MyTiCon Timber Connectors

ASSY® STRUCTURAL SCREWS
WITHDRAWAL VALIDATION TESTING IN S-P-F
CROSS LAMINATED TIMBER (CLT)

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1. INTRODUCTION

The Withdrawal (pull-out) capacity of ASSY® structural self tapping screws (STS) in S-P-F based Cross Laminated Timber (CLT) was the subject of the verification research project that recently concluded at the University of British Columbia. The purpose of this test campaign was to validate the withdrawal capacity of 5/16" (8mm) and 3/8" (10mm) outside thread diameter fasteners against previously obtained research data, as well as the currently utilized Design Values that are available for STS screws from CCMC Report 13677-R (Canada), and ICC Reports 3178.

Three parameters were varied in this project:

1. Fastener outside thread diameter - 5/16" and 3/8" (8mm and 10mm)
2. Fastener penetration depth into CLT — 8 and 12 times the diameter (8*d* and 12*d*)
3. Angle of insertion of the fastener axis relative to the grain orientation of the top layer—90° and 45°

A further goal was to confirm the inherent factors of safety in design values versus actual capacities of the screws. Safety ratios were found to be as high as a factor of 2.8.

2. TEST SETUP

The testing campaign took place at the University of British Columbia's Centre for Advanced Wood Processing (CAWP). Testing was performed on STS in Canadian Cross Laminated Timber (SPF, G=0.42). The general test setup, as illustrated in Figures 1 and 2, consisted of CLT samples fixed to the test table with STS drilled in from the top.

The STS where then pulled out by a test fixture that was directly connected to a hydraulic actuator. The actuator was displacement controlled and therefore pulled on the STS at a constant rate of 1/8"/min (3.50 mm/min). Additionally, the test was stopped when the capacity of the screws in withdrawal decreased to about 80% of the peak load. It can be noted that for ease of testing execution, instead of driving the screws at 45° to the direction of the grain of the top layer, the specimens were cut at 45° and then placed flat on the testing fixture.

Fig.1 : Test Setup for Withdrawal of STS in CLT at 90° (Source: UBC)

Fig.2: Test Setup for Withdrawal of STS in CLT at 45° (Source: UBC)

3. Test Results: Load-Displacement Curves

Load-Displacement curves are an essential piece of information obtained by testing. A better understanding of the behaviour of CLT assemblies and/or timber connection systems is obtained. In this test campaign, the load-displacement curves that are presented, are the displacement recordings of the actuator head plotted against the recorded load in the actuator's load cell.

It is quite important to recognize that due to the test setup utilized and the fact that displacement measurements were obtained through the actuator displacement, these plots exhibit a much "softer" response than what is the true behaviour of self-tapping screws in withdrawal. This is simply because slip will occur within the test apparatus and fixtures that are not intrinsic with the specific behaviour of the screws. Yet, even though the actual stiffness values can not (and should not) be obtained from these plots, several key performance characteristics can be determined. The recorded load displacement relationship curves for 5/16" fasteners are shown in Fig.3, and respectively for 3/8" fasteners in Fig.4.

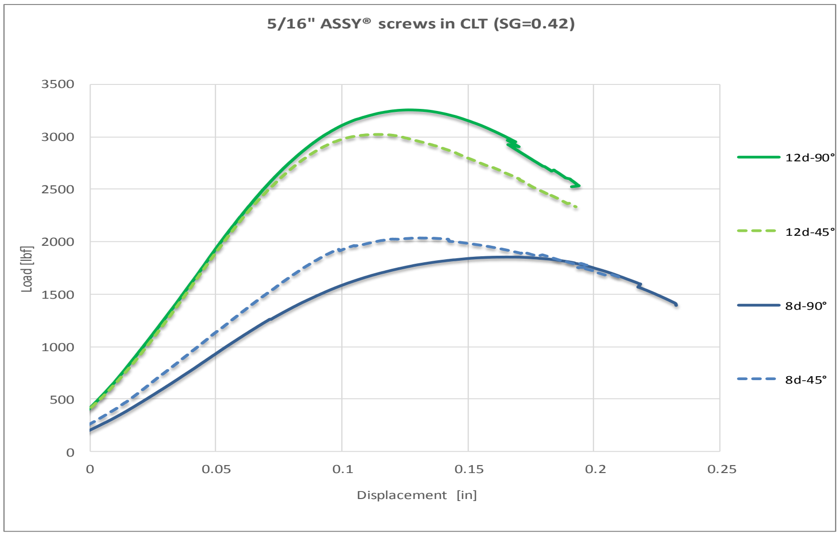


Fig.3 Avg. Load-Displacement curves for 5/16" STS in CLT

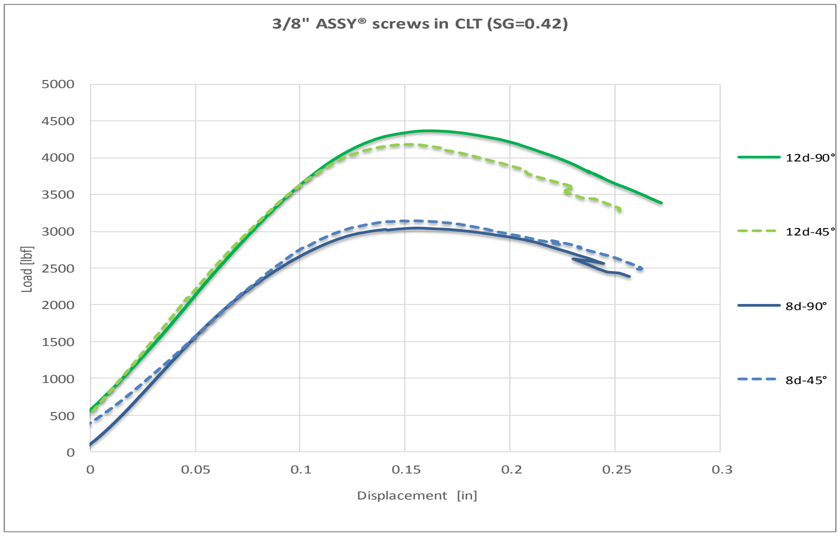


Fig.4 Avg. Load-Displacement curves for 3/8" STS in CLT

A summary of the obtained results is presented in Table 1. First, the average Peak Loads attained are presented. Interestingly, for both 5/16” and 3/8” fasteners, the average peak load at 12*d* embedment is higher at 90° than for fasteners at 45°. Conversely, at 8*d* embedment, the average peak load is higher for fasteners at 45° than for fasteners at 90°. This phenomenon may be attributed to the selected test configuration. Due to the setup screws barely engage the top layer and therefore for 8*d* penetration most of the fastener’s axis runs at 45° to the orientation of the grain. However for 12*d* penetration, the fastener extends all the way to the third layer and now only about 60% of the embedment length is at 45° to the grain and the remainder is embedded perpendicular to the grain of the third cross layer. The typical failure modes observed for both test series are shown in Figures 5 and 6, which are consistent with the expected associated rather brittle nature of mechanical fasteners in withdrawal.

Table 1. Summary of Results

Series	Avg. Peak Load [lbf]		5% Peak Load [lbf]		C.O.V [%]		Std. Deviation [lbf]	
	8*d*	12*d*	8*d*	12*d*	8*d*	12*d*	8*d*	12*d*
5/16” @ 90°	1,899	3,432	1,527	2,911	16.5	12.0	1,395	1,832
5/16” @ 45°	2,183	3,135	1,558	2,290	14.5	14.5	1,407	2,017
3/8” @ 90°	3,108	4,436	2,703	3,650	9.8	14.9	1,360	2,939
3/8” @ 45°	3,280	4,432	2,737	3,643	13.2	12.9	1,928	2,552

Second, a general idea of the behaviour associated with self-tapping wood screws in CLT can be obtained. From a serviceability standpoint, it can be seen that the effect of angle of insertion of screws in CLT does not seem to have a significant impact on stiffness. Additionally, it can also be observed that within the linear region the stiffness of fasteners at the same embedment length but inserted at a different angle relative to the grain of the top layer, do not exhibit significant variation.

One may state, that a deeper embedment may result in higher stiffness values and higher average peak loads for structural screws in withdrawal up until the upper boundary, the tensile resistance of the screw, is reached. Yet, the angle of insertion seems to have a slight effect on the behaviour of STS in withdrawal. As pointed out, this can be attributed to the fact that a variety of screw in angles are apparent when fasteners are driven inclined into CLT.

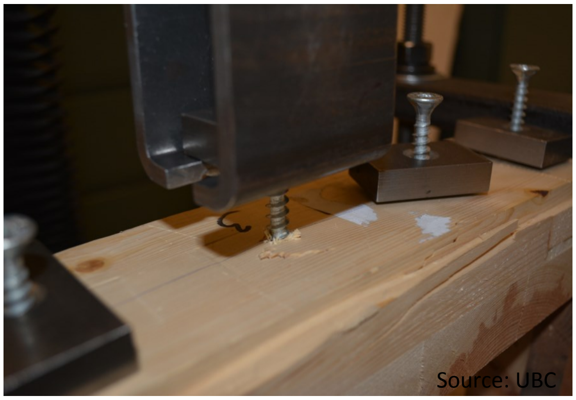


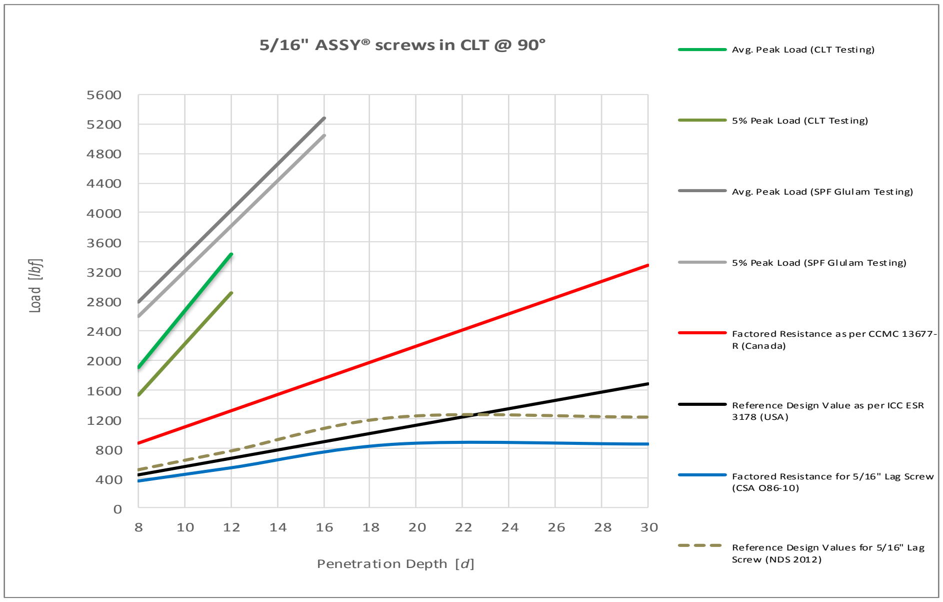
Fig.5 Typical Failure mode at 90° in CLT

Fig.6 Typical Failure mode at 45° in CLT

4. Comparison of Test Results vs. Design Values

Obtained results consistently provided reasonable variance (COV consistently between 13-16%), for the purposes of design and an essential factor of safety was found.

The following plots depict this phenomenon in an illustrative manner. First, 5/16” (8mm) screws’ average peak loads obtained during this test campaign is compared against calculated 5th percentile test values, as well as design values constructed from their respective Canadian and US Code approvals. Even though these approvals utilize two very different design approaches, the plots nicely demonstrate the inherent margin of safety. Additionally, the withdrawal test results for ASSY fully threaded screws in SPF Glulam are also plotted. This simply aims to illustrate the performance differences utilizing the same material species but different material quality i.e. lower and higher density. Figures 7 and 8 illustrate these findings for 5/16” diameter STS embedded at 90° and 45°, respectively.



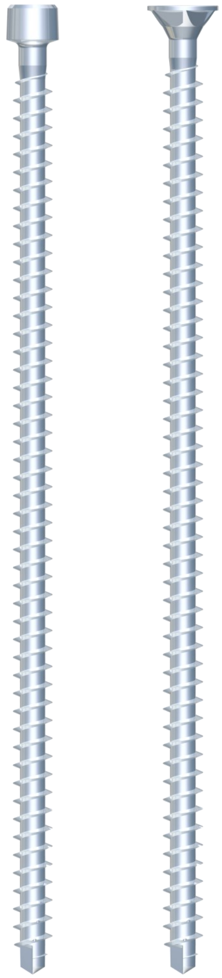


Fig.7 Comparison of 5/16” @ 90° in CLT vs. Design Values

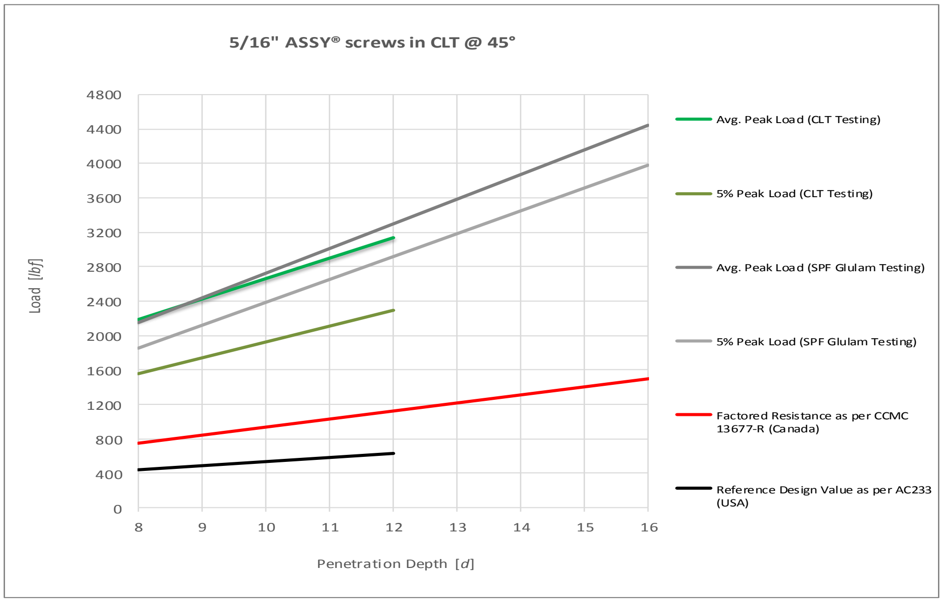


Fig.8 Comparison of 5/16” @ 45° in CLT vs. Design Values

Similarly, Figures 9 and 10 illustrate the findings for 3/8" fasteners embedded at 90° and 45°, respectively.

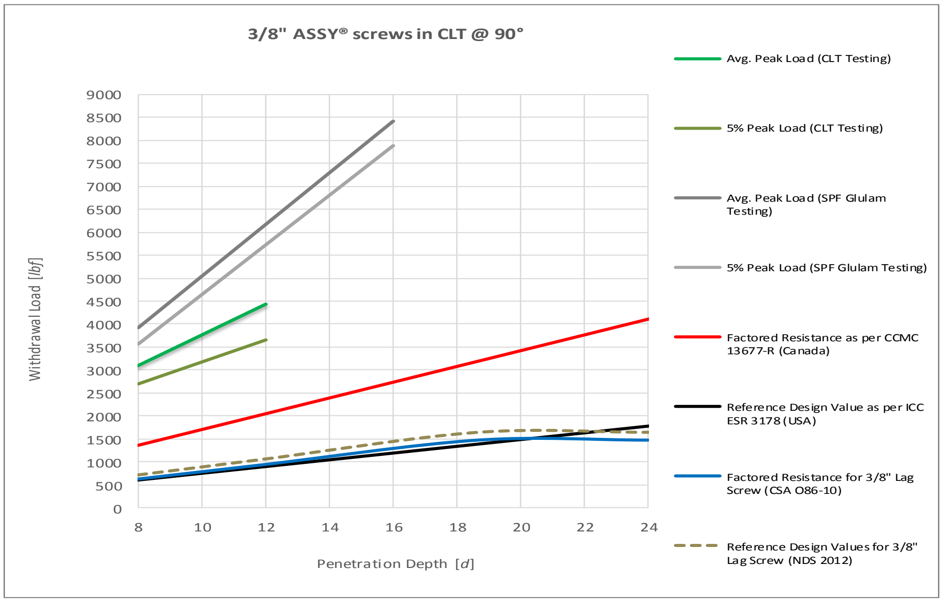
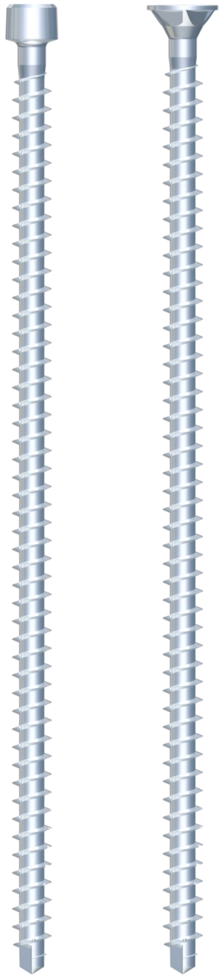


Fig.9 Comparison of 3/8" @ 90° in CLT vs. Design Values



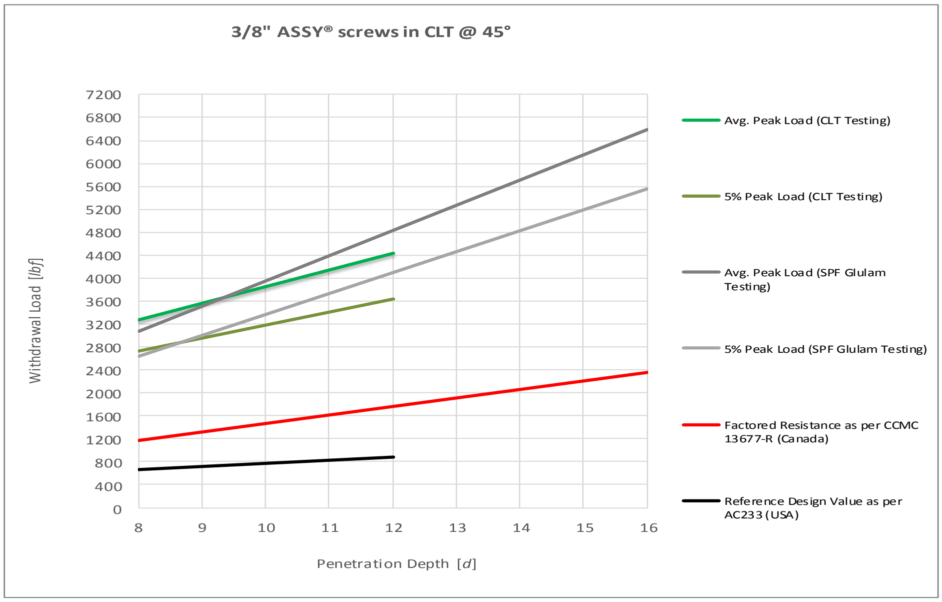


Fig.10 Comparison of 3/8" @ 45° in CLT vs. Design Values

Figures 11-14 provide a visual comparative between the obtained test data for the four different test series in this research campaign and the Design Values utilized for ASSY® fully threaded screws as per their respective product Code Approval Reports valid in Canada and the USA.

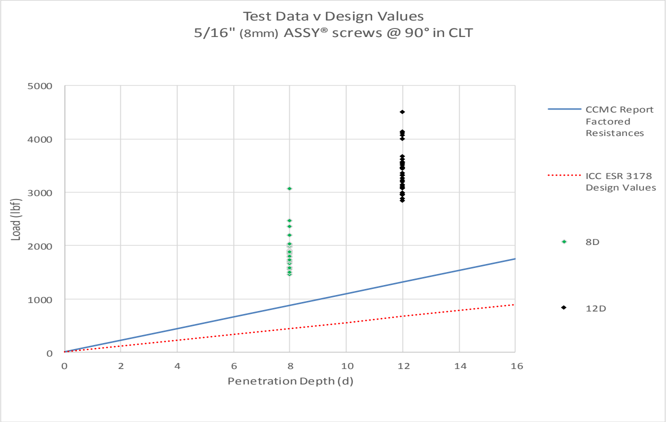


Fig.11 5/16” @ 90° in CLT Test Data vs. Design Values

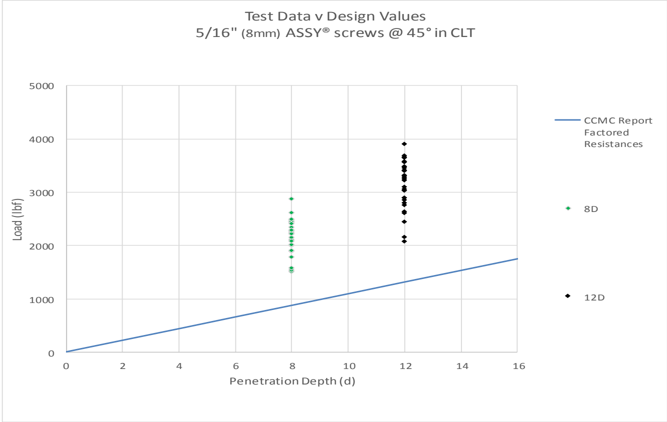


Fig.12 5/16” @ 45° in CLT Test Data vs. Design Values

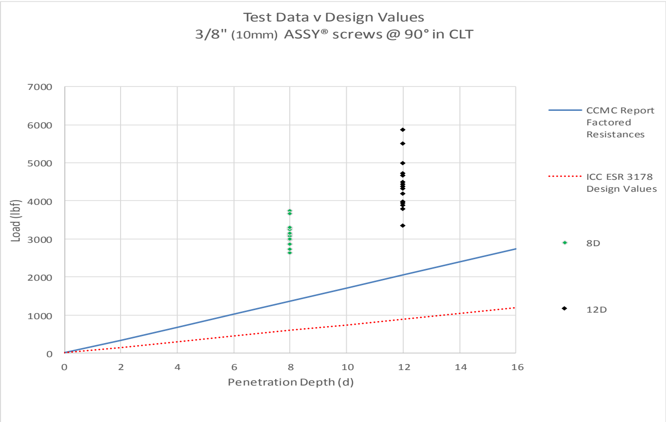


Fig.13 3/8” @ 90° in CLT Test Data vs. Design Values

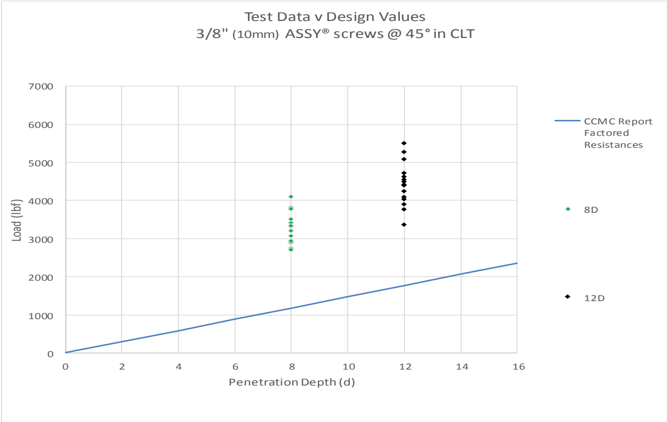


Fig.14 3/8” @ 45° in CLT Test Data vs. Design Values

Table 2. Factors of Safety associated with ASSY® STS under Withdrawal in CLT

Comparison between Avg. Peak Test Load with:	5/16” @ 90°	5/16” @ 45°	3/8” @ 90°	3/8” @ 45°
Factored Resistance as per CCMC Report 13677-R (Canada)	2.6	2.8	2.2	2.5
Reference Design Values as per ICC Report ESR 3178	5.2	—	5.0	—
Reference Design Values as per AC233 (USA)	—	5.0	—	5.0

*Note: The associated Factors of Safety that are presented herein were calculated by dividing the corresponding Avg. Peak Load value obtained from the test data of this research campaign by, the corresponding Design Values as noted in Table 2.

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