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# Testing of Glued Rod Imbeds for Glued in Rod Timber Connections
## Phase II

Prepared for

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# TABLE OF CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

## 1 INTRODUCTION

This project investigated the effect of Glued Rod Imbeds (GRI) on the performance of Glued-in-Rod timber connections. The GRIs were manufactured by F3 Timber Technologies (Abbotsford, BC). In Phase I, the wood material was Spruce-Pine Glulam, and in Phase II, Doulas fir Glulam was tested.

## 2 MATERIAL AND METHODS

The GRIs, Douglas Fir 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. According to the information provided by the client, 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. The inside of GRI was threaded to fit the Ø 15.9 mm (5/8 in) threaded rod. The same epoxy, steel rods, and GIRs were used in both Phase I and Phase II. The Douglas fir Glulam (intended as column material, however its grade was not specified) had a cross section of 914 mm × 914 mm (3 ft × 3 ft), and they were cut into 102 mm × 152 mm (4 in × 6 in) to make Glued-in-Rod specimens. The testing matrix for Phase II 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. Each cell was named as "embedment length (in mm), wood species (D), and with or without imbeds (Y or N)".

Table 1 Testing matrix

| Specimens | Without GRI | | With GRI | |
|---|---|---|---|---|
| Group Code | 60D-N | 120D-N | 60D-Y | 120D-Y |
| Embedment length (mm) | 60 | 120 | 60 | 120 |
| Number of specimens | 30 | 10 | 29 | 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. During the test, the rod was loaded under tension while the wood was clamped to the testing base, as shown in Figure 2. The loading rate was 0.5 mm/min. Before 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.

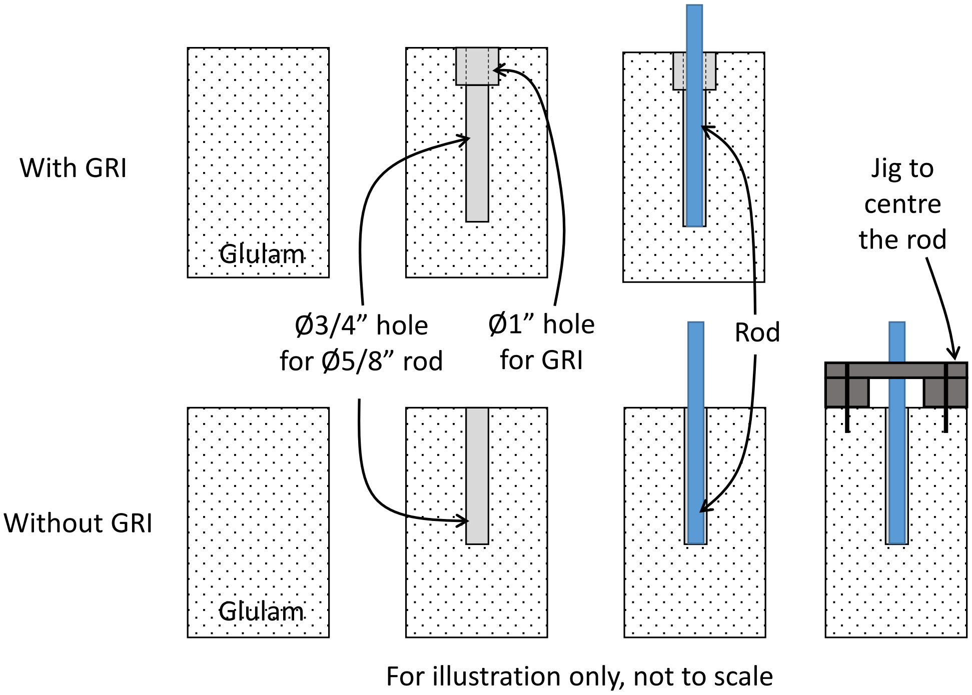

Figure 1 Manufacturing the specimens

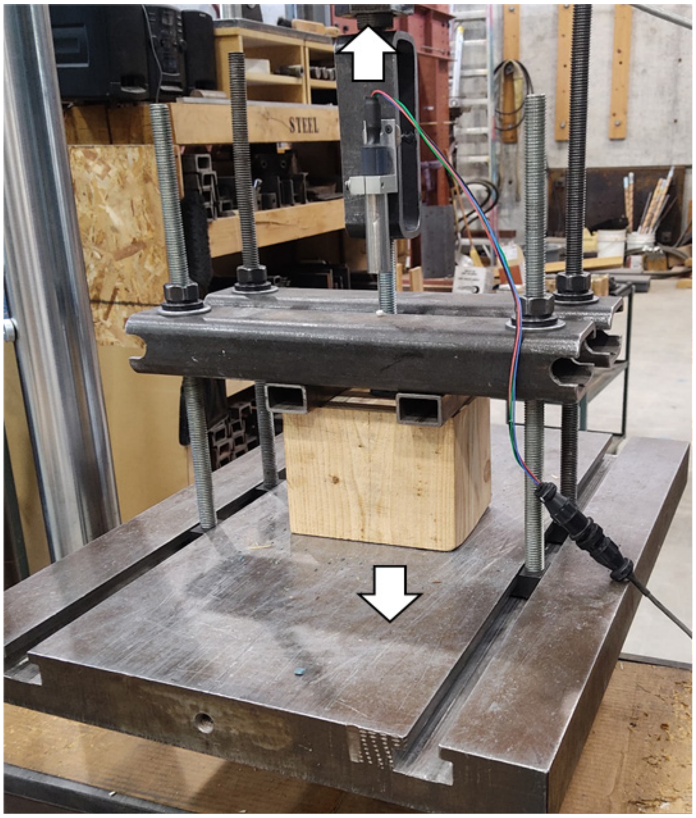

Figure 2 Tension test setup

# 3 RESULTS

The moisture content (MC) and density results are shown in Table 2. The average MC was in the range of 11.9-12.1%, and the average density was in the range of 537-561 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

| Item | Moisture content (%) | | | | Density at testing (kg/m$^3$) | | | |
|---|---|---|---|---|---|---|---|---|
| Group | 60D-N | 60D-Y | 120D-N | 120D-Y | 60D-N | 60D-Y | 120D-N | 120D-Y |
| Average | 12.1 | 12.0 | 11.9 | 12.1 | 537.4 | 540.4 | 561.9 | 549.1 |
| Stdev | 0.5 | 0.4 | 0.5 | 0.4 | 43.3 | 31.0 | 52.0 | 50.0 |
| CV | 5% | 4% | 4% | 3% | 8% | 6% | 9% | 9% |
| Max | 13.7 | 12.6 | 13.3 | 12.8 | 626.2 | 585.5 | 654.1 | 651.1 |
| Min | 11.0 | 11.3 | 11.0 | 11.5 | 479.0 | 493.1 | 454.9 | 467.6 |

The peak load results are shown in Table 3. For comparison, the results of Spruce-Pine Glulam connections obtained in Phase I are also shown. For Douglas fir, by installing the GRI the average peak load increased by 38% at 60 mm embedment length and by 20% at 120 mm embedment length. The Coefficient of Variation (CV) was in the range of 12-20%. For Spruce-Pine, the increasing of average peak load was 45% and 29% at 60 mm and 110 mm embedment lengths, respectively. For the same embedment length at 60 mm, the average peak load of Douglas fir specimens was 3% higher than the average peak load of the Spruce-Pine specimens when GRI was used, and the difference was 7% if no GRI.

Table 3 Peak load results (kN)

| Group | Embedment length 60 mm | | | | Embedment length 120 or 110 mm | | | |
|---|---|---|---|---|---|---|---|---|
| | 60D-N | 60D-Y | 60S-N | 60S-Y | 120D-N | 120D-Y | 110S-N | 110S-Y |
| Average | 23.4 | 32.3 | 21.7 | 31.4 | 52.2 | 62.9 | 42.1 | 54.5 |
| Stdev | 4.6 | 5.2 | 3.1 | 3.6 | 7.7 | 11.2 | 7.0 | 5.2 |
| CV | 20% | 16% | 14% | 12% | 15% | 18% | 17% | 10% |
| Max | 34.9 | 41.5 | 27.1 | 35.6 | 65.4 | 75.4 | 51.4 | 60.9 |
| Min | 15.3 | 18.4 | 17.7 | 26.9 | 39.3 | 40.4 | 25.0 | 45.0 |
| 5th PCT* | 15.5 | 20.6 | / | / | / | / | / | / |

*: non-parametric 5th percentile; 60S-N, 60S-Y, 110S-N, and 110S-Y correspond to SSA, SSB, SA, and SB in TEAM Report 2021-07, respectively.

The summary of the failure modes in Phase II is shown in Table 4. The majority of the specimens failed in the withdrawal of steel rod. And a few specimens failed in the splitting of the wood due to the limit of the specimen length, and this failure could be prevented in a longer specimen. Examples of the withdrawal failure are shown in Figure 3.

Table 4 Failure mode

| Group | 60D-N | 60D-Y | 120D-N | 120D-Y |
|---|---|---|---|---|
| Embedment (mm) | 60 | 60 | 120 | 120 |
| # of Rod withdrawal | 28 | 27 | 10 | 8 |
| # of wood split | 2 | 2 | 0 | 2 |

Figure 3 Examples of rod withdrawal failure

The distribution of the peak load for the 60 mm embedment length is shown in Figure 4. The non-parametric 5th percentile peak load was 15.5 kN for specimens without GRI and 20.6 for specimens with GRI. The non-parametric 5th percentile peak load was about 2/3 of the average peak load in the two tested cells. A 2-parameter Weibull distribution was fitted to the data and the parameters are shown in Table 5. The estimated 5th percentile was 14.8 kN for the cell with GRI and 23.3 kN for the cell without GRI.

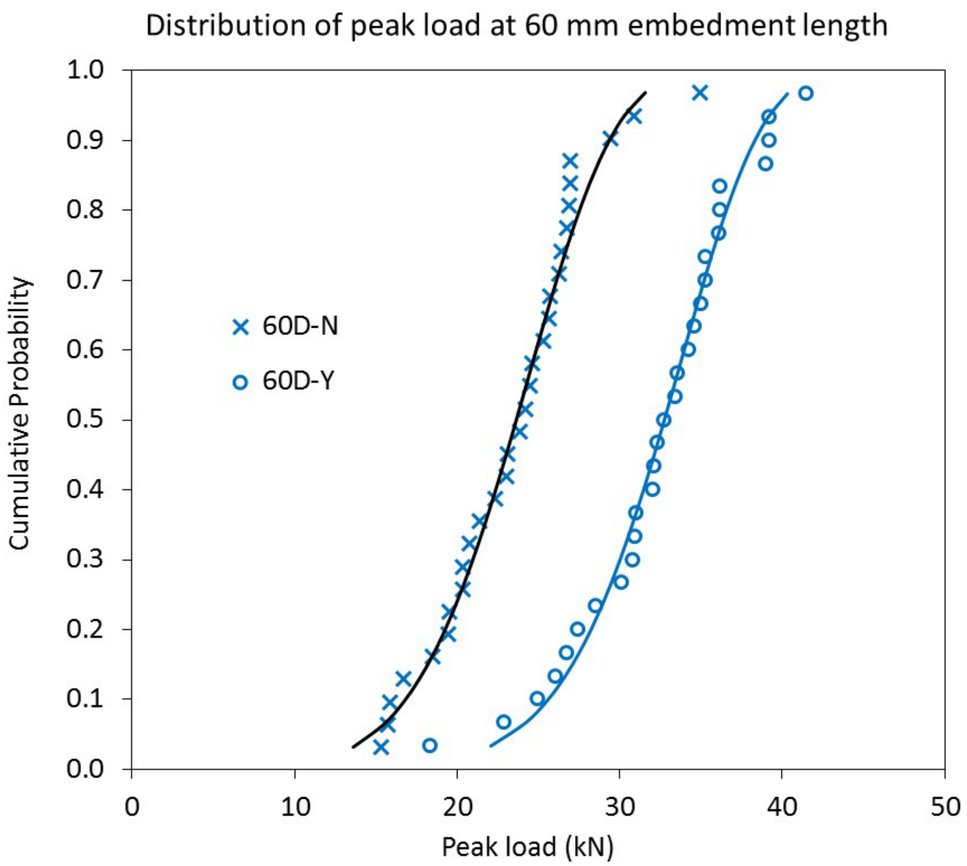

Figure 4 Distribution of peak load at 60 mm embedment length

Table 5 Two parameter Weibull distribution for 60 mm embedment length

| Group | 60D-N | 60D-Y |
|---|---|---|
| Shape | 5.54 | 7.65 |
| Scale | 25.27 | 34.38 |
| 5th percentile (kN) | 14.8 | 23.3 |

Since rod withdrawal was the dominant failure mode, the withdrawal strength was calculated by the average or non-parametric 5th percentile peak load divided by the embedment length and the results are shown in Table 6. The difference of average withdrawal strength between Spruce-Pine and Douglas fir was 3-8% at shorter embedment length, and the difference increased to 6-14% at longer embedment length. For specimens without GRI, the average withdrawal strength increased as the embedment length increased from 60 mm to 110-120 mm, while for specimens with GRI the trend was the opposite. However, the difference was all within 10%.

The average peak load results are shown in Figure 5. 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:

When $h < H$, $F = \alpha \times h$

When $h \geq H$, $F = F_{max}$

where $F$ is the average peak load of a single rod connection, in kN; $h$ is the embedment length of the threaded rod, in mm; $F_{max}$ is the average peak load of a single rod under tension; $H$ is the minimum embedment at which the rod yields.

The parameters for each cell are shown in Table 7. For the configuration with GRI, the effect of species was not significant. For the ones without GRI, a denser wood led to a higher load carrying capacity.

Table 6 Average withdrawal strength (N/mm)

| Wood species | | Spruce-Pine | | Douglas fir | |
|---|---|---|---|---|---|
| Embedment length (mm) | | 60 | 110 | 60 | 120 |
| Based on average | Without GRI | 362 | 383 | 390 | 435 |
| | With GRI | 524 | 496 | 538 | 524 |
| Based on non-parametric 5th percentile | Without GRI | / | / | 259 | / |
| | With GRI | / | / | 344 | / |

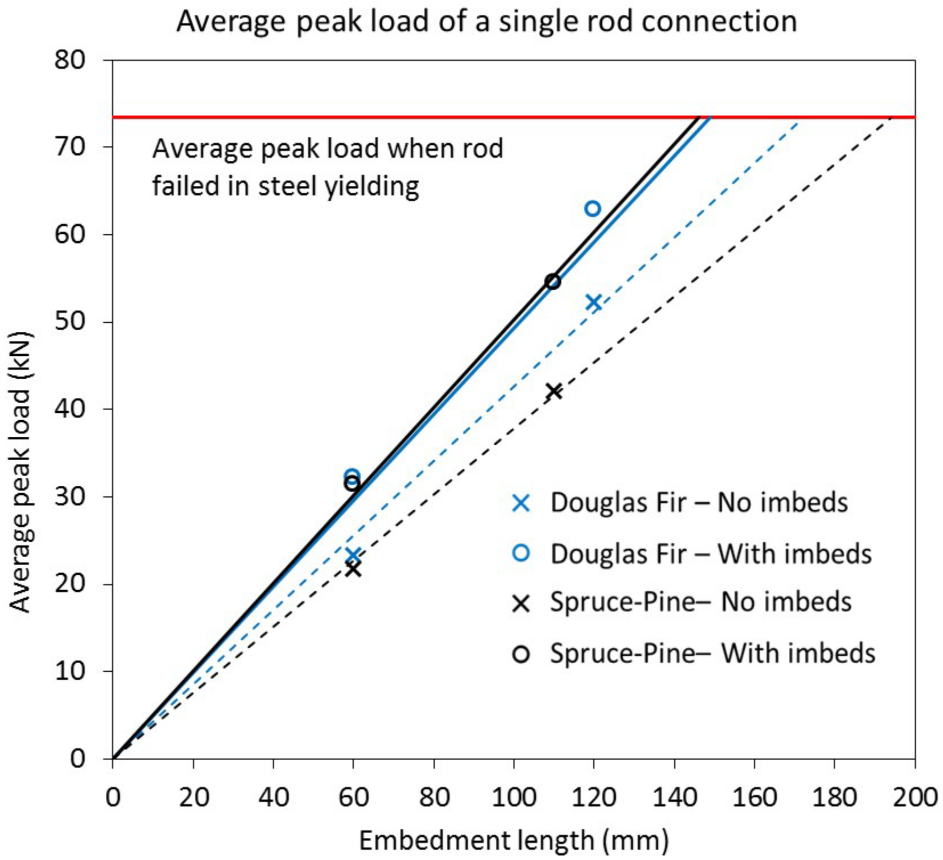

Figure 5 Average peak load of each cell

Table 7 Parameters to estimate the average peak load

| Species | Douglas fir | | Spruce-Pine | |
|---|---|---|---|---|
| GRI (Yes or No) | N | Y | N | Y |
| $H$ | 174 | 150 | 196 | 148 |
| $\alpha$ | 0.4263 | 0.4927 | 0.3781 | 0.5022 |
| $F_{max}$ | 74.3 | 74.3 | 74.3 | 74.3 |

## 4 CONCLUSIONS

This project investigated the performance of Glued-in-Rod timber connections with GRI and without GRI. Douglas fir Glulam was used to make the specimens in Phase II and Spruce-Pine Glulam was used in Phase I. Side by side comparisons showed that the group with GRI performed consistently better than the group without GRI in different embedment lengths and in two different wood species. By installing GRI, the average peak load was increased by 20-40%, and the effect was more significant at short embedment length (60 mm in the test). The cell with GRI in most cases had a lower coefficient of variation than their counterparts. 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. For one configuration (60 mm and Douglas fir), the sampling size was increased to > 28. The non-parametric 5th percentile and the 5th percentile based on Weibull distribution were obtained. The 5th percentile peak load of the cell with GRI was at least 33% higher than that of the cell without GRI.

## 5 A NOTE ON INSTALLATION

For the connections with GRI in Phase I, the threaded rods were installed by hand turning the rod, and it was time-consuming, especially for the longer embedment length. For Phase II, the client provided a different installation method. Two holes were drilled at one end of the rod to fit a spanner insert bit. The spanner bit was used to drive the rod into the GRI by a hand drill, which was set a low toque to prevent overturning when the rod reached the bottom. This technique was found to be efficient and no overturning of the rod occurred during the installation.

## 6 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

TEAM Report 2021-07, Testing of Glued Rod Imbeds for Glued in Rod Timber Connections. Reported prepared for F3 Timber Technologies. Dated Nov 2, 2021. By Timber Engineering and Applied Mechanics Laboratory at the University of British Columbia.

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