-tapping screw and common nail were the fasteners evaluated. Connection assemblies with self-tapping screws showed much greater stiffness, yield load, and load-carrying capacity than nailed assemblies, indicating that self-tapping screws may be a viable option for connections between wood-based molded core panels and solid sawn lumber.

Keywords: Self-tapping screws, molded core panels, sandwich panels, wood connectors, lateral connections.

INTRODUCTION

Self-tapping screws (STSs) with continuous threads have gained interest in the timber engineering community due to their elevated tensile strength compared with traditional wood screws (Martin 2009). High withdrawal capacities of the screws are exploited for lateral connections by inserting the fastener at an angle to the connection plane, allowing load to be transferred by a truss-like system where the screw is loaded in tension and the connected members in compression (Hossain et al 2015).

* Corresponding author
† SWST members

Similar to wooden I-joists, molded core sandwich panels (MCPs) are efficiently designed using relatively high strength, thin facings adhesively bonded to a deep corrugated core; generating high strength- and stiffness-to-weight ratios (Hunt and Winandy 2002; Voth 2009; Way 2015). Previous MCP research indicated that lateral connection properties may benefit from alternative connectors since connections with a common sheathing nail represented the largest scope for product improvement (Way 2015). This study was performed to determine if MCP lateral connection properties could be improved through the use of STS. More specifically, the objectives were to characterize MCP to wood connection with STS and compare the performance of STS connections with that of a connection using a common nail.

MATERIALS AND METHODS

Lateral connection performance of a single shear plane connection was evaluated based on testing procedures outlined in ASTM D1761 (ASTM 2012). Twenty-four lateral connection assemblies consisting of solid sawn lumber main member and MCP side member were prepared. The 89 mm wide × 89 mm deep × 356 mm long main members were No. 1 Douglas-fir (*Pseudotsuga menziesii*). The MCP side members were 89 mm wide and 356 mm long. Two mechanical fasteners (Fig 1) and two thickness of MCP (43.2 mm [Type A] and 46.8 mm [Type B]) were investigated, providing six replicates in each of the following series:

1. Nailed connection, Type A MCP.
2. Nailed connection, Type B MCP.
3. STS connection, Type A MCP.
4. STS connection, Type B MCP.

Nailed connections were made with galvanized nails (diameter = 5.5 mm, length = 116 mm) purchased from a local hardware store. Bending yield strength was experimentally determined to be 674 MPa following ASTM F1575 (ASTM 2008). STS connections were made with continuous thread, self-tapping wood screws (SWG ASSY® VG plus Cyl.) purchased from My-Ti-Con

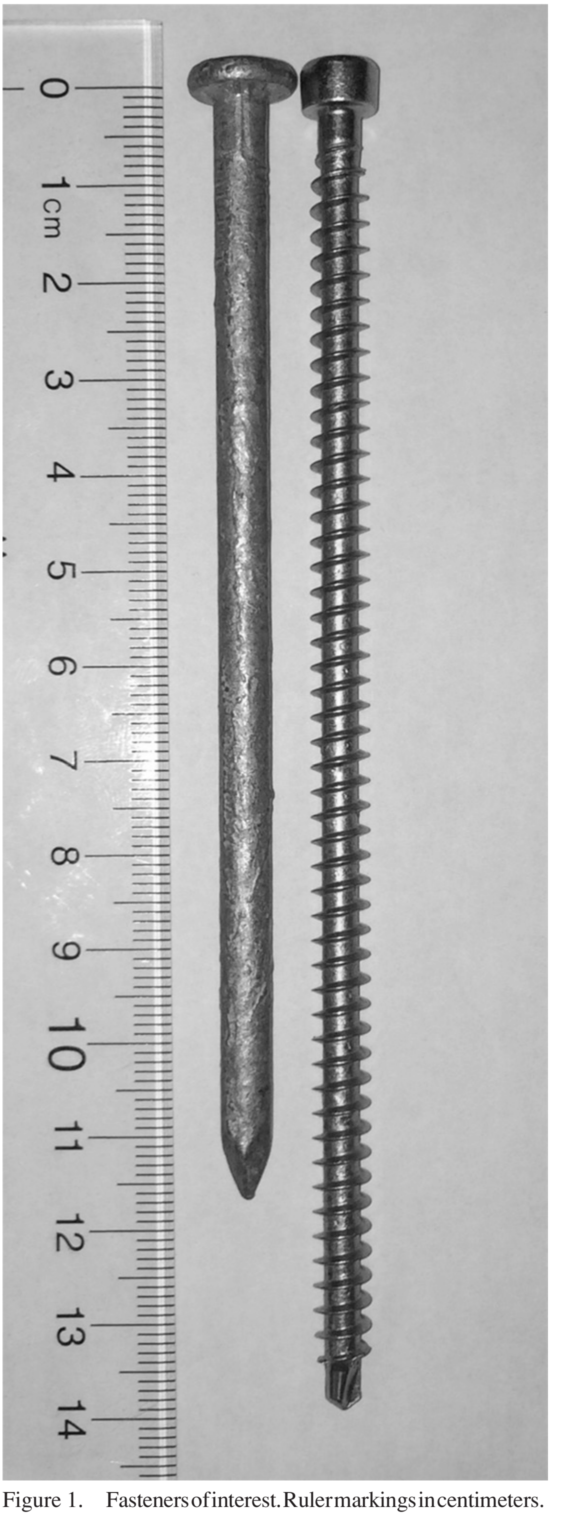

Figure 1. Fasteners of interest. Ruler markings in centimeters.

Timber Connectors (Surrey, British Columbia, Canada). Outside and inside diameters of the screws were 6.0 and 3.8 mm, respectively (length = 140 mm). Published bending yield strength of the screws is 969 MPa (CCMC 2014).

Molded cores were produced with a patented (Fujii 2014), bidirectional corrugated core pattern previously studied by Way (2015). Wood strands used in core manufacturing were typical of those found in the core layer of three-layer commercial oriented strand board (OSB) panel and consisted of 90% aspen (*Populus* sp.) and 10% assorted hardwoods obtained from a manufacturer in the Great Lakes Region. Strands were blended with a phenol-formaldehyde adhesive, targeting 4% resin solids by weight. A random strand orientation was targeted while hand-forming the mat. Density of the core averaged 0.64 g/cm^3. Facing material consisted of commercial OSB, which was laminated on each face of the core with a phenol-resorcinol-formaldehyde adhesive system at a spread rate of 0.061 g/cm^2. A complete description of MCP manufacturing can be found in Way (2015), where the reader is directed for additional background.

Each molded core had a total depth of 25.4 mm and corrugation wall thickness of 6.4 mm. Type A MCPs were produced with 9.5-mm (3/8 inch nominal) OSB, with a final facing thickness of 8.9 mm after surface preparation. Type B MCPs were produced with 11.1-mm (7/16 inch nominal) OSB, with final facing thickness of 10.7 mm after surface preparation. The two thickness chosen represent the two smallest Span-Rated thicknesses, each from a different manufacturer. Average density of the OSB facings was 0.66 and 0.60 g/cm^3 for Types A and B MCPs, respectively.

Schematic details of each assembly can be found in Fig 2. Effective penetration depth (P_d) was 64.6, 61.0, 48.1, and 44.6 mm for series 1-4, respectively. STS spacing requirements for the loaded end of each member to the fastener, as outlined in CCMC (2014), were exceeded for series 3 and 4 assemblies. End spacing for series 1 and 2 assemblies was set to meet or exceed those outlined for STS, since there are no

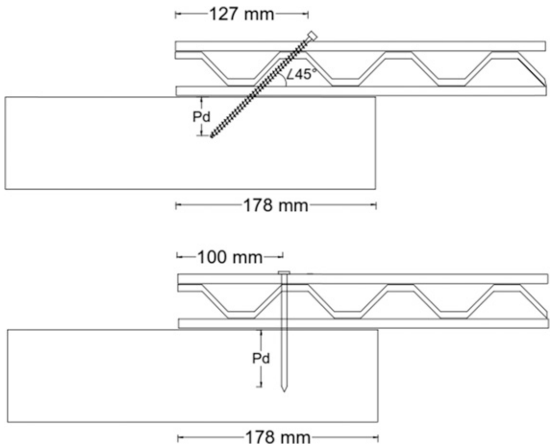

Figure 2. Schematic of connection assemblies: self-tapping screw (STS) (top) and nail (bottom).

requirements for nails with diameter less than 6.35 mm in the National Design Specifications (NDS) for Wood Construction (AFPA 2012). STS were installed at an angle of 45° with respect to the shear plane, since this is one of the manufacturer's recommended installation angles for lateral connections (CCMC 2014). Nails were inserted perpendicular to the shear plane. A 3.5-mm lead hole was drilled through the side member and 75 mm into the main member for nailed connections, whereas no lead holes were drilled for the screws. Both members were conditioned at 20°C and 65% RH for 2 wk prior to specimen assembly. Average dry-basis MC at time of testing was 13.7 and 8.0 for the main and side members, respectively.

Mechanical testing was performed at Oregon State University's timber engineering laboratory on an Instron Series 5582 universal testing machine (UTM). The main member was clamped to a rigid frame attached to the UTM base (Fig 3). The bolt assembly attached to the UTM cross head was equipped with a pivoting joint to reduce eccentricities during loading. A 21-mm-diameter hole, centered across the width, was bored 75 mm from the MCP end. The purpose of this hole was to allow for tensile loading of the specimen using a 19-mm-diameter bolt. Steel plates containing 21-mm bolt holes were attached to each side of the MCP with six wood screws (diameter = 2.5 mm)

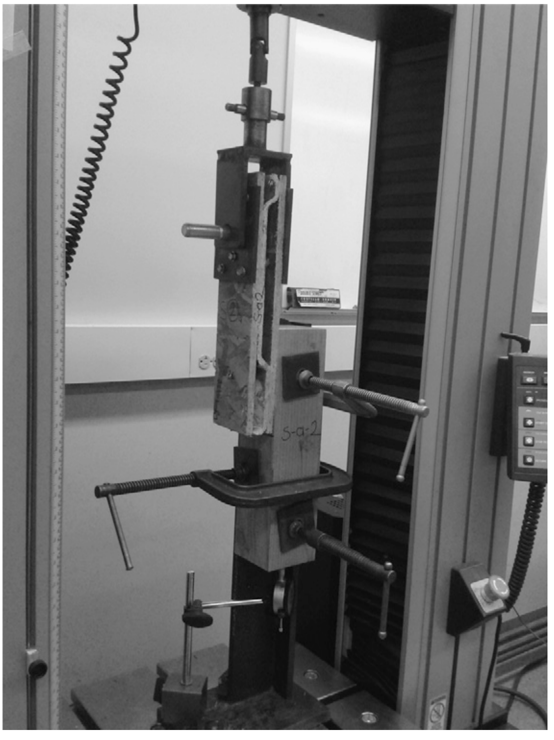

Figure 3. Experimental test assembly.

to increase load distribution and prevent bearing failure in the vicinity of loading. Displacement-controlled tensile loading occurred at a rate of 5 mm/min. Load and cross head displacement data were captured with a data acquisition system throughout the entire test.

Experimental load and displacement data were used to determine connection stiffness in the linear region of the load-displacement diagram along with the yield load determined by the 5% offset method, as suggested in AFPA (2012). Load-carrying capacity, as judged by the maximum load, was also compared. Statistical analysis was performed using two-sample t tests at the 5% significance level. Yield modes and failure mechanisms were characterized by carefully extracting each fastener after connection failure.

RESULTS AND DISCUSSION

Experimental results are presented in Table 1. Comparing fasteners between assemblies with the same side member thickness, specimens with STS had significantly higher average yield loads than those with nails ($p < 0.001$ for both MCP types). No statistical evidence was found to indicate a difference in mean yield load between MCP types connected with the same fastener type ($p = 0.98$ for nails and 0.10 for STS). The effects of reduced bearing area for Type A MCP (8% less) are likely offset by higher facing density (10% more) compared with Type B MCP, which may explain why differences between MCP type were insignificant.

General loading behavior of the connections is presented in Fig 4. The loading behavior differed between nailed assemblies (series 1 and 2) and STS assemblies (series 3 and 4). Inserting STS at an angle loads the screw in both tension and shear and places the members in compression. This effect led to STS assemblies exhibiting a lengthened period of linearity along with higher stiffness compared with nailed connections (Fig 4), until fiber tear-out capacity in the members was exceeded. Nailed connections exhibited a diminishing slope after combined yielding of the fastener in bending and localized crushing of the wooden members, but continued to increase load until a maximum was reached, approximately 20 mm after yielding. This is typical of connections with MCP (Way et al 2016).

Series 3 and 4 specimens exhibited a sharp drop in load shortly after reaching maximum load,

Table 1. Experimental results.[a]

Series	Fastener	Side member	Stiffness (N/mm)	Yield load (N)	Maximum load (N)
1	Nail	Type A MCP	826 (30.6)	1867 (20.6)	4235 (15.3)
2	Nail	Type B MCP	822 (35.7)	2053 (20.6)	4413 (5.8)
3	STS	Type A MCP	1822 (17.3)	4525 (17.0)	5252 (18.1)
4	STS	Type B MCP	1764 (32.1)	5226 (10.0)	6079 (14.2)

MCP, molded core sandwich panel; STS, self-tapping screw.
[a] Values in parentheses represent the coefficient of variation (%).

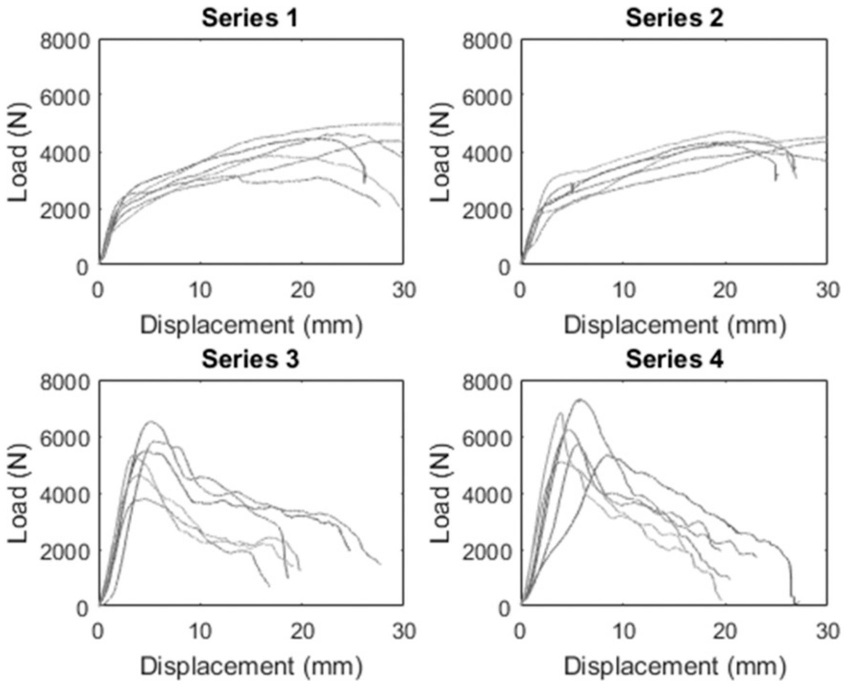

Figure 4. Load-displacement diagrams for all specimens.

caused by a combination of fiber tear out in the both members. Classifying failures according to the connection yield modes listed in the NDS, Mode IIIs failure was observed in the screws as well (AFPA 2012). Nailed connections exhibited typical dowel yielding behavior where excessive deformation occurred before reaching maximum load, which was allowed by crushing of the wood and bending of the fastener. Yield modes observed for series 1 and 2 were either Mode IIIs or Mode IV.

Using the withdrawal capacity of continuous threads in both connections, members greatly increased connection stiffness in series 3 and 4 by taking advantage of wood's tension parallel to the grain properties. Series 1 and 2 yielded on average at 45% of the maximum load, whereas series 3 and 4 yielded on average at 86% of maximum load. The NDS (AFPA 2012) recommends using yield load as the ultimate load when designing nailed connections. Using this principal for STS design realizes nearly the entire capacity (design) of the fastener, leading to a leaner design as the yielding and failing occur close to each other due to the high connection stiffness. In the case of MCP lateral connections, the hollow area of the MCP leads to greater moment at the shear plane in nails, resulting in weaker connections. Using the insertion angle and continuous threads of the STS connectors resulted in a large improvement in lateral connection behavior, in which the ultimate failure was governed by fiber tear-out capacity of both the main and side member, opposed to the bending strength of the fastener.

CONCLUSIONS

Lateral connection assemblies with STS produced a much stiffer connection with considerably higher load-carrying capacity compared with nailed assemblies. No statistical evidence was found that MCP type influenced connection properties, regardless of the fastener used. Results show that STSs have potential to greatly improve connection performance of MCPs, although further research is necessary to validate results from this small sample size, investigate additional insertion angles, additional STS diameters, reverse-cycle loading behavior, and model connection behavior.

REFERENCES

American Forest and Paper Association (AFPA) (2012) National design specification (NDS) for wood construction. American Forest and Paper Association, Washington, DC.

American Society for Testing and Materials (ASTM) (2008) F1575. Standard test method for determining bending yield moment of nails. American Society for Testing and Materials, West Conshohocken, PA.

American Society for Testing and Materials (ASTM) (2012) D1761. Standard test methods for mechanical fasteners in wood. American Society for Testing and Materials, West Conshohocken, PA.

CCMC (2014) Evaluation Report: SWG ASSY VG Plus and SWG ASSY 3.0 Self-Tapping Wood Screws. Canadian Construction Materials Centre Report No. CCMC 13677-R. http://www.swg-produktion.de/fileadmin/Zulassungen/13677eCCMCEvaluationReportASSY30ASSYplusVG.pdf (Accessed 25 August 2015).

Fujii JS (2014) Dry forming three dimensional wood fiber webs. U.S. Patent 8,852,485.

Hossain A, Lakshman R, Tannert T (2015) Shear connections with self-tapping screws for cross-laminated timber panels. ASCE Structures Congress 2015, 2251-2259. http://ascelibrary.org/doi/pdfplus/10.1061/9780784479117.195. (Accessed 12 April 2016).

Hunt J, Winandy JE (2002) 3D engineered fiberboard: A new structural building product. Pages 106-117. Proc 6th Panel Products Symposium, Session 2: New Products. Llandudno, Wales. http://www.treesearch.fs.fed.us/pubs/8599. Accessed 16 April 2015.

Martin I (2009) Self-tapping screws as reinforcement for timber structures. Pages 12-23. Proc IASS Symposium, Evolution and Trends in Design, Analysis and Construction of Shell and Spatial Structures. Universidad Politecnica de Valencia, Valencia, Spain. https://riunet.upv.es/bitstream/handle/10251/6537/PAP_TRAUTZ_456.pdf;sequence=1. Accessed 16 June 2015.

Voth C (2009) Lightweight sandwich panels using small-diameter timber wood-strands and recycled newsprint cores. MS thesis, Washington State University, Pullman, WA. 90 pp.

Way D (2015) Proof of concept for a three-dimensional molded core wood-strand sandwich panel. MS thesis, Oregon State University, Corvallis, OR. http://ir.library.oregonstate.edu/xmlui/handle/1957/56239.

Way D, Sinha A, Kamke FA, Fujii JS (2016) Evaluation of a wood-strand molded core sandwich panel. J Mater Civ Eng 10.1061/(ASCE)MT.1943-5533.0001589, 04016074. http://dx.doi.org/10.1061/(ASCE)MT.1943-5533.0001589.