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EVALUATION OF BEARING STRENGTH PERFORMANCE OF STS CONNECTION ACCORDING TO BEARING SECTION ON LOADING DIRECTION

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ABSTRACT: Since self-tapping screws (STS) are widely used for structural cross-laminated timber(CLT) connections, the bearing performance according to the shape information of fasteners is required to design connections for CLT. In this study, to evaluate the bearing strength of STS connection using the lamina of domestic softwoods, the half-holed bearing test was conducted according to the bearing section on loading direction. The species of lamina were japanese larch, korean pine and japanese cedar. The specimen was prepared according to the thread part (thread + tip) and shank part (shank + shank cutter) of STS and three types of diameters (8, 10, 12 mm) in the bearing section (cross section, radial section, tangential section). The 5 % offset yield bearing load of cross section of japanese larch was the highest value according to the specific gravity of laminas. As the diameter of STS increased, the bearing load showed a tendency to decrease. Even STS with same diameter, the bearing strength of thread part was higher than shank part due to the difference of effective bearing area.

KEYWORDS: Self tapping screw, Bearing strength, Connection, Domestic softwood, Half-holed test

1 INTRODUCTION

The use of engineered wood, known as a carbon storage, has expanded the scale of wooden buildings. The cross laminated timber (CLT), which is generally used in high-rise wooden buildings, is one of the engineered woods and is widely used for shear walls and floors. The lateral resistance of a wooden structure is an important design value to secure its seismic performance. The strength performance of the CLT itself and the lateral strength performance of the connection are important factors for the lateral resistance capacity of the CLT structure. The self-tapping screw (STS) are mainly used for CLT connections. The lateral strength design of the connection can be predicted by the bending performance of the fastener and the bearing strength of members of connection by Korean Design Standard (KDS). In this study, to evaluate on the bearing strength performance of STS connection, the bearing test of CLT using the domestic species was conducted according to the shape of STS and loading direction to the grain.

2 EXPERIMENTAL

2.1 MATERIAL

As the lamina for the CLT, japanese larch (*Larix kaempferi* Carr.), korean pine (*Pinus koraiensis*) and japanese cedar (*Cryptomeria japonica*) were used, which are structural materials for softwoods in Korea (KS F 2020). The cross section of specimens was 50 × 50 mm. The fasteners used in the bearing strength test were the self-tapping screw (galvanized carbon steel) from Rothoblaas (Italia) shown in Figure 2. The type of STS ccording to the diameter is divided into 3 types (8, 10, 12 mm), and their length is 120 mm. The diameter (ds) of the shank was 5.8 mm, 7.0 mm and 8 mm, and the diameter (dc) of the shank cutter was 6.8 mm, 8.4 mm and 9 mm, which is larger than the diameter of the shank. The diameter of the thread is divided into an inner diameter (d2) and an outer diameter (d1).

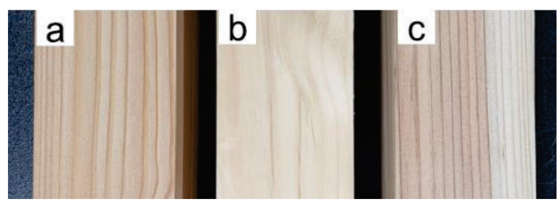

Figure 1: *Photographs of timber (a- Japanese larch, b- Korea pine, c- Japanese cedar)*

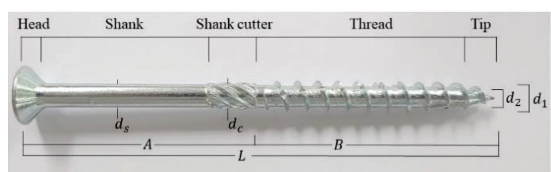

Figure 2: *Photographs and details of self-tapping screw*

The bearing strength test specimens is classified and manufactured according to the shape of STS fastener in bearing section. The bearing part of STS fastener was divided into T-series for bearing with the thread of STS and the S-series for bearing with a shank. The nomenclature of specimens was named according to the species and species cross-section, 8, 10, and 12 mm of the

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__Table 1:__ Dimension information of Self-tapping screw on diameters

CODE	L	A	B	d_1	d_2	d_s	d_c
HBS8120	120	60	60	8	5.4	5.8	6.8
HBS10120	120	60	60	10	6.4	7	8.4
HBS12120	120	40	80	12	6.8	8	9

L: Total length of self-tapping screw
A: Length of shank and shank cutter part in the self-tapping screw
B: Length of thread part in the self-tapping screw
d_1: Inner diameter of thread part in the self-tapping screw
d_2: Outer diameter of thread part in the self-tapping screw
d_s: Diameter of the shank part in the self-tapping screw
d_c: Diameter of the shank cutter part in the self-tapping screw

__Table 2:__ Types of Specimens and Nomenclature

Species	Gain Directions	Nomenclature On diameter and shape information of STS				
		Thread + Tip			Shank + Shank Cutter	
		8 mm	10 mm	12 mm	8 mm	10 mm
Japanese larch *(Larix kaempferi Car.)*	Longitudinal section	LC8T	LC10T	LC12T	LC8S	LC10S
	Radial section	LR8T	LR10T	LR12T	LR8S	LR10S
	Tangential section	LT8T	LT10T	LT12T	LT8S	LT10S
Korean pine *(Pinus koraiensis)*	Longitudinal section	KC8T	KC10T	KC12T	KC8S	KC10S
	Radial section	KR8T	KR10T	KR12T	KR8S	KR10S
	Tangential section	KT8T	KT10T	KT12T	KT8S	KT10S
Japanese cedar *(Cryptomeria japonica)*	Longitudinal section	CC8T	CC10T	CC12T	CC8S	CC10S
	Radial section	CR8T	CR10T	CR12T	CR8S	CR10S
	Tangential section	CT8T	CT10T	CT12T	CT8S	CT10S

STS standard diameter (d1), and the location of the bearing STS (thread part and sank part). The STS with a diameter of 12 mm was not tested due to the fact that the length of the shank was 40 mm shorter than the length of the specimen. A total of 450 specimens were produced, 10 specimens for each type.

2.2 METHODS

The half-holed bearing test of STS connections was conducted in accordance with KS F 2156. The bearing test specimens was drilled with the diameter of STS fastener. The T-series was tested by inserting it into the groove so that only the thread part, excluding the tip part, was in contact. S-series included both shank and shank cutter, and tested after inserting STS into the groove. A bearing load and an embedment were measured by the universal testing machine (Instron 5585) with the 30 ton load capacity. The loading speed was 0.5 mm/min.

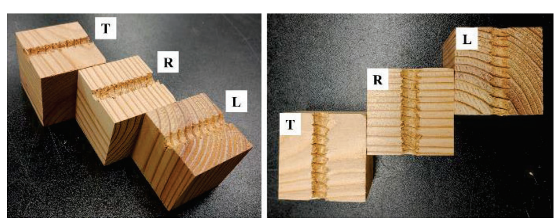

__Figure 3:__ Configuration of bearing test specimen (note : C, R and T means the cross, radial and tangential section of specimens respectively.)

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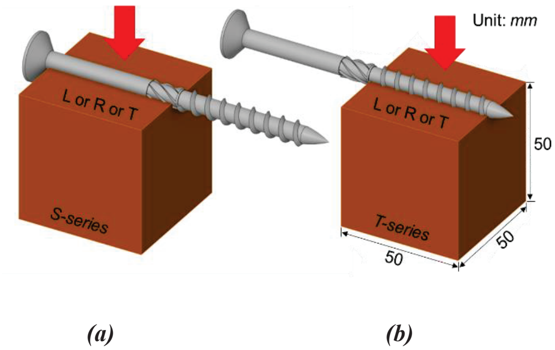


Figure 4: *Direction of bearing loading on types (a : S-series, b : T-series).*

3 RESULTS AND DISCUSSION

3.1 5% OFFSET YIELD LOAD ACCORDING TO SPECIES AND BEARING SECTION

The maximum load of the specimens in longitudinal section is easy to measure because of the clear load drop, but the maximum load of the radial and tangential sections specimens is difficult to measure because the load drop is not clear. Therefore, the bearing strength was calculated jointly as the yield strength, and the results were compared and analyzed.

The yield strength was calculated by the 5% offset of the thread diameter of the STS fastener. The yield strength was calculated according to KS F 2156 (2017). First, the initial straight line of the load-deformation curve obtained in the experiment was shifted 5% of the STS diameter in parallel, as shown in Fig. 6. Then, the yield load way was calculated at the intersection of the moved straight line and the load-deformation curve.

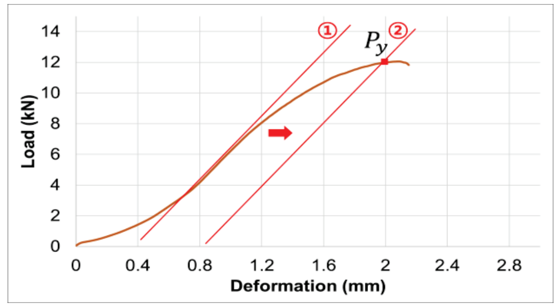


***Figure 6**: Load-deformation curve at 5% offset yield load*

Figure 8 shows the average yield load of softwood with STS. The average yield load by tree species was calculated as 6.01 kN for Japanese larch, 5.47 kN for Korean pine, and 4.15 kN for Japanese cedar, with the yield load in the order of Japanese larch, Korean pine, and cedar. It appears that a higher specific gravity of the species resulted in a higher yield load.

The average yield load of the longitudinal section was the highest in all directions at 7.93 kN, the radial section was 3.69 kN, and the tangential section had the lowest yield load at 4.01 kN. The average coefficient of variation was 0.18, 0.14, and 0.18, respectively, and the reliability of the value was high.

For the longitudinal section, the loading direction and the grain direction are parallel, so it can be assumed that the resistance to the bearing load is large. This phenomenon shows a similar trend in structural glulam (Kim and Hong 2008). According to STS type, the average yield load tended to increase with increasing diameter, and the T-series had a higher average yield load than the S-series.

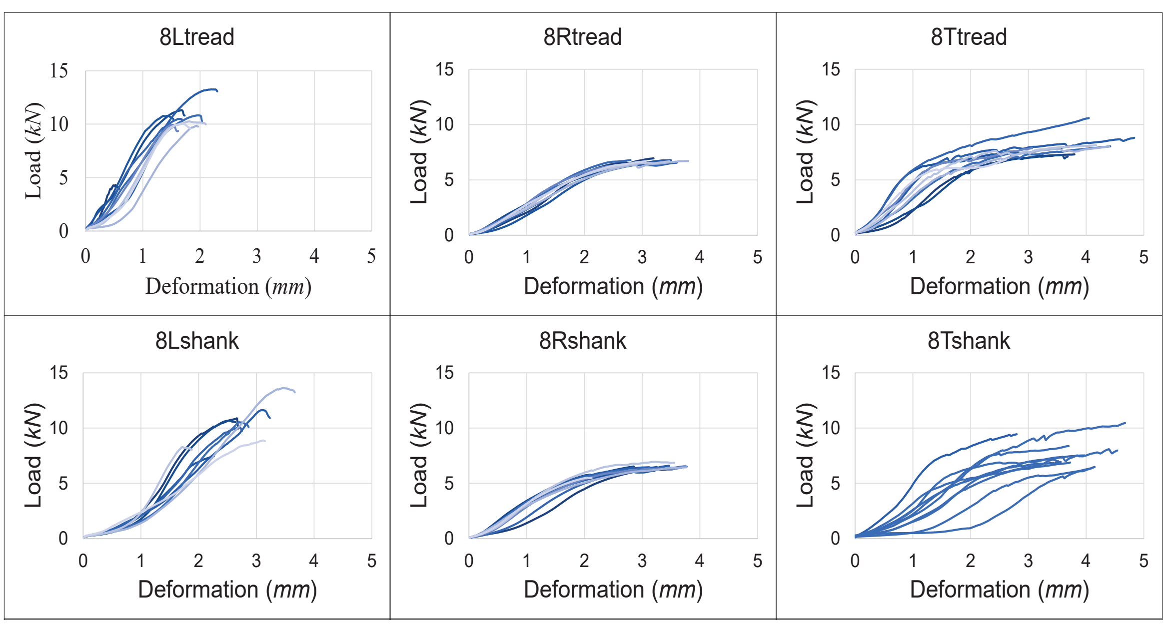


Figure 5: *Load—deformation curves of Japanese larch specimens with 8mm diameter of STS*

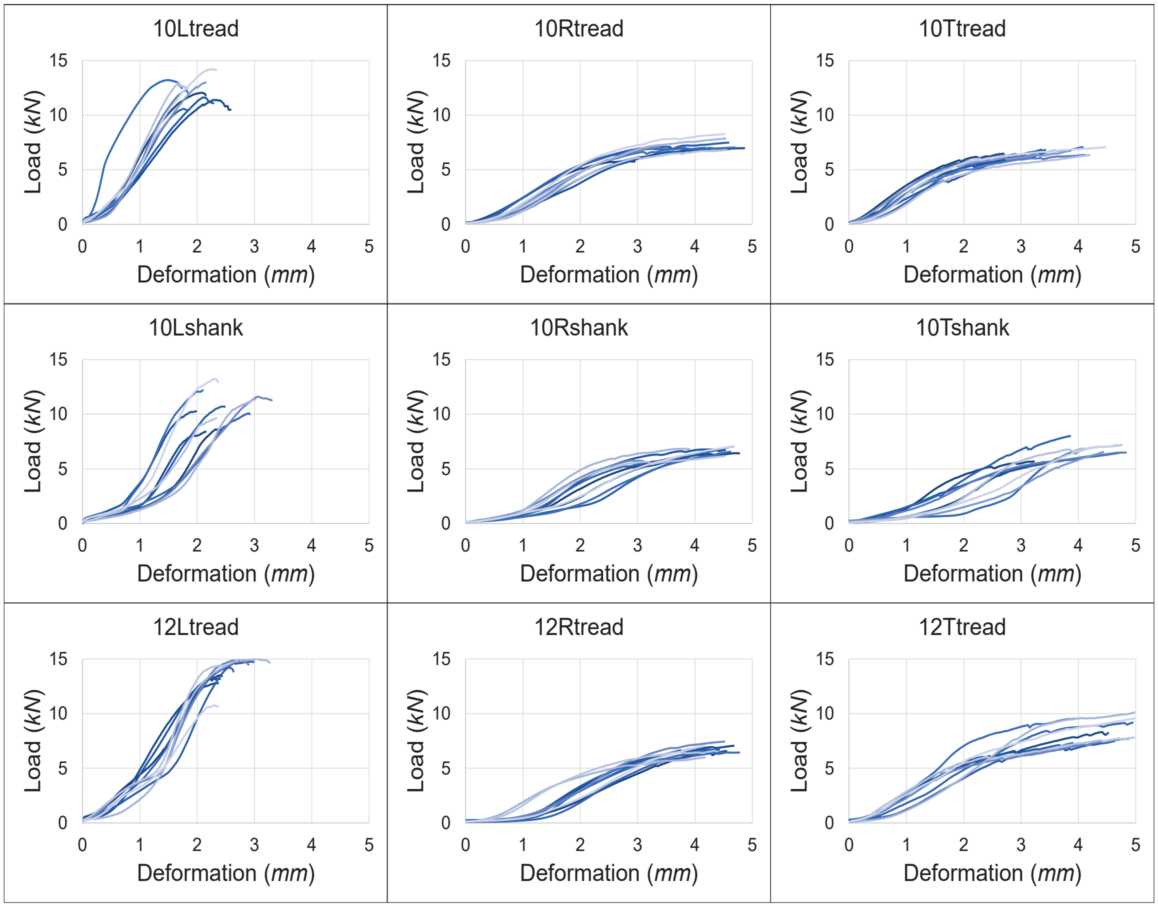
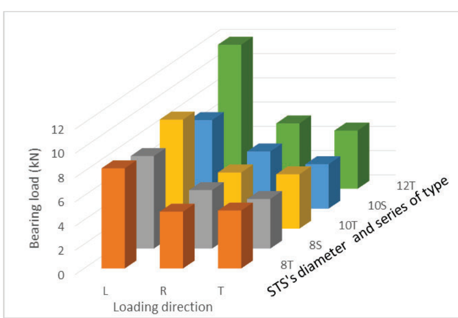
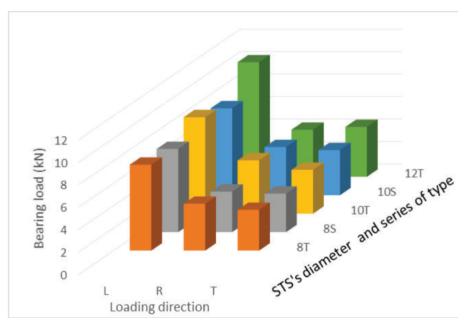


Figure 7: *Load—deformation curves of Japanese larch specimens with 10mm and 12mm diameter of STS*



(a)



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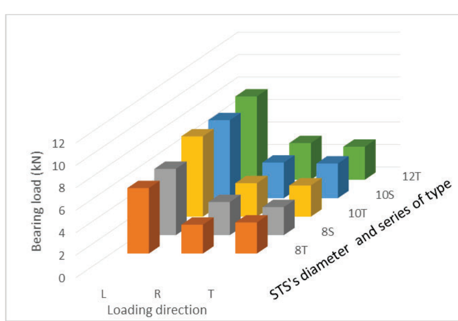

(C)

Figure 8: *Relationship of 5% offset bearing load on loading direction and STS's diameter types(a-Japanese larch, b-Korean pine, c-Japanese cedar*

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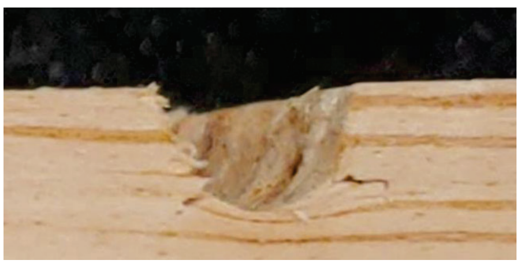
In case of the series of STS, the average yield load of the T-series specimens with 8mm STS was measured 0.87 ~ 1.17 times than the S-series. The average yield load of the T-series specimens with 10mm STS was measured 0.90 ~ 1.23 times than the S-series. It is considered to because the bearing area of the S-series is smaller than that of the T-series.

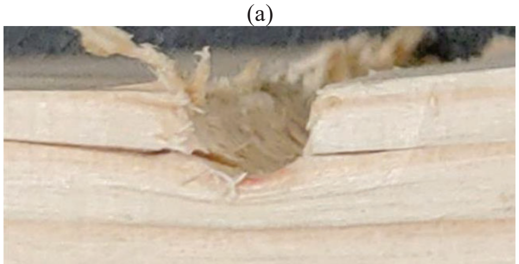
3.2 FAILURE MODE UNDER BEARING LOAD

Most of the failure modes of the specimens on the longitudinal section showed that the wood split slightly along the direction of the grain in parallel to the loading direction by STS.

In case of the specimens on radial and tangential secion, the failure mode of bearing area showed that the bearing load at the shank or thread part of STS were concentrated the wood in perpendicular to the grain, resulting in short cleavage. This is the same result as the failure mode for each direction of the pine wood in a previous study (Lee *et. al.* 2022).



(a)



(b)

Figure 9: *Failure mode of the radial specimens on T-series(a-Japanese larch, b-Korean pine)*

4 CONCLUSIONS

To evaluate the bearing strength performance of STS connection using domestic species, the bearing test on the loading direction to the grain was conducted. The conclusions can be drawn as follows :

1. The bearing load showed a proportional relationship with the specific gravity of the species and the STS diameter.

2. Since the effective bearing area of shank and thread parts of STS is different according to the shape's characteristics of STS, it is necessary to reflect this in the prediction formula of the bearing strength for the connection design.

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