

Study of the Shear Performance of Glulam Joints Using Mechanical Connectors and Self-Tapping Screws

Min-Chyuan Yeh,^{1,2)} Yu-Li Lin,¹⁾ Gien-Ping Huang¹⁾

【 Summary 】

Two types of mechanical connectors, of either steel or aluminum, were developed with the application of self-tapping screws for Japanese cedar glulam member connections. The characteristic strength properties of a beam-column joint assembled using different numbers of self-tapping screws in an H-type structure were studied using a shear test. For the π -type connector, connections that used 9 and 12 self-tapping screws showed a slight improvement in the maximum shear loading capacity over the use of 6 screws. Connections assembled using a dovetail-type connector exhibited greater initial stiffness and ductility than the π -type connector, but had a lower maximum load capacity and yield strength. Joints assembled using the aluminum dovetail-type connectors dissipated energy 3 times more effectively than those assembled using steel dovetail-type connectors. The derived allowable shear capacity values for a connection, obtained from the strength limit, were lower than values derived using yield strength criteria and were about 28.5~32.5% of the average maximum shear load. The π -type connection showed a 42.4% higher allowable shear load capacity than that of dovetail-type connections.

Key words: joint strength, glulam, self-tapping screw, Japanese cedar.

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¹⁾ Department of Wood Science and Design, National Pingtung Univ. of Science and Technology, 1 Shuehfu Rd., Neipu Township, Pingtung 91201, Taiwan. 國立屏東科技大學木材科學與設計系，91201屏東縣內埔鄉學府路1號。

²⁾ Corresponding author, e-mail: yehmc@mail.npust.edu.tw 通訊作者。

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研究報告

集成材以金屬連結件及自攻螺絲扣件接合之剪斷性能¹⁾葉民權^{1,2)} 林玉麗¹⁾ 黃健評¹⁾

摘 要

本研究開發鋼製及鋁製之兩種連結件，並應用自攻螺絲為扣件於柳杉集成材之接合，在剪斷試驗中採用H型結構，以不同數量之自攻螺絲組合成梁柱接合，用以探討其強度特性。在 π 型連結件方面，採用9或12支自攻螺絲接合之最大剪斷載重容量較6支試驗條件略有增進，以鳩尾型連結件組成之接合則較 π 型連結件接合有較大之初始剛性及延展性，但有較低之最大載重容量及降伏強度，以鋁製鳩尾型連結件組成之接合較鋼製鳩尾型連結件有其3倍之能量散逸。以強度極限法所推導之容許剪斷容量值，低於以降伏強度準則所決定之數值，約為平均最大剪斷載重值之2.85~32.5%，以 π 型接合之容許剪斷載重容量則高於鳩尾型接合42.4%。

關鍵詞：接合強度、集成材、自攻螺絲、柳杉。

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INTRODUCTION

A self-tapping screw has a sharp blade at the tip to cut off wood fibers, which differs from common wood screws. It features a good holding ability and increases the operational efficiency of wood-working projects. In recent years, medium and large self-tapping screws have become common in timber engineering as alternative fasteners for structural connections. Several studies have shown that the withdrawal capacity of a self-tapping screw is influenced by several parameters, including the penetration angle, the screw diameter, the screw tip, the lead hole, the screw spacing, the edge distance, the board thickness, and the wood density, and recommendations for design and construction purposes are detailed (Hübner et al. 2010, Uibel and Blaß 2010, Ellingsbo and Malo 2012, Ringhofer and Schickhofer 2014). Most self-tapping screws can be laid out with a small spacing and edge distance without the risk of

splitting the wood, which often occurs with bolted connections. Closen and Lam (2012) developed a moment-resisting connection for glulam beam-column structures using the withdrawal resistance of 10-mm self-tapping screws assembled at 30° with a reduced edge distance. The connection allows a double bending moment design capacity and demonstrates the suitability of self-tapping screws as fasteners in timber engineering applications.

Self-tapping screws are also commonly used to reinforced load-carrying curved or tapered beams because they give greater tensile strength perpendicular to the grain (Blass and Steck 1999, Kasal and Heiduschke 2004, Jonsson 2005). They are equally effective in the repair of cracked wood members using an FRP (Fiber reinforced polymer) sheet or to repair cracked timber connections in-situ, to restore the tensile capacity (Song et al. 2012, Delahunty et al. 2014). Self-tapping screws

can improve the ductility and load-carrying capacity of a bolted timber connection by preventing brittle failure due to splitting or shear (Bejtka and Blaß 2005, Blaß and Schadle 2011). The greatest increase was 80% for a load-carrying ductile connection and 120% for a brittle load-carrying connection. Gehloff et al. (2010) obtained an increase of 38% in the ultimate moment capacity and a significant increase in the stiffness of a bolted beam-column connection, even with a reduced edge distance, using self-tapping screws for reinforcement.

Timber-to-timber connections that are joined using self-tapping screws are a major structural application, and their characteristic strength properties have been well established. Bajtka and Blaß (2002) showed that the withdrawal strength of a self-tapping screw is the same when the penetration angle between the screw axis and the wood grain ranges from 30° to 90°. Hübner et al. (2010) proposed a bilinear model for hardwood timber, which showed a constant withdrawal strength of between 30° and 90° and a decrease to 70% of 5%-percentiles at 30° from 30° to 0°. The nailing of self-tapping screws also affects the structural performance of a joint. Yeh et al. (2014) showed that toe nailing is superior to face nailing, in terms of the maximum load capacity, the initial stiffness, and the dissipated energy, using a beam-girder connection that was fastened using 8 self-tapping screws. They also reported that the maximum shear capacity of a connection fastened with half-threaded self-tapping screws significantly improved when the number of screws was increased from 8 to 12, i.e., 38.6 and 63.3% for 8- and 10-mm screws, respectively. However, no further improvement was seen when either double-threaded or fully threaded screws were used. When the timber members are connected using a metal con-

necter, fasteners such as bolts or dowels are also used. Connections mostly fail because there is a split along the wood grain at the bolted hole caused by the large difference in the strength and stiffness of the wood and the steel bolt (Yeh et al. 2007, 2008). A study of the structural performance of a joint that uses self-tapping screws is logical.

Japanese cedar is the most important commercial plantation timber in Taiwan and is the most suitable local plantation wood for glulam products. However, it is necessary to ensure the strength and quality of glulam and to evaluate the adequacy of the connector performance in timber construction applications. In this study, the characteristic strength properties of a joint constructed using structural glulam members made from fast-grown Japanese cedar were evaluated. Two types of mechanical connectors were developed for the glulam beam-column, using self-tapping screws as fasteners. Both steel and aluminum materials were used for the connectors, to determine their effect on the performance of the structural joint.

MATERIALS AND METHODS

Material preparation

Structural glulam members were produced from 35-yr-old Japanese cedar (*Cryptomeria japonica* D. Don) plantation timber, which was harvested from Hsinchu Forest District, Taiwan Forestry Bureau. The laminar layout for E65-F225 grade symmetric mixed-grade composition glulam with a size of 135×304 mm was assigned following CNS11031 requirements (BSMI 2006). Resorcinol phenol formaldehyde (RPF) adhesive was applied at a rate of 250 g m⁻² at a pressure of 0.98 MPa, during the glulam assembly process. Two inserted mechanical connectors were developed for connections

between the glulam beam and column members. π -type connectors were produced using both SS400 steel and A6061 aluminum of 130 (width) $\times$ 170 (length) $\times$ 280 mm (depth) and 3-mm-thick plates, as shown in Fig. 1. The second mechanical connector was a dovetail type, which was also made of both steel and aluminum. The dovetail connector was 18 (thickness) $\times$ 110 (width) $\times$ 280 mm (depth), as shown in Fig. 2. The size of the connectors and the layout for the fastener locations were determined using spacing requirements for bolt applications, as specified in the Taiwanese building code (Ministry of the Interior 2011).

Self-tapping screws, which have electroplated zinc coatings, of a nominal 8-mm diameter and 120-mm length with a countersunk head were used as fasteners in this study. The dimensions of the self-tapping screws were 5.2 mm in root diameter and 80 mm in thread length, including a 9-mm tip length, 5.2 mm in pitch, and 5.8 mm in shank diameter.

Beam-column assembly and joint test

For a full-size shear evaluation, an H-shaped structure was constructed that had 2 column members on both sides and one short beam member at the center. The respective sizes of the glulam column and beam members were 135 $\times$ 304 $\times$ 800 and 135 $\times$ 304 $\times$ 900 mm. The π -type connector was mounted on the column using pre-drilled holes on the connector and 10 self-tapping screws. The screws were directly fastened through both the beam and 2 aluminum plate extensions when the connector was inserted into the slotted beam member (Fig. 3). Pre-drilled holes on the extension plates were also required for the π steel connector. Amounts of 6, 9, and 12 self-tapping screws were used to fasten each end of a beam member, for both the aluminum and steel connectors used in the study. The dovetail-type connector was mounted on the glulam column member using 2 self-tapping screws driven normally and 8 screws at 60° to the column surface or the longitudinal wood grain, and 3 screws were

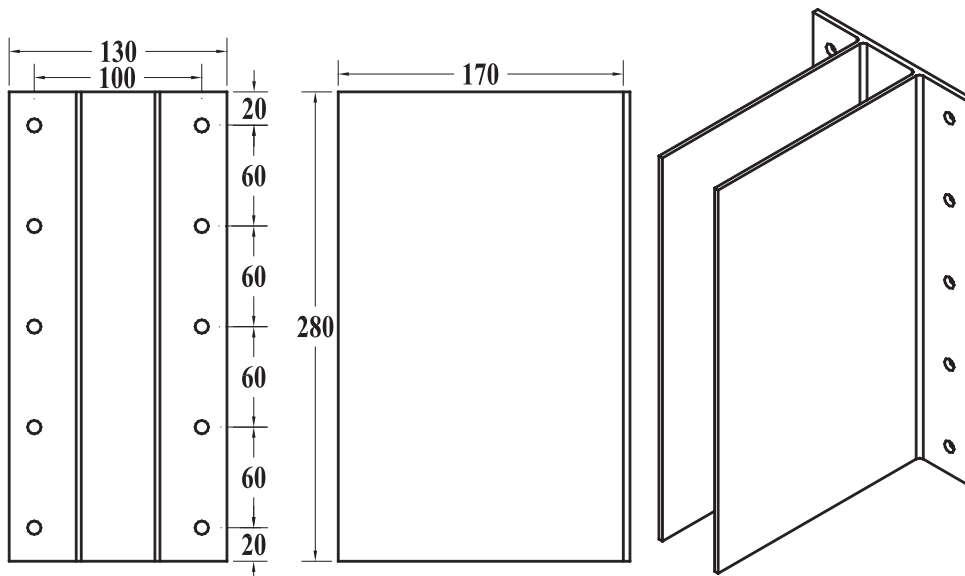


Fig. 1. Aluminum/steel π connectors with a size of 130 $\times$ 170 $\times$ 280 mm and a 3-mm thickness.

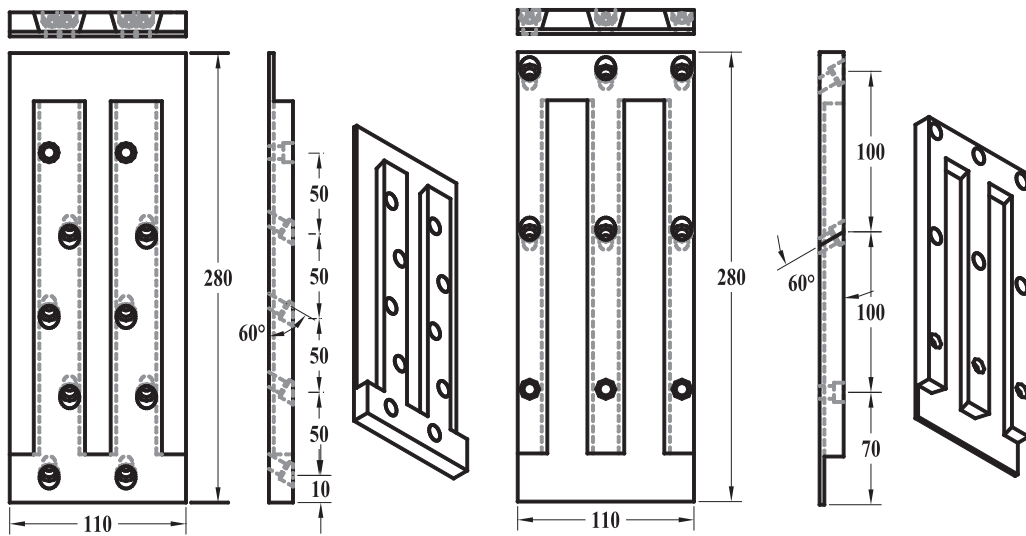


Fig. 2. Aluminum/steel dovetail connectors with size of $18 \times 110 \times 280$ mm.

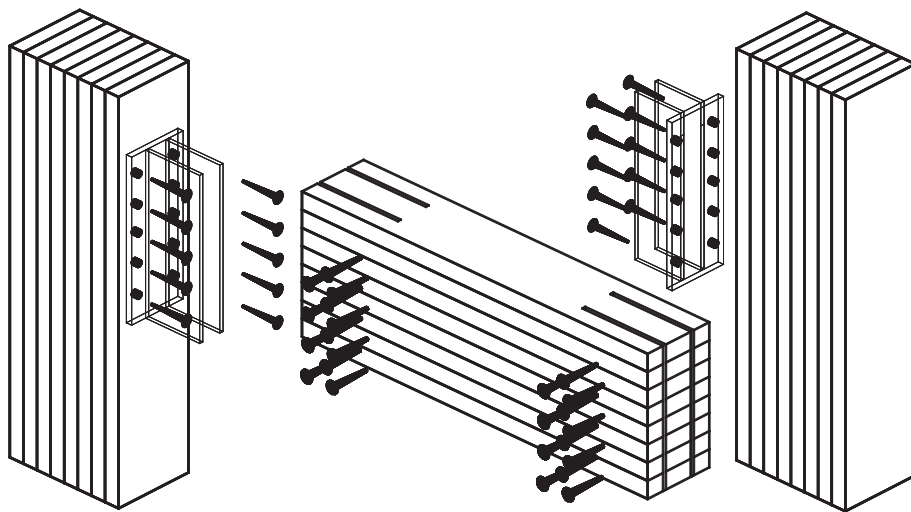


Fig. 3. Configuration of a glulam beam-column connection using π -type aluminum connectors (π -A-12).

fastened at 0° and 6 screws at 30° to the beam axial direction of the beam or the longitudinal wood grain with the aluminum/steel plates on the beam member cross-sections at both ends (Fig. 4). The beam ends were also routed to embed the connectors. The drilling process used an adjustable jig (Ryobi, model VSD-311RS, Hiroshima, Japan). The edge distance

and spacing for the placement of the self-tapping screws followed the recommendations specified in the building code for bolt applications. It requires a distance longer than $7d$ (d , nominal screw diameter) for the fastener spacing and member end distance, and $4d$ for the member edge distance. A hydraulic loading machine with a capacity of 500 kN

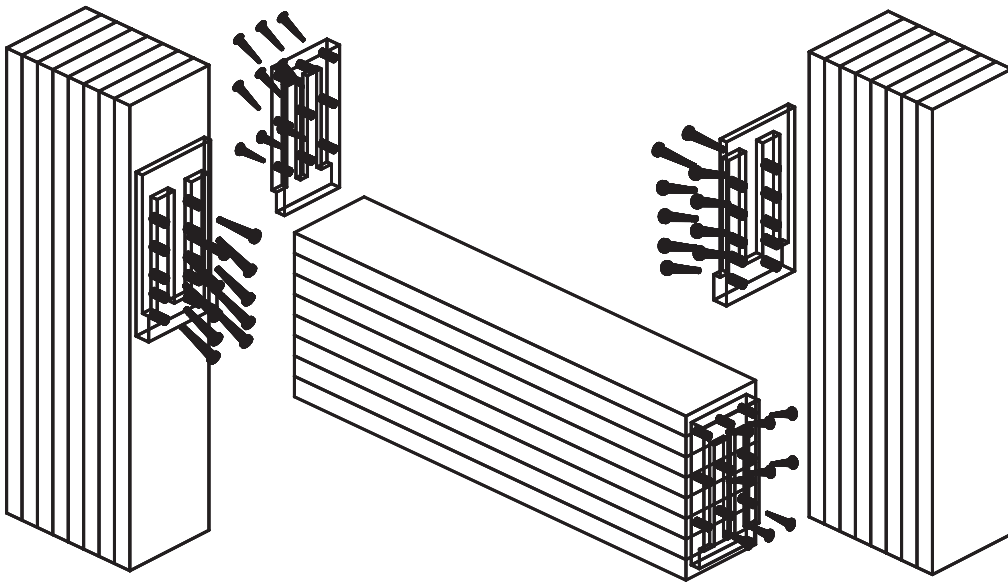


Fig. 4. Configuration of a glulam beam-column connection using dovetail-type aluminum connectors (MT-A).

was used for the test. The specimen, which was constructed using a short beam and 2 columns, was subjected to a centrally concentrated load. In total, 8 different fastening methods were used and each test condition was replicated 3 times. A concentrated load at a speed of $0.8\text{--}5.1\text{ mm min}^{-1}$ was applied at the center of the beam member (Fig. 5). Displacement transducers installed at both ends of the beam measured the vertical displacement of the beam. The characteristic shear properties of the glulam joint fastened with self-tapping screws were then calculated using a method proposed by The Japan Housing and Wood Technology Centre (2001).

The vertical withdrawal resistance from Japanese cedar structural glulam for self-tapping screws was also determined (Fig. 6). The screws penetrated vertically into the wide surface of the glulam member to a depth of 80 mm, as measured from the tip of the self-tapping screw. The shear resistance of a single self-tapping screw inserted through a steel/

aluminum plate was tested in tension perpendicular to the longitudinal wood grain (Fig. 7). To simulate the embedding of a π -type connector fastened with a self-tapping screw, slots at each side of the glulam that accommodated the 2 metal/aluminum plates were produced before drilling. Each test condition was replicated 12 times.

RESULTS AND DISCUSSION

Holding ability of self-tapping screws

The results showed that the average vertical withdrawal capacity of an 8-mm self-tapping screw from a Japanese cedar structural glulam was 12.14 kN, with a standard deviation of 2.16 kN. When the average value was divided by the embedded thread length, the vertical withdrawal resistance was 0.152 kN mm^{-1} . This is 14% less than the value obtained in other studies, in which a longer self-tapping screw of the same diameter was driven into E75-F240 glulam members (Yeh et al.

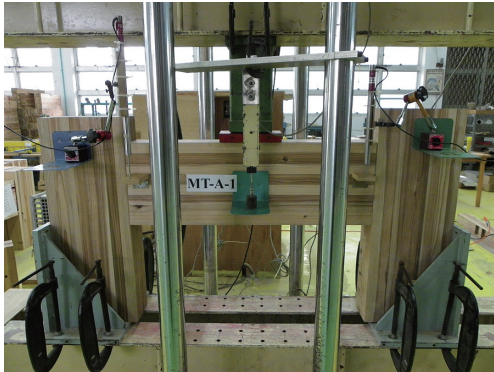


Fig. 5. Shearing test for a glulam beam-column connection.



Fig. 6. Tensile test for the vertical withdrawal resistance of self-tapping screws from a glulam member.



Fig. 7. Tensile test for the shearing strength of a single self-tapping screw through slotted steel/aluminum plates on a glulam member loaded perpendicular to the wood grain.

2014). The difference may have been due to the fact that the screw tip length was included and a higher grade of glulam was used in that work. The estimation of the allowable vertical withdrawal capacity, as specified in the building code for wood screws, could be applied to similar fasteners such as self-tapping screws. Consequently, the allowable vertical withdrawal resistance for a nominal 8-mm screw, estimated with the entire threaded shank's penetration depth is 1.48 kN, which is only 12.2% of the measured values.

Results of the shearing strength test for a single self-tapping screw driven through inserted steel/aluminum plates in to glulam members are shown in Table 1. In most test specimens, the center part of wood between the 2 metal/aluminum plates failed by splitting and separated when subjected to a tensile force perpendicular to the wood grain. Both the maximum shearing capacity (P_{max}) and the yield strength (P_y) results were similar for joints that used metal and aluminum connectors, which shows the suitability of aluminum as an alternative material. When the split resistance is considered, the projected area of the self-tapping screw embedded inside the glulam is estimated using the screw shank diameters and the penetration length. The tensile stress perpendicular to the wood grain at failure is calculated using the projected area of the self-tapping screws. The results were 22.18 and 23.40 MPa for metal-and aluminum-connected joints, respectively. Yeh et al. (2012a) reported a maximum tensile stress of 11.6 MPa for a 15.9-mm dowel loaded similarly, but with a single metal connector inserted. It was found that the self-tapping screw performed more efficiently. The code does not provide a double shear estimation procedure for a screws so the method for a bolted joint was used. For loading perpendicular to the wood grain, the yield force calculated using

Table 1. Shearing capacity of self-tapping screw-joined Japanese cedar glulam with slotted steel and aluminum connectors

Connector type		P_{max} (kN)	P_y (kN)	K (kN/mm)
Steel	Mean	13.45	7.49	2.07
	S.D	2.37	1.59	0.41
Aluminum	Mean	14.19	7.56	3.36
	S.D	2.42	1.64	0.65

P_{max} , maximum load capacity; P_y , yield load; K , stiffness.

the code procedure was 0.549 kN. This is only 7.3% of the experimental value obtained in this study, which demonstrates a conservative estimation procedure for a self-tapping screw assembled with double metal or aluminum plates.

Joint strength properties of beam-column connections

Failure of beam-column connections

Most wood-splitting failures began around the self-tapping screw holes and propagated along the wood grain at the beam ends of the beam-column specimens, when the glulam beam was subjected to a shear load (Fig. 8). This major failure mode occurred in joints assembled using both the π -type and dovetail-type connectors. The failure mode was similar to that for assemblies using bolts or dowel

fasteners (Yeh et al. 2012a, 2012b). However, wood splits occurred evenly at each screwed row across the beam depth in this study, while most wood failures due to vertical shear force in previous studies occurred at bolt holes near the center and lower portions of the glulam beam. Therefore, using slender self-tapping screws as fasteners in joints distributes the shear loads more evenly than the use of rigid bolts or dowels. For π -type connectors, the driven self-tapping screws bent near both the metal and aluminum plates, which resulted in a failure mode that was similar to the yield mode III in the NDS Code (AFPA 1997). There was serious bending of the self-tapping screws when the beam was fastened using metal connectors, but slightly bent self-tapping screws and deformation of the drilled holes occurred when aluminum plates were used. The plate that was attached to the glulam column face also became curved under tension. It was noted that deformation of the self-tapping screws decreased as the number of screws fastened at each beam joint increased from 6 to 12.

For dovetail-type connectors, the driven self-tapping screws bent near the screw head causing 1 plastic hinge point. There was serious bending of the screws at the lower location of the connections at both the beam end and column member where the metal or aluminum plates were attached. There was crushing perpendicular to the grain around the driven holes for all connections, which



Fig. 8. TWood splitting across a glulam beam section fastened with self-tapping screws.

resulted in sliding at the interface between the beam and column members. Prat-Vincent et al. (2010) reported that majority of joist-to-header specimens failed due to screw tension fractures and found that the applied loads exceeded the strength of the screw material when 1 or 2 pairs of self-tapping screws were used. However, this study noted no major screw fracture, so it is appropriate to use more screws at each connection.

Joint strength properties

Figure 9 shows the load-displacement relationship for Japanese cedar glulam beam-column connections that were subjected to a shear load, for 2 connector types and when 6 to 12 self-tapping screws were used. The shearing load capacities are listed in Table 2. This shows that the joint assembled using the dovetail-type connectors was more ductile. Results from the overall testing indicated

that connections assembled using 9 and 12 self-tapping screws showed a slight improvement in the maximum shear loading capacity (P_{max}) over the value for connections using 6 screws. In this study, the aluminum connector performed similarly to the steel connector, in terms of the joint strength. Fujiwara et al. (2007) evaluated the shear strength of spruce glulam beam-column connections using 3 sizes of HOWTEC template metal connectors and 2 or 3 12-mm pins. Values of 25.2~42 kN for P_{max} were obtained. Yeh et al. (2012a) reported a value of 96.9 kN of P_{max} for a Japanese cedar glulam joint assembled using steel T-type connectors and fastened using 4 15.9-mm pins and 1 bolt. This similar shear loading capacity demonstrates the effectiveness of 6 to 12 self-tapping screws. However, the average value for the maximum shear loading capacity for the joint assembled using dovetail-type connectors was 69.6% of that for

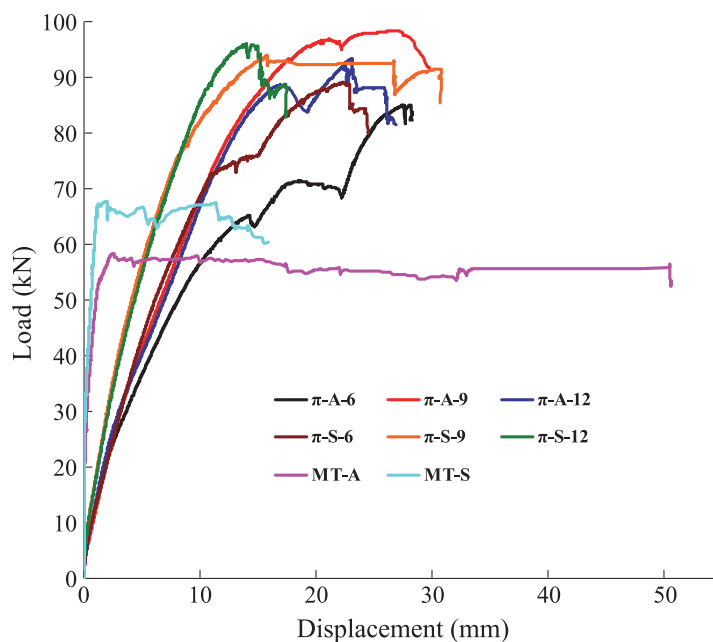


Fig. 9. Load-displacement relationship for Japanese cedar glulam beam-column connections assembled using various connectors and self-tapping screws. Connector types are described in the footnotes to Table 2.

Table 2. Shearing load capacity of a Japanese cedar glulam beam-column connection assembled using different connectors and numbers of self-tapping screws

Connection type	Max. (kN)	Min. (kN)	Mean, P_{max} (kN)	P_y (kN)	P_u (kN)
π -A-6	95.34	86.62	90.49 ± 4.44	47.04 (52.0%)	83.58
π -A-9	100.95	96.89	99.33 ± 2.15	52.55 (52.9%)	92.02
π -A-12	108.42	88.22	100.21 ± 10.62	56.54 (56.4%)	93.45
π -S-6	98.60	76.97	90.04 ± 11.50	51.43 (57.1%)	85.02
π -S-9	108.90	93.50	98.94 ± 8.64	58.18 (58.8%)	93.16
π -S-12	104.15	96.25	98.90 ± 4.55	53.33 (53.9%)	90.59
MT-A	72.26	58.27	63.85 ± 7.41	31.44 (49.2%)	58.88
MT-S	72.53	67.76	70.24 ± 2.39	31.97 (45.5%)	64.52

π , MT, connector type; A, S, aluminum and steel connector materials respectively 6, 9, 12, screw quantity per connection; P_y , P_u , yield strength and ultimate strength respectively, values in () under P_y represent ratios of P_y/P_{max} in %.

π -type connectors. The lower shear loading capacity may have been due to the different screw orientations during assembly. The self-tapping screws were driven into the cross-section of the beam ends when the dovetail-type connectors were attached. For π -type connectors, the screw axis was perpendicular to the wood grain when the screw penetrated into the radial or tangential surface of the glulam. The joint capacity is related to the slenderness (l/d) of the self-tapping screw, where l is the maximum effective penetration length and d is the screw diameter. The most common slenderness values for softwood range from 11 to 27 (Hübner et al. 2010). For the Japanese cedar glulam beam-column connections used in this study, a slenderness value of 15 allowed adequate screw penetration.

To determine the joint strength properties estimated with the load-displacement relationship, we used the method proposed by the Japan Housing and Wood Technology Centre (2001). The respective estimated yield strengths (P_y) of joints assembled using aluminum and steel π connectors were 52.0~56.4% and 53.9~58.8% of the P_{max} . Lower values of 49.2 and 45.5% were respectively obtained for joints assembled using

aluminum and steel dovetail-type connectors. The study of a joint assembled using pin fasteners and T-type steel connectors gave a value of 73.0%, for P_y/P_{max} (Yeh et al. 2012a). Results of this study showed that the joint fastened using the dovetail-type connector had much greater initial stiffness than the joint fastened using the π -type connector (Fig. 10). The bending of self-tapping screws in the π -type connection may have caused larger deformation than that of screws in the dovetail-type connection, during the shearing load application. Hayashi et al. (2002) reported that respective values of initial stiffness for sugi glulam girder-beam and post-beam joints using a Haratec connector with 3 pieces of 13-mm drift pins were 4.75~7.93 and 3.57~7.54 kN/mm for a standard connector with 2 pins. Nakashima et al. (2006) also obtained values of initial stiffness of 6.5~8.8 kN/mm for both the sugi glulam girder-beam and post-beam joints using a double shear plate Kuretec connector with 3 or 4 12-mm drift pins. It is expected that increasing the number of self-tapping screws and distributing them evenly on the beam section will improve the initial stiffness of the joints. In this study, the connector using steel material performed better

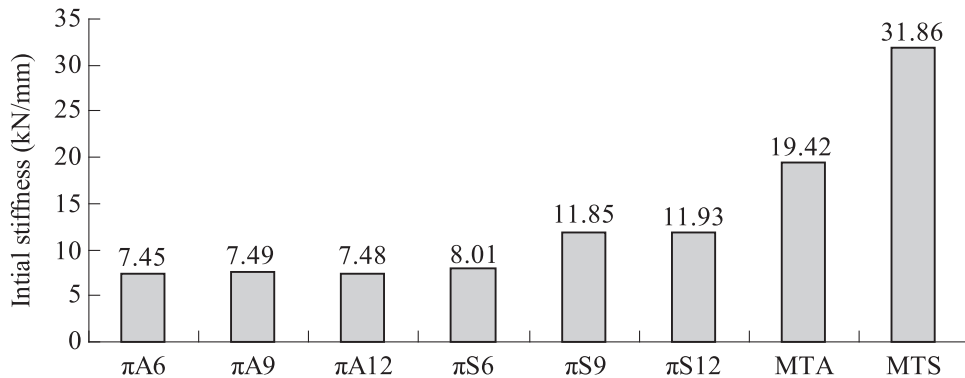


Fig. 10. Initial stiffness values of Japanese cedar glulam beam-column connections fastened using self-tapping screws. Connector types are described in the footnotes to Table 2.

than the aluminum connector in terms of joint rigidity. Yeh et al. (2014) reported that the initial stiffness of a beam-girder connection, assembled using only self-tapping screws without a metal connector, improved by 50.4 to 200% when the number of self-tapping screws was increased from 8 to 12. In this study, when the aluminum and steel π -type connectors were inserted in the joint configuration, the initial stiffness values were 7.48 and 11.93 kN/mm, respectively, for connections using 12 self-tapping screws, compared to values of 11.1 kN/mm from other studies. The effect of the quantity of fasteners on the initial stiffness also has some limitations.

The plastic behavior or ductility of a beam-column joint depends on the type of connectors and the quantity of fasteners. The ductility factor of a connection is defined as the ratio of the maximum deformation limit to the yield deformation limit from the test results. The joints assembled using π connectors and 6–12 self-tapping screws had a lower ductility factor ($\mu = 2.65$ on average), which indicates a tendency toward brittle joint performance (Fig. 11). There was no difference in joint ductility when aluminum or steel connectors were used. Nakata and Komatsu (2009b) reported values of 1.84 and 2.50 for

the ductility factor for glulam column-to-base joints connected using 9-mm steel plates and 8–12 pins, in moment-application tests. The characteristic ductility of a joint assembled using self-tapping screws is similar to that for assembly using steel plates and pins. Yeh et al. (2014) reported that respective ductility values of a beam-girder connection assembled using only self-tapping screws, without a metal connector, were 1.61 and 1.78 when 8 and 12 self-tapping screws were used. In this study, when a π -type connector was inserted in the joint configuration, average respective ductility values for connections using 6, 9, and 12 self-tapping screws were 2.42, 3.28, and 2.25.

Dovetail-type joints allow a plastic joint; i.e., $\mu = 58.4$ for a steel connector and 167.1 for an aluminum connector. Nakata and Komatsu (2009a) also reported values of 6.34–6.97 for joints connected using both compressed LVL plates and pins, which exhibit significant plastic behavior.

The dissipated energy of a glulam beam-column joint is estimated using the idealized elastic-plastic relationship between an applied load and the corresponding deformation (The Japan Housing and Wood Technology Centre 2001). The dissipated energy of a joint

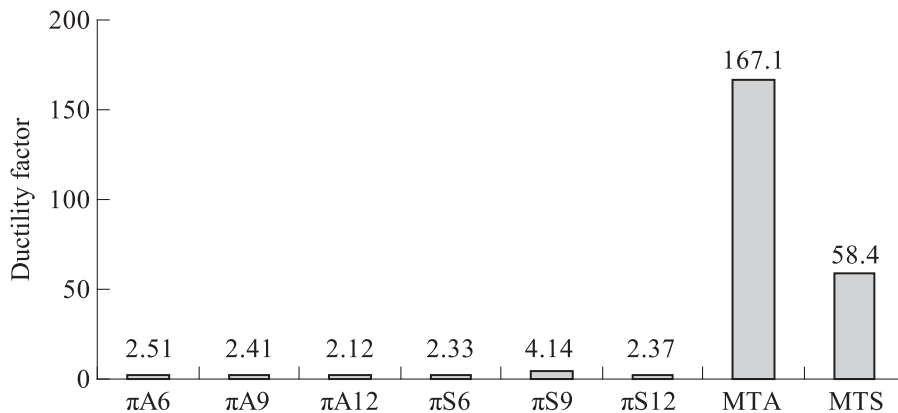


Fig. 11. Ductility factors for Japanese cedar glulam beam-column connections fastened using self-tapping screws. Connector types are described in the footnotes to Table 2.

represents its tendency to reduce the risk of instant crush failure during application of a load. The dissipated energy of a joint fastened using π connectors and 9 self-tapping screws was greater than that for 6 or 12 screws (Fig. 12). Hayashi et al. (2002) reported that a sugi glulam beam-column joint assembled using standard connectors and 2 13-mm drift pins had a dissipated energy of between 1.32 and 1.63 kN·mm for a large displacement. Values between 1.96 and 2.65 kN·mm were also obtained for Douglas-fir glulam specimens. These gave similar test results to those for π -type connectors. Joints assembled using aluminum dovetail-type connectors also produced 3 times more dissipated energy than steel dovetail-type connectors, because the steel dovetail connectors used in this study allowed only a small amount of displacement at the joint.

Allowable shear capacity for a connection

Allowable shear loads for the glulam beam-column connection fastened with self-tapping screws and connectors were estimated using ASTM recommendations. Allowable values use the smallest of the values for the test strength limit and test deflection limit

(ASTM 2005). The test strength limit for a specific beam-column joint is the lowest ultimate load for the tested specimens divided by 3.0. The average value of all tested joint specimens measured at a 3.175-mm vertical deflection was the test deflection limit load. Table 3 shows the critical allowable loads for beam-column joints, as determined using the test strength limit. On average, the π -type connection allowed a 42.4% greater allowable shear load capacity than did dovetail-type connections based on the ASTM approach. The allowable shear load for a joint was also derived using the method proposed by the Japanese Housing and Wood Technology Centre at the 5th percentile, with a 75% confidence interval (The Japan Housing and Wood Technology Centre 2001). This also shows that the P_y value and not the P_{max} value is a decisive factor when the connection is subjected to a shearing load. Allowable shear loads in the π -A-12 and π -S-12 joints were lower because of the large variation in the test results due to a high tendency of the wood to split when more fasteners were applied within the same assembly area. This means that the effect of the number of self-tapping screws used is not certain. On average, the π -type con-

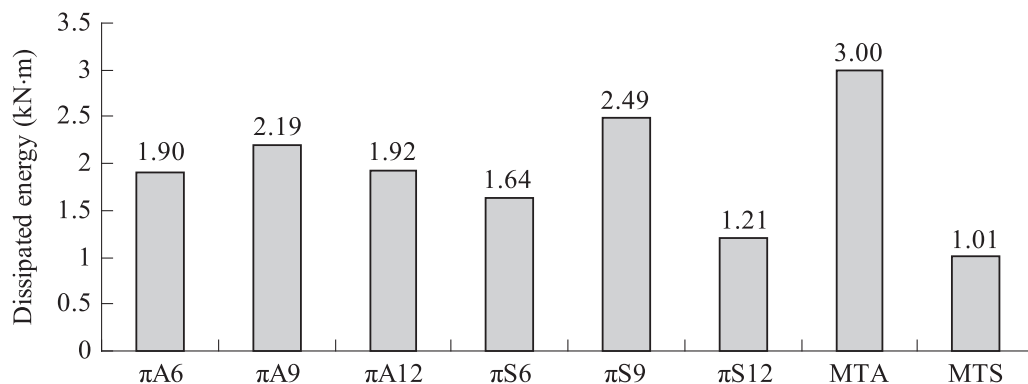


Fig. 12. Energy dissipation for Japanese cedar glulam beam-column connections fastened using self-tapping screws. Connector types are described in the footnotes to Table 2.

Table 3. Derived allowable shearing capacity for Japanese cedar glulam beam-column connections assembled using different connectors and numbers of self-tapping screws

Connection type	P_{a-SL} (kN)	P_{a-DL} (kN)	$2/3P_{a-max}$ (kN)	P_{a-yld} (kN)
π-A-6	28.9	30.0	51.0	35.9
π-A-9	32.3	36.1	61.7	48.8
π-A-12	29.4	30.1	44.5	17.4
π-S-6	25.7	36.8	35.9	34.1
π-S-9	31.2	45.3	47.8	47.9
π-S-12	32.1	40.3	56.4	23.0
MT-A	19.4	50.4	27.0	19.5
MT-S	22.6	62.4	41.8	29.1

π, MT, connector type; A, S, aluminum and steel connector materials, respectively; 6, 9, 12, screw quantity per connection; P_{a-SL} , P_{a-DL} , allowable load based on the test strength limit and test deflection limit, respectively; P_{a-max} , P_{a-yld} , allowable load based on P_{max} and P_y , respectively.

nection also showed a 42.0% greater allowable shear load than dovetail-type connections based on the Japanese approach. In general, the allowable values obtained using the strength limit were lower than those derived from P_y , and were about 28.5~32.5% of the average value for P_{max} . Yeh et al. (2014) estimated the allowable joint stresses for a 300×140-mm Japanese glulam beam-girder that was directly fastened using 8 or 12 self-tapping screws, with no metal connector, and respective P_{a-SL} values of 7.36~11.22 and 9.31~12.74 kN were obtained. These results show the advantage of using a metal connector.

CONCLUSIONS

Structural glulam members fabricated using fast-grown Japanese cedar plantation timber were constructed into a beam-column structure, using different numbers of self-tapping screws and 2 types of connector, to evaluate the characteristic shear capacity of the connections for wood-framed construction applications. The connection assembled using the π-type connector gave better shear performance, in terms of the maximum load capacity and yield strength, than did the dovetail-type connector. The dovetail-type connection

had greater initial stiffness and ductility than the π -type connection. Similar shear resisting performances for the π -type joint were found for both the aluminum and steel connectors, but the aluminum connector was easier to use during assembly. For dovetail-type connections, aluminum connectors gave greater ductility and dissipated more energy from the joint than did steel connectors, but the initial stiffness was lower less. The critical allowable shear loading capacity for a connector fastened using self-tapping screws in a Japanese cedar glulam structure was derived using the strength limit or yield strength.

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