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Testing of Glued Rod Imbeds for Glued in Rod Timber Connections

Prepared for

F3 Timber Technologies
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by

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1 INTRODUCTION

The effect of Glued Rod Imbeds (GRI) on the performance of Glued-in-Rod timber connections was evaluated in this project. The GRIs were manufactured by F3 Timber Technologies (Abbotsford, BC).

2 MATERIAL AND METHODS

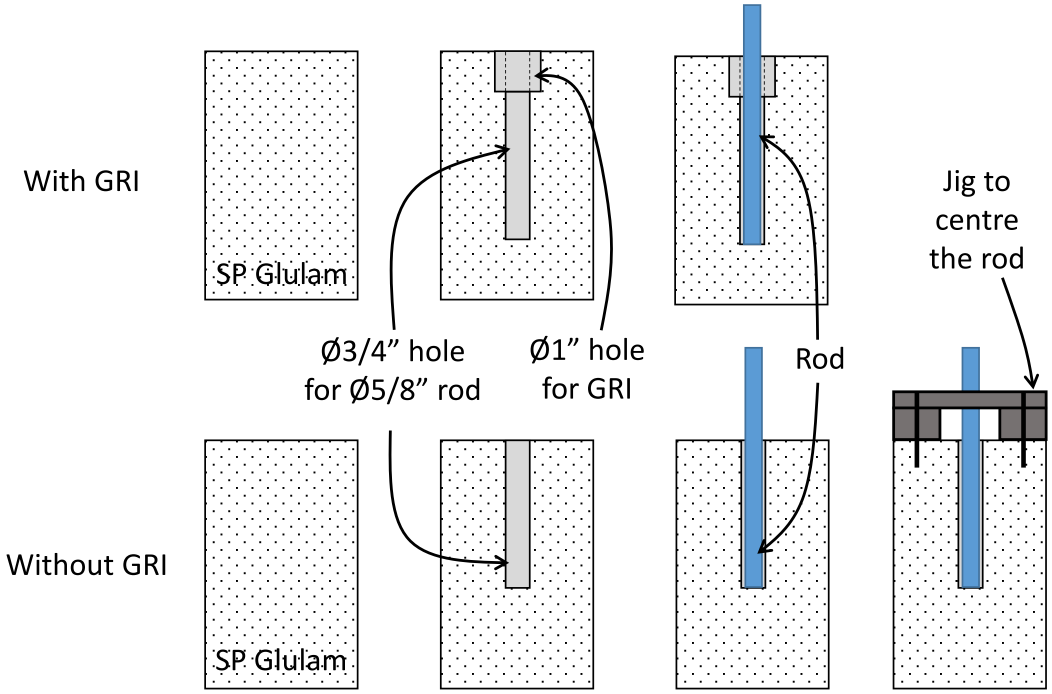
The GRIs, Spruce-Pine Glulam, adhesive, and steel rods were sampled by the client. The adhesive was SIMPSON SET-XP high strength epoxy with two components at 1:1 ratio. The steel rods were Ø 15.9 mm (5/8 in) Zinc threaded rods of ASTM A307 Grade A. The GRI (GRI 0104) had an outer diameter of 25.4 mm (1 in) and a length of 45 mm. Its inside was threaded to fit the Ø 15.9 mm (5/8 in) threaded rod. The Spruce-Pine Glulam (intended as column material, however its grade was not specified) had a cross section of 305 mm × 305 mm (12 in × 12 in), and they were cut into 102 mm × 152 mm (4 in × 6 in) to make Glued-in-Rod specimens. The testing matrix is shown in Table 1. For every Glued-in-Rod specimen, one rod was installed into the centre center of the specimen in the end grain direction.

Table 1 Testing matrix

Specimens	Rod	Glued-in-Rod without GRI			Glued-in-Rod with GRI		
Group Code	ROD	SSA	SA	LA	SSB	SB	LB
Embedment length (mm)	N/A	60	110	220	60	110	220
Number of specimens	10	10	10	10	10	10	10

The process of making the specimens is shown in Figure 1. For specimens with GRI, the hole for the imbed was drilled first with a diameter of 25.4 mm (1 in) and a depth of 45 mm. Then the hole for the threaded rod was drilled to its designated depth. The GRI was tapped into its hole before applying epoxy. The adhesive was injected at the bottom of the hole and excessive adhesive was squeezed out of the hole when positioning the rod. The specimens were left at room temperature for at least 48 hours before testing. For specimens without GRI, a wooden jig was screwed to the Glulam to center the rod, and the jig was taken off after the epoxy cured.

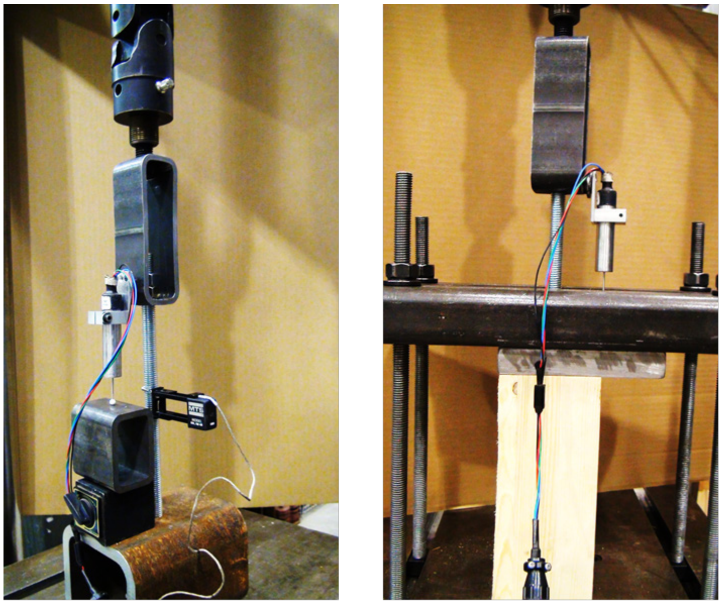
For the rod specimens, the two ends of the rod were connected to the test fixture to load the rod under tension at a rate of 1.5 mm/min. For Glued-in-Rod specimens, the rod was loaded under tension while the wood was clamped to the testing base (pull/push configuration). The loading rate was 0.5 mm/min for SSA/SSB and SA/SB, and 1.5 mm/min for LA/LB. After the test, the moisture content of the wood was measured by a Delmhorst RDM-3 moisture meter. A block (25 mm thick) was cut from the end of each specimen and the density was measured in accordance with ASTM D2395-17.



For illustration only, not to scale

Figure 1 Manufacturing the specimens

Figure 2 Specimens with GRI and without GRI



Rod testing Glued-in-Rod testing

Figure 3 Tension test setup

3 RESULTS

The moisture content (MC) and density results are shown in Tables 2 and 3, respectively. The average MC was in the range of 12.8-13.6%, and the average density was in the range of 425-443 kg/m^3. When comparing the two groups with the same embedment length, the difference of MC or density was not statistically significant. Therefore, the effects of MC and density were not considered when comparing the peak loads of the various test groups.

Table 2 Moisture content results

MC (%)	SSA	SSB	SA	SB	LA	LB
Average	13.1	12.8	13.6	13.2	13.5	13.0
Stdev	0.8	0.8	1.2	0.7	1.2	1.1
CV	6%	7%	9%	5%	9%	8%
Max	14.7	14.6	15.3	14.0	15.6	14.3
Min	12.5	12.0	11.2	11.6	11.5	10.4

Table 3 Density results

Density (kg/m^3)	SSA	SSB	SA	SB	LA	LB
Average	424.8	426.8	443.4	440.2	442.0	431.8
Stdev	26.6	25.5	21.3	25.4	27.3	23.8
CV	6%	6%	5%	6%	6%	6%
Max	471.1	465.3	491.3	485.0	492.9	469.0
Min	387.8	396.8	413.2	396.0	406.2	403.3

The peak load results are shown in Table 4 and Figure 4. The failure modes are shown in Table 5 and Figure 5. At 60 mm and 110 mm embedment lengths, all the Glued-in-Rod specimens failed in rod withdrawal, as shown in Figure 5. The average peak load for SSB (with GRI) was 45% higher than the average peak load for SSA (without GRI under the same embedment length of 60 mm). At 110 mm embedment length, SB (with GRI) had a 29% higher average peak load than SA (without GRI). The withdrawal strengths for the four groups are shown in Table 6. When the embedment length increased to 220 mm, all LB specimens failed in steel rod yielding, and eight out of ten LA specimens failed in steel yielding, while the other two failure in rod withdrawal. The groups with GRI also had lower Coefficient of Variation (CV) than their counterparts.

Table 4 Peak load results

Group	ROD	SSA*	SSB*	SA*	SB*	LA	LB
Embedment (mm)	N/A	60	60	110	110	220	220
Specimen 01	74.1	17.8	27.4	40.9	53.9	76.2	75.4
Specimen 02	72.7	19.5	27.1	39.4	51.2	64.2*	74.6
Specimen 03	72.8	17.7	26.9	42.9	56.4	74.4	74.3
Specimen 04	73.6	20.4	30.6	44.8	45.0	74.6	74.4
Specimen 05	73.6	20.9	35.2	39.8	54.8	75.8	73.2
Specimen 06	74.6	23.4	32.8	47.9	59.8	74.3*	75.9
Specimen 07	73.6	27.1	29.2	25.0	60.3	76.2	75.7
Specimen 08	74.0	22.4	35.6	45.0	60.9	75.6	74.4
Specimen 09	71.7	22.3	34.4	51.4	48.3	75.1	72.9
Specimen 10	73.1	25.8	35.3	44.0	54.6	72.9	73.8
Average	73.4	21.7	31.4	42.1	54.5	73.9	74.5
Stdev	0.8	3.1	3.6	7.0	5.2	3.6	1.0
CV	1%	14%	12%	17%	10%	5%	1%
Max	74.6	27.1	35.6	51.4	60.9	76.2	75.9
Min	71.7	17.7	26.9	25.0	45.0	64.2	72.9

*: specimen or specimen group that failed in rod withdrawal

Table 5 Failure mode

Failure mode	ROD	SSA	SSB	SA	SB	LA	LB
Embedment (mm)	N/A	60	60	110	110	220	220
# of Steel yield	10	0	0	0	0	8	10
# of Rod withdrawal	N/A	10	10	10	10	2	0

Table 6 Withdrawal strength

Group	SSA	SSB	SA	SB
Strength (N/mm)	362	524	383	496

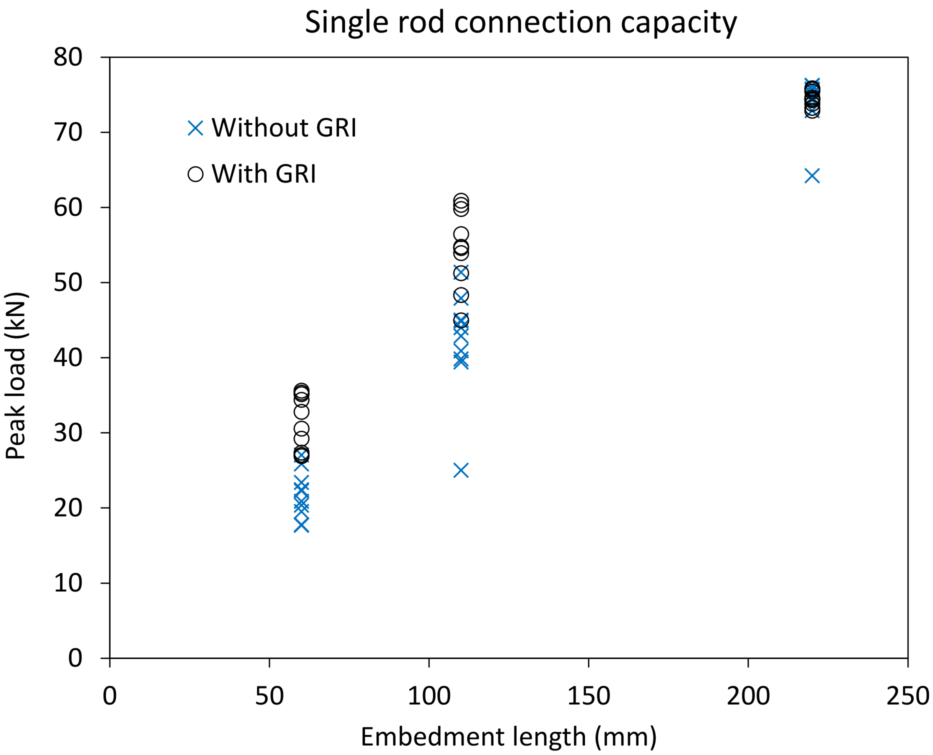


Figure 4 Peak load of every specimen

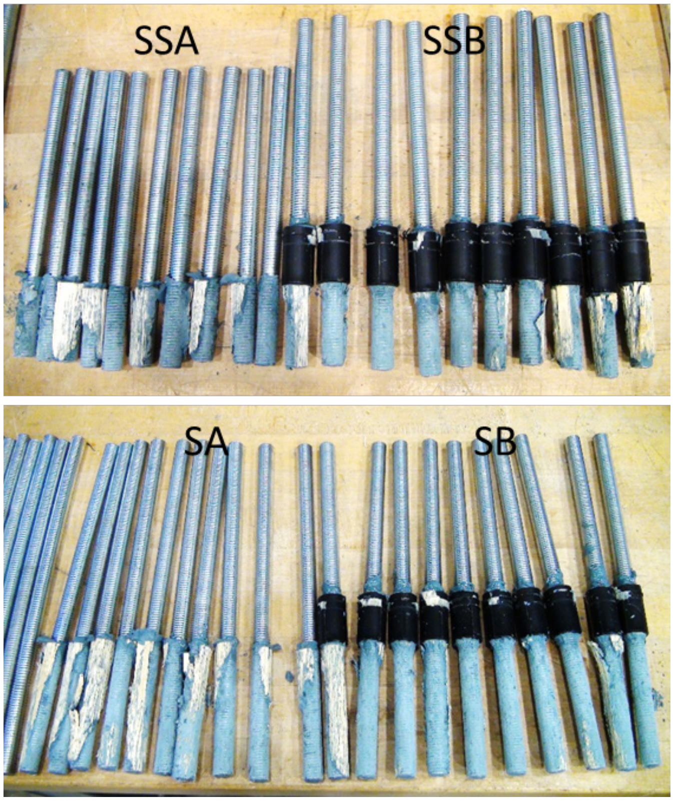


Figure 5 Withdrawal failure mode

The peak load results are also plotted in Figure 6. The average peak load of all specimens that failed in steel yielding was 74.3 kN (10 ROD specimens, 8 LA specimens, and 10 LB specimens). Assuming the withdrawal capacity of the Glue-in-Rod connection is in linear relationship with the embedment length, the peak load for the tested connections can be estimated by:

For connections without GRI,

When h<196 mm, F=0.3781×h

When h≥196 mm, F=74.3 kN

For connections with GRI,

When h<148 mm, F=0.5022×h

When h≥148 mm, F=74.3 kN

where F is the peak load of a single rod connection, in kN; h is the embedment length of the threaded rod, in mm.

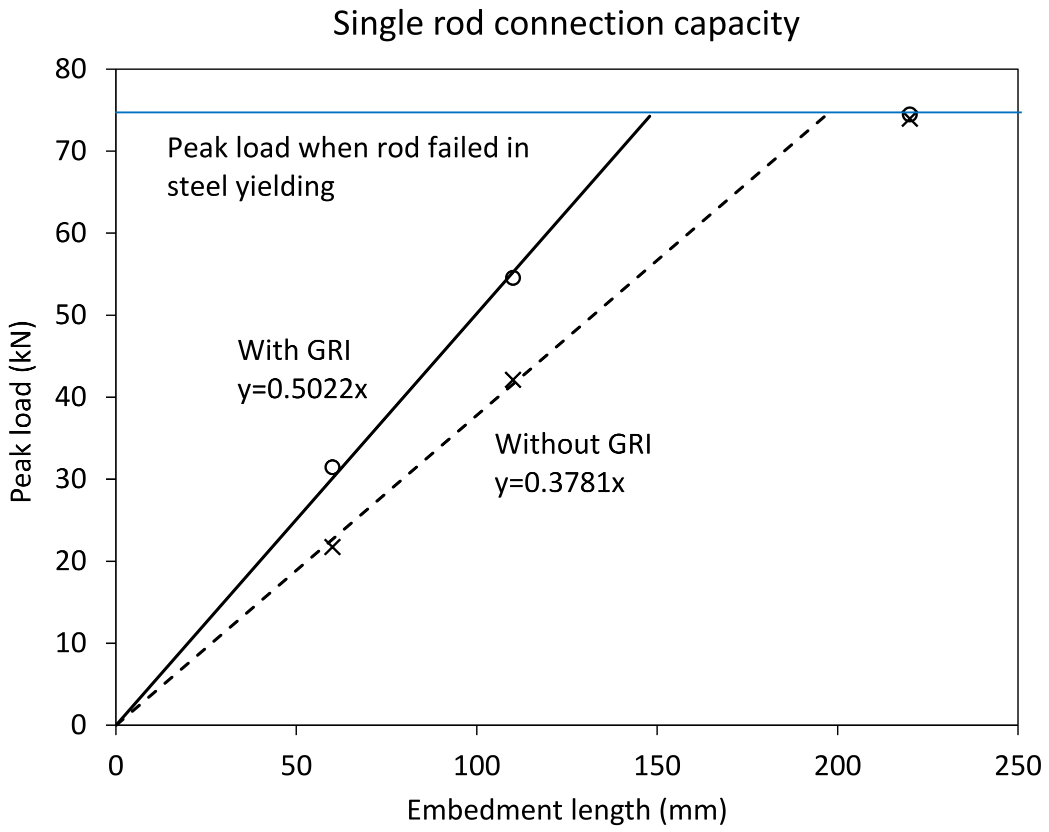


Figure 6 Average peak load of each group

Based on the type of connections tested in this work, the average withdrawal strength of connections with GRI was estimated to be 502 N/mm, about 33% higher than the average withdrawal strength of connections without GRI (378 N/mm). For design consideration a larger sample size is needed to examine the characteristic withdrawal strengths of the various groups and the influence of GRI on the characteristic withdrawal strengths.

4 CONCLUSIONS

This project investigated the performance of Glued-in-Rod timber connections with GRI and without GRI. Side by side comparisons showed that the group with GRI performed consistently better than the group without GRI in all three embedment lengths. At an embedment length of 60 mm and 110 mm, all specimens failed in rod withdrawal, and the withdrawal strength of the group with GRI was 33% higher on average. Under an embedment length of 220 mm, the group without GRI had eight out of ten specimens failed in steel yielding, while the group with GIR had all ten specimens failed in steel yielding. For peak load, the GRI groups also had a lower coefficient of variation than their counterparts with the same embedment length. The results indicate that compared to the conventional installation technique, using GRI improves the bonding quality of the Glued-in-Rod in the wood leading to a higher average withdrawal strength and better consistency.

It is to be noted that the above conclusions are based on the type of configurations designed in this test. Various factors would influence the performance of a Glued-in-Rod timber connection, such as wood species, type of engineered wood, type of adhesive, rod grade, rod diameter, orientation of the wood grain, etc. Even though the trend observed in this work may occur in other configurations, the difference between the case with GRI and the case without GRI may not be as significant as what was found here.

The following works are recommended for future studies:

1. Investigate the effect of GRI under other connection configurations, including changing wood species, type of engineered wood, type of adhesive, rod grade, rod diameter, and orientation of the wood grain. Also increasing the sample size is needed to quantify the performance at the characteristic strength level.
2. Investigate the effect of GRI with multiple rods in one connection.
3. Evaluate the performance of connections with GRI when the rod is loaded under shear. Under this circumstance, lateral loads will be applied to the GRI, and the engineers need to consider how to deal with this 50 mm or so segment of rod that has no direct contact with wood.
4. Explore ways to improve the efficiency of installing the rods into GRI.

5 REFERENCES

ASTM A307-21, Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength, ASTM International, West Conshohocken, PA, 2021, www.astm.org

ASTM D2395-17, Standard Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials, ASTM International, West Conshohocken, PA, 2017, www.astm.org

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