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# Withdrawal Capacity of a Novel Rigging Device for Prefabricated Wood I-Joist Floor Panels †

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**Abstract:** Prefabricated wood construction relies heavily on efficient material handling, yet rigging system design for floor panels remains understudied. This study introduces a novel rigging device that attaches to prefabricated wood I-joist floor panels using self-tapping screws, avoiding potential damage caused by predrilled holes in the sheathing panels and framing members. To establish allowable lifting capacities and optimal installation practices, comprehensive withdrawal tests were conducted on 114-floor panel specimens. Factors influencing withdrawal capacity, such as anchor plate placements, flange materials and width, screw type and quantity, and sheathing panel thickness, were systematically evaluated. Results indicate that withdrawal capacity does not scale linearly with screw quantity and that anchor plates with eight screws centered on the flange enhance performance by up to 20% compared to four-screw configurations. Unexpectedly, thinner sheathing panels yielded higher capacities, potentially due to increased screw penetration depth in the joist flange. In addition, anchor plate orientation, flange width, and flange materials also impact capacity. These findings provide essential data for designing reliable and efficient rigging systems in prefabricated wood construction.

**Keywords:** rigging device; prefabricated floor panels; wood I-joists; withdrawal capacity

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## 1. Introduction

Over the past two decades, there has been a global surge in interest in constructing multi-storey buildings with wood. Several jurisdictions in North America have led the way by lifting restrictions on wood-frame buildings beyond four storeys. The shift reflects the substantial market potential of mid-rise wood construction in commercial and multi-family residential sectors. Another key factor driving this interest is the ease of prefabrication with wood products, leading to a faster speed of construction since most components can be fabricated offsite in the factory. Prefabricated floor, wall, and roof panels have been extensively incorporated into wood construction. This trend is a natural evolution toward the use of modern methods of construction, which brings many benefits for both productivity and quality in the construction process [1].

In anticipation of these market opportunities, an increasing number of companies have established production lines for prefabricated engineered wood panels. Various innovative lightweight wood panel products are now widely used in walls, floors, and roofs. Prefabricated wood I-joist panels have particularly thrived, building on the extensive use of I-joists in North American residential floor construction since the 1970s. They account for over 50% of the residential floor market [2] and are readily available for mid-rise projects.

Once all the prefabricated panels and building components are completed, they are shipped to construction sites and assembled. This construction technique, known as panelized building construction, is highly mechanized. Material handling and lifting equipment dominate construction sites and are critical for achieving productivity. In recent construction practice, panelized wood I-joist floor panels are typically lifted into place by a mobile crane using flexible slings (e.g., polypropylene straps) inserted through the predrilled holes in the I-joist web and sheathing panels above the I-joist top flange (see Figure 1), then wrapped around the I-joists at the four corners. This rigging assembly has been commonly used for years in the construction of panelized wood buildings. Nevertheless, the predrilled holes in the web and sheathing may weaken the floor panels.

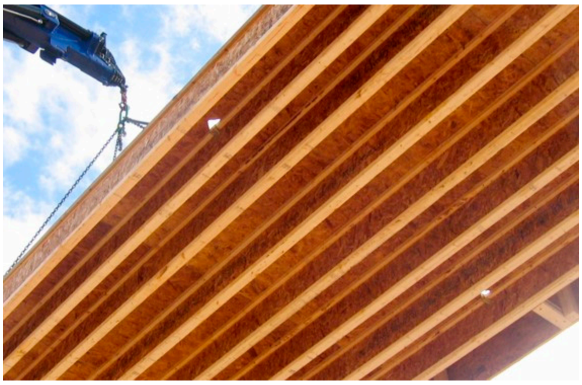


**Figure 1.** Rigging sling for I-joist panels (Source: H+ME Technology).

On the other hand, mass timber floor systems, particularly cross-laminated timber (CLT) floors, are emerging as popular building solutions and are increasingly used in construction. A range of techniques for lifting and handling CLT panels have been developed. As shown in Figure 2, a typical rigging technique consists of a lifting ring and a steel plate with pre-drilled holes. The CLT panel is connected to the rigging device using self-tapping screws (STSs) for lifting. However, prefabricated wood I-joist floor panels are much lighter than CLT panels and the wood I-joist flange is relatively narrow and thin. The rigging device for CLT panels cannot be applied directly to wood I-joist panels. Instead, a modified design can be developed specifically for prefabricated wood I-joist floor panels and other lightweight wood panels, such as structural insulated panels.

**Figure 2.** A typical rigging assembly for CLT panels [3].

This study aims to develop a novel rigging device for lightweight wood I-joist panels and evaluate its capacity through withdrawal tests. A prototype of the rigging device was manufactured, featuring a steel anchor plate with a welded lifting ring. The design allows for installation on the panel surface by using STSs, thereby avoiding predrilled holes in the sheathing panels and framing members. To determine the lifting capacity and identify influential factors, withdrawal tests were conducted on 114 wood I-joist panel specimens. Key variables included anchor plate placement, joist flange material and width, screw type and quantity, and sheathing panel thickness.

## 2. Prototype of a New Rigging Device

As shown in Figure 3, a novel rigging device was developed for prefabricated wood I-joist floor panels and other lightweight wood panels, including structural insulated panels. The device consists of a steel anchor plate (a custom-made steel plate) and a lifting ring welded to the plate. The plate has eight predrilled holes to accommodate eight STSs. The screw pattern is designed to fit the flange of the I-joist and maximize the grip of the screws, even if the plate is incorrectly installed on the construction site. Detailed dimensions of the anchor plate can be found in Figure 4. The versatile device offers a high degree of flexibility in terms of allowable capacity, which can be expanded by increasing the number of screws. For simplicity, two screw arrangements are recommended: four screws in the middle and eight screws. The rigging device is designed to be compatible with 6 mm diameter STSs.

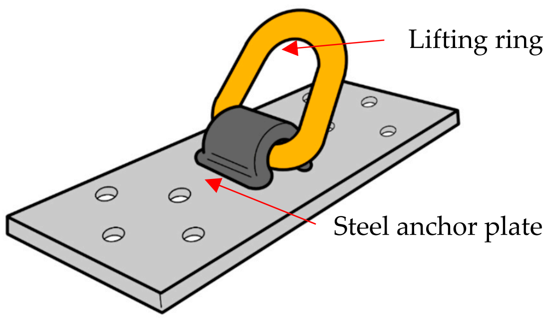



**Figure 3.** Prototype of the rigging device.

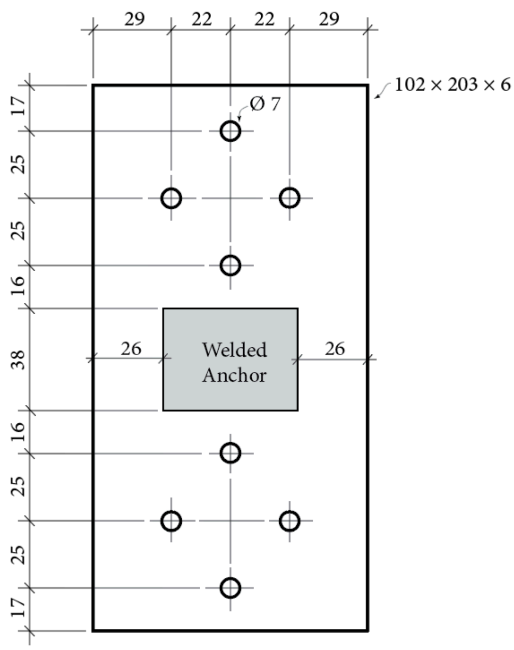



**Figure 4.** Dimensions of the anchor plate (unit: mm).

## 3. Withdrawal Test Program

While extensive research exists on the withdrawal capacity of STSs in solid timber and timber products (e.g., [4,5]), few studies have examined how these STSs perform when inserted into two different timber materials simultaneously. This knowledge gap necessitated the current experimental study. To determine lifting capacities and establish installation guidelines, withdrawal tests were conducted on the rigging device. The study examined several factors that can influence the lifting capacity, including anchor placement, joist flange material and width, screw quantity, and sheathing thickness.

### *3.1. Test Materials*

Two types of STSs were used in the tests: one with full thread (FT) and one with partial thread (PT). Their basic dimensions are listed in Table 1. These screws feature large washer heads for enhanced pull-through resistance. I-joist flanges consisted of either laminated veneer lumber (LVL) or solid sawn lumber (SSL). Thus, two types of wood I-joists were tested: those with LVL flanges (IJLVL) and those with SSL flanges (IJSSL). In addition, each type of I-joist was tested with two flange widths. For IJLVL, flange widths of 53 mm and 89 mm were used, denoted as IJLVL53 and IJLVL89, respectively. For IJSSL, flange widths of 64 mm and 89 mm were tested, referred to as IJSSL64 and IJSSL89. In total, four different wood I-joists were studied: IJLVL53, IJLVL89, IJSSL64, and IJSSL89, where the numerical designation indicates flange width in millimeters. Additionally, two oriented strand board (OSB) thicknesses, 15 mm (19/32 in) and 18 mm (23/32 in), and two STS quantities (4 and 8) were included. All test variables are summarized in Table 2.

**Table 1.** STSs used for tests.

| Screws | Diameter (mm) | Length (mm) | Thread Length (mm) |
|---|---|---|---|
| FT-50 | 6 | 50 | 45 |
| PT-60 | 6 | 60 | 37 |

**Table 2.** Test variables.

| Items | Parameters |
|---|---|
| Sling angle | 60° |
| Screw types | Full thread (FT) and partial thread (PT) |
| Wood I-joists | IJLVL53, IJLVL89, IJSSL64 and IJSSL89 |
| Flange width | 53 mm, 64 mm and 89 mm |
| OSB panels | 15 mm (19/32 in) and 18 mm (23/32 in) |
| STS quantities | 4 and 8 |
| Anchor placements | Centered, rotated and offset |

### *3.2. Test Specimens*

Test specimens were fabricated by fastening two oriented strand board (OSB) strips (i.e., sheathing panel) to the top and bottom flanges of wood I-joists using nails, creating symmetric specimens. A pair of rigging devices was used repeatedly in the withdrawal tests. The anchor plate of the rigging device was connected to the OSB and I-joist flanges using STSs. To cover various construction scenarios during the lifting process, three anchor plate placements were considered, as illustrated in Figure 5: (a) centered on the flange of the I-joist; (b) with a 30° rotation and only half of the STSs in the flange; and (c) offset from joist flanges with all STSs into the sheathing panel only. Note that centered placement (Figure 5a) is often the preferred placement. The rotated and offset placements (Figures 5b and 6c) were included in the project to indicate alternative on-site installation methods. The OSB strips were 609 mm (24 in) in length. Four different widths of OSB strips/panels were used, namely 76 mm (3 in), 100 mm (4 in), 152 mm (6 in), and 305 mm (12 in). In particular, the 305 mm OSB panels were used for specimens with the offset placement (Figure 5c).


(**a**) Centered (**b**) Rotated (**c**) Offset

**Figure 5.** Three anchor plate placements.

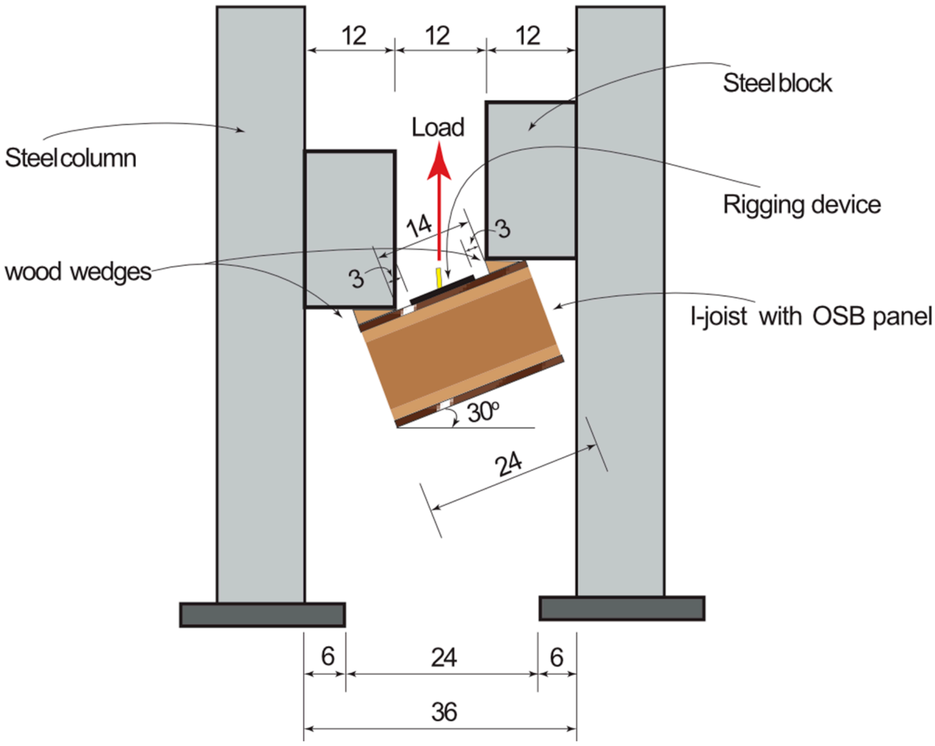



**Figure 6.** Schematic diagram of test setup (unit: inch, 1 in = 25.4 mm).

By incorporating all test variables, a test matrix is presented in Table 3. In total, there are 19 specimen configurations, each with six replicates. For ease of identification of each specimen configuration, the following designation was adopted:

*Anchor plate placement–OSB thickness–STS length–STS quantity–Flange width–Flange material*

For instance, **C-15-60-4-53-LVL** denotes a specimen with the anchor plate centered, an OSB panel thickness of 15 mm, an STS length of 60 mm, four STSs, and a joist flange width of 53 mm and made of LVL.

**Table 3.** Test matrix for withdrawal tests.

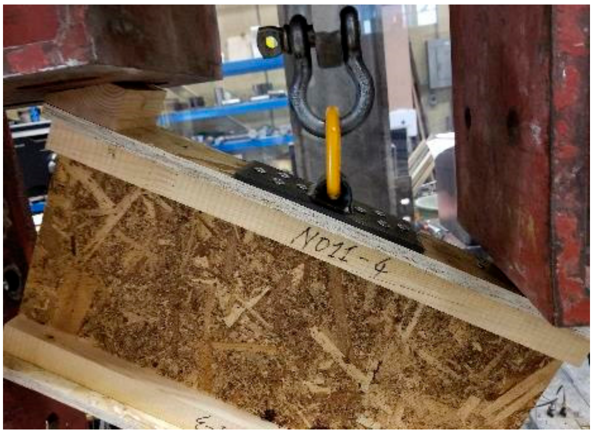
| No. | Label | Placement | OSB | | STS | | Wood I-Joist | |
|---|---|---|---|---|---|---|---|---|
| | | | *t* (mm) | b (mm) | $L_s$ (mm) | $N_s$ | Type | $b_i$ (mm) |
| 1 | C-15-60-4-53-LVL | centered | 15 | 76 | 60 | 4 | IJLVL | 53 |
| 2 | C-15-60-4-64-SSL | centered | 15 | 76 | 60 | 4 | IJSSL | 64 |
| 3 | C-15-60-8-64-SSL | centered | 15 | 100 | 60 | 8 | IJSSL | 64 |
| 4 | C-15-60-8-89-SSL | centered | 15 | 100 | 60 | 8 | IJSSL | 89 |
| 5 | C-15-60-8-89-LVL | centered | 15 | 100 | 60 | 8 | IJLVL | 89 |
| 6 | C-18-60-4-64-SSL | centered | 18 | 76 | 60 | 4 | IJSSL | 64 |
| 7 | C-18-60-8-64-SSL | centered | 18 | 100 | 60 | 8 | IJSSL | 64 |
| 8 | C-18-60-8-89-SSL | centered | 18 | 100 | 60 | 8 | IJSSL | 89 |
| 9 | C-15-50-4-53-LVL | centered | 15 | 76 | 50 | 4 | IJLVL | 53 |
| 10 | C-15-50-4-64-SSL | centered | 15 | 76 | 50 | 4 | IJSSL | 64 |
| 11 | C-15-50-8-64-SSL | centered | 15 | 100 | 50 | 8 | IJSSL | 64 |
| 12 | C-15-50-8-89-SSL | centered | 15 | 100 | 50 | 8 | IJSSL | 89 |
| 13 | C-15-50-8-89-LVL | centered | 15 | 100 | 50 | 8 | IJLVL | 89 |
| 14 | C-18-50-4-64-SSL | centered | 18 | 76 | 50 | 4 | IJSSL | 64 |
| 15 | C-18-50-8-64-SSL | centered | 18 | 100 | 50 | 8 | IJSSL | 64 |
| 16 | C-18-50-8-89-SSL | centered | 18 | 100 | 50 | 8 | IJSSL | 89 |
| 17 | R-15-60-8-64-SSL | rotated | 15 | 152 | 60 | 8 | IJSSL | 64 |
| 18 | R-15-50-8-64-SSL | rotated | 15 | 152 | 50 | 8 | IJSSL | 64 |
| 19 | O-18-50-8 | offset | 18 | 305 | 50 | 8 | IJSSL | N.A. |

Note: *t* and *b* are the thickness and width of OSB panels, respectively. $L_s$ is the screw length and $N_s$ is the number of screws. $b_i$ is the flange width of I-joists.

### *3.3. Test Setup and Method*

The test frame was built by using two steel columns and two adjustable steel blocks, as shown in Figure 6. The test specimen was secured at the bottom of the steel blocks, which were attached to the steel columns. The adjustable steel blocks allowed for the creation of different angles for specimen installation. A withdrawal angle of 90 degrees (perpendicular to the specimen surface) exhibits the maximum withdrawal capacity, which decreases with any reduction in angle. In the rigging practice, the sling-to-panel angle is typically restricted to be larger than 60 degrees. Therefore, the withdrawal angle was set to 60 degrees for conservative purposes. Two wood wedges were attached to the OSB strips to maintain a 60-degree angle to the sheathing surface during the withdrawal tests. Figure 6 shows the schematic details of the setup. Actual test setups for three anchor placements are illustrated in Figure 7.

The tests were conducted using a universal test machine. Specimens were tested right after the rigging anchor was fastened to the specimen until failure, following the ASTM D1761 [6] procedure for screw withdrawal test. A tension load was applied via the lifting ring on the anchor plate at a loading rate of 1 mm/min and the test was stopped when the peak load dropped more than 20%. After each test, a small cube was cut from the wood I-joist flange of one specimen from each group of six replicates and moisture content (MC) was determined using the oven-dry method in accordance with the ASTM D4442 [7].




(**a**) Centered (No.11-4)


(**b**) Rotated (No.17-2)

(**c**) Offset (No.19-1)

**Figure 7.** Actual test setup for three different anchor placements.

## 4. Test Results

During the tests, displacement measurements were obtained from the actuator's displacement, while loads were recorded using the actuator's load cell. Typical load–displacement curves are presented in Figure 8. The average MC for LVL and SSL flanges were approximately 8% and 9%, respectively.

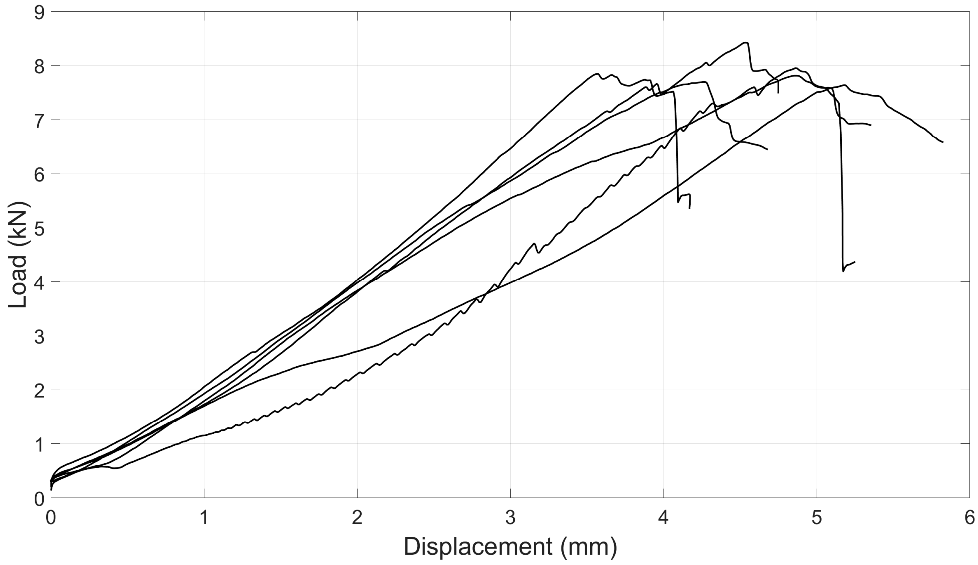



**Figure 8.** Load–displacement curves for C-15-50-4-53-LVL specimens.

The peak loads of individual withdrawal tests on wood I-joist specimens, except for the offset specimens (No. 19), are tabulated in Table 4, along with their mean values, variability, and failure modes. Two main failure modes were observed: screw withdrawal and flange splitting. Screw withdrawal was the primary failure mode, accounting for two-thirds of the specimens. Flange splitting occurred in about one-third of the specimens and is highlighted in bold in Table 4. Typically, the screw withdrawal failure did not exhibit a recognizable failure part as it often occurred within the wood. However, some withdrawal failures showed observable lifting of the anchor plate, as illustrated in Figure 9. Conversely, flange splitting failures occurred either on the side or at the bottom of the flange, with examples of these two typical splitting failures shown in Figure 10.

It should be noted that an unexpected failure occurred in specimen No. 8#5 (marked in red in Table 4). In this test, the I-joist flange was pulled out as shown in Figure 11. This failure may have been caused by the bottom flange touching the testing frame and being restrained from moving during the withdrawal test or by a manufacturing defect in the wood I-joist, such as insufficient glue between the flange and the web.

**Table 4.** Withdrawal test results.

| No. | Label | Peak Load (kN) | | | | | | | COV (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | #1 | #2 | #3 | #4 | #5 | #6 | Mean | |
| 1 | C-15-60-4-53-LVL | 13.6 | 10.6 | **10.3** | 11.2 | 12.1 | 11.8 | 11.6 | 10.2 |
| 2 | C-15-60-4-64-SSL | 14.2 | 13.9 | 11.3 | **15.4** | 15.4 | 17.6 | 14.6 | 14.3 |
| 3 | C-15-60-8-64-SSL | 15.6 | 14.7 | 14.8 | **14.0** | 18.2 | 17.6 | 15.8 | 10.7 |
| 4 | C-15-60-8-89-SSL | 17.1 | 13.9 | **17.5** | 17.5 | 20.6 | 18.7 | 17.5 | 12.5 |
| 5 | C-15-60-8-89-LVL | 18.0 | 19.1 | 18.4 | 15.6 | 18.6 | 16.0 | 17.6 | 8.3 |
| 6 | C-18-60-4-64-SSL | 10.5 | 11.7 | **12.8** | 12.9 | 13.6 | **13.6** | 12.5 | 9.7 |
| 7 | C-18-60-8-64-SSL | **11.1** | 14.2 | 14.9 | **16.0** | 13.8 | 17.4 | 14.6 | 14.8 |
| 8 | C-18-60-8-89-SSL | 14.5 | 17.3 | 14.7 | 16.2 | 16.8 | 13.0 | 15.4 | 10.7 |
| 9 | C-15-50-4-53-LVL | 7.7 | 8.4 | 7.8 | 7.6 | **8.0** | **7.8** | 7.9 | 3.6 |
| 10 | C-15-50-4-64-SSL | 11.0 | 12.4 | 10.4 | 10.1 | 11.1 | 14.1 | 11.5 | 13.0 |
| 11 | C-15-50-8-64-SSL | 13.4 | 11.5 | **15.7** | 11.2 | **15.1** | 12.3 | 13.2 | 14.1 |

**Table 4.** *Cont.*

| No. | Label | Peak Load (kN) | | | | | | | COV (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | #1 | #2 | #3 | #4 | #5 | #6 | Mean | |
| 12 | C-15-50-8-89-SSL | **15.5** | **11.6** | **14.0** | **14.9** | **14.2** | 14.7 | 14.2 | 9.6 |
| 13 | C-15-50-8-89-LVL | **12.8** | **12.1** | **12.0** | 13.3 | **10.5** | **14.4** | 12.5 | 10.5 |
| 14 | C-18-50-4-64-SSL | 12.8 | 12.4 | 10.4 | 12.3 | 12.2 | 7.3 | 11.2 | 18.7 |
| 15 | C-18-50-8-64-SSL | **10.7** | **10.8** | 13.4 | **10.8** | **14.3** | **17.2** | 12.9 | 20.4 |
| 16 | C-18-50-8-89-SSL | **15.2** | **15.5** | **14.5** | 12.7 | 16.5 | 17.2 | 15.3 | 10.2 |
| 17 | R-15-60-8-64-SSL | 10.9 | 11.1 | 13.8 | 10.5 | 17.3 | 12.6 | 12.7 | 20.2 |
| 18 | R-15-50-8-64-SSL | **10.6** | **8.6** | **10.7** | **12.1** | **9.8** | **6.7** | 9.8 | 19.3 |

Note: Peak load values in bold font indicate flange splitting failures; peak load values marked in red signify flange pull-out failures; and the remaining represent screw withdrawal failures.


**Figure 9.** Withdrawal failure of specimen No.9 #2.


(**a**) Flange splitting on the side (No.6 #3) (**b**) Flange splitting at the bottom (No. 12 #1)

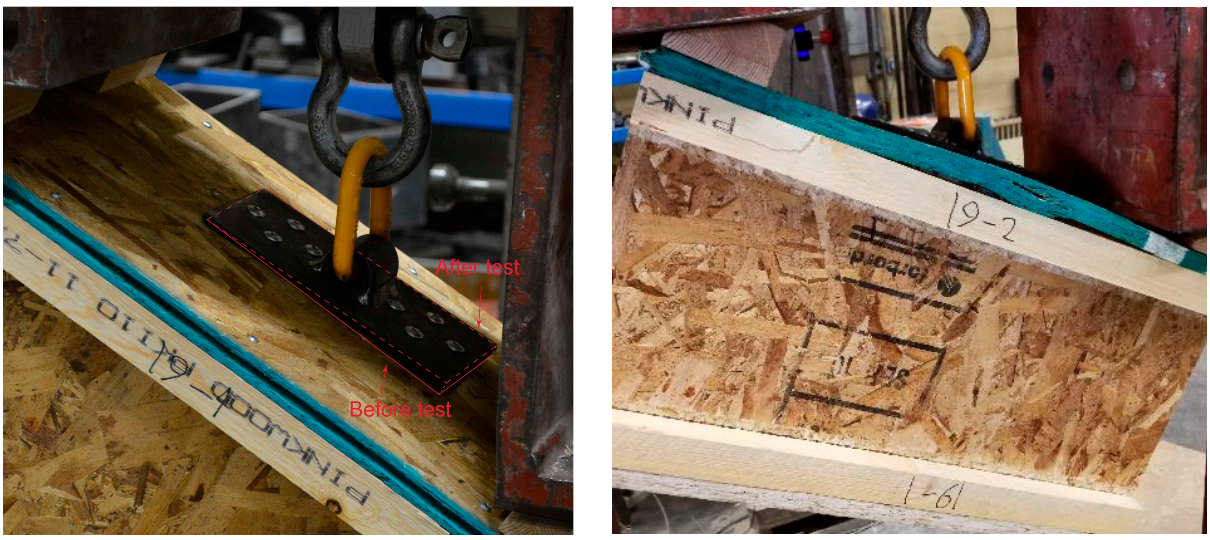
**Figure 10.** Typical flange splitting failures.

**Figure 11.** Flange pull-out of No.8 #5.

The test results for the No. 19 specimens with offset anchor plates, which were only screwed to OSB panels, are shown in Table 5. Two failure modes were observed, as illustrated in Figure 12: screw withdrawal and plate lifting and OSB panel failure. Table 5 indicates that, although the anchor plate was only screwed into the OSB panel, their withdrawal capacities did not significantly reduce. Direct fastening into OSB (No. 19 specimens) still retained about half or two-thirds of the capacity of the No. 15 and 16 specimens, where all eight screws were threaded into the wood I-joist flange.

**Table 5.** Peak loads of withdrawal tests for the offset specimens (O-18-50-8).

| Specimen | Peak Load (kN) | Failure Mode |
|---|---|---|
| No.19 #1 | 8.4 | Screw withdrawal and plate lifting |
| No.19 #2 | 7.7 | OSB failure |
| No.19 #3 | 8.0 | OSB failure |
| No.19 #4 | 8.0 | Screw withdrawal and plate lifting |
| No.19 #5 | 8.6 | Screw withdrawal and plate lifting |
| No.19 #6 | 7.2 | OSB failure |
| | Mean: 8.0 kN | COV: 6.1% |




(**a**) Screw withdrawal and plate lifting (**b**) Sheathing panel failure

**Figure 12.** Failure modes of the offset specimens.

## 5. Discussions

This section discusses the influence of screw types and quantities, OSB thickness, and joist flange material and width on the withdrawal capacity.

### *5.1. Effect of Screw Types*

Two screw types were employed in the withdrawal tests: PT-60 and FT-50. Although the PT-60 screw is partially threaded with a shorter thread length (37 mm) compared to the FT-50 (45 mm), PT-60 screws consistently exhibited higher withdrawal capacity than that of FT-50 screws, as shown in Table 6 and Figure 13. This may be because the penetration thread length of the PT-60 in the I-joist flange is longer than that of the FT-50.

**Table 6.** Withdrawal capacity and difference in specimens with two different screws.

| Label | Withdrawal Capacity | | | | Comparison $P_{60}/P_{50}$ |
|---|---|---|---|---|---|
| | PT-60 | | FT-50 | | |
| | Mean Value $P_{60}$ (kN) | COV (%) | Mean Value $P_{50}$ (kN) | COV (%) | |
| C-15-60/50-4-53-LVL | 11.6 | 10.2 | 7.9 | 3.6 | 1.47 |
| C-15-60/50-4-64-SSL | 14.6 | 14.3 | 11.5 | 13.0 | 1.27 |
| C-15-60/50-8-64-SSL | 15.8 | 10.7 | 13.2 | 14.1 | 1.20 |
| C-15-60/50-8-89-SSL | 17.5 | 12.5 | 14.2 | 9.6 | 1.24 |
| C-15-60/50-8-89-LVL | 17.6 | 8.3 | 12.5 | 10.5 | 1.41 |
| C-18-60/50-4-64-SSL | 12.5 | 9.7 | 11.2 | 18.7 | 1.11 |
| C-18-60/50-8-64-SSL | 14.6 | 14.8 | 12.9 | 20.4 | 1.13 |
| C-18-60/50-8-89-SSL | 15.4 | 10.7 | 15.3 | 10.2 | 1.01 |
| R-15-60/50-8-64-SSL | 12.7 | 20.2 | 9.8 | 19.3 | 1.30 |

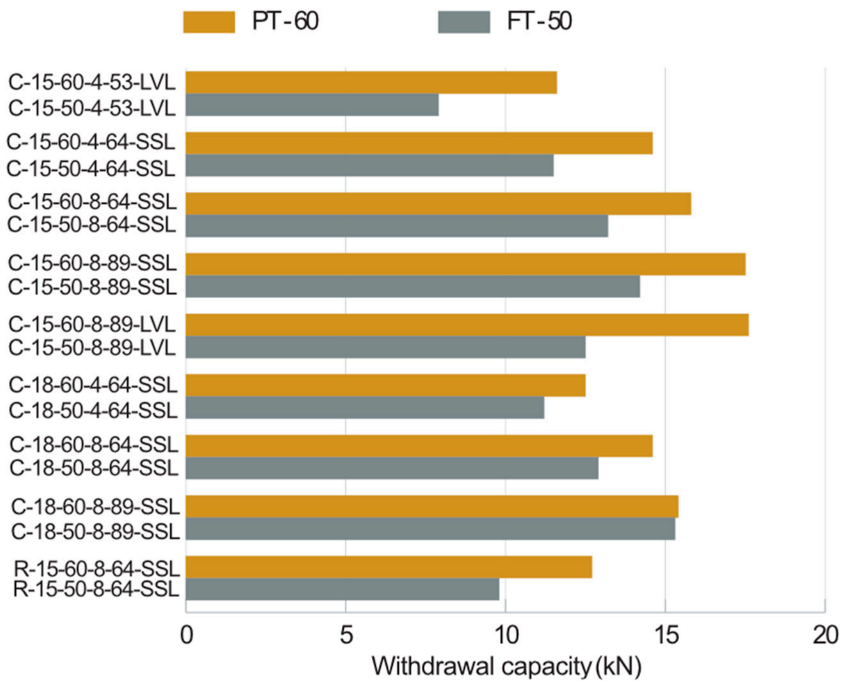



**Figure 13.** Withdrawal capacity for specimens with different screws.

*5.2. Effect of OSB Thickness*

Table 7 and Figure 14 reveal that the specimens with 15 mm OSB panels generally outperformed those with 18 mm OSB panels, except for specimens of the C-15-50-8-89-SSL specimens, which predominantly experienced flange splitting failures. This enhanced withdrawal capacity for the thinner sheathing specimens can be attributed to increased screw penetration depth into the I-joist flange for thinner OSB panels, similar to the screw-type findings. Results suggest that screw penetration depth within the I-joist flange is a primary determinant of withdrawal capacity in wood I-joist floor panels.

**Table 7.** Withdrawal capacity of specimens with two OSB thicknesses.

| Label | Withdrawal Capacity | | | | Comparison $P_{15}/P_{18}$ |
|---|---|---|---|---|---|
| | 15 mm OSB | | 18 mm OSB | | |
| | Mean $P_{15}$ (kN) | COV (%) | Mean $P_{18}$ (kN) | COV (%) | |
| C-15/18-60-4-64-SSL | 14.6 | 14.3 | 12.5 | 9.7 | 1.2 |
| C-15/18-60-8-64-SSL | 15.8 | 10.7 | 14.6 | 14.8 | 1.1 |
| C-15/18-60-8-89-SSL | 17.5 | 12.5 | 15.4 | 10.7 | 1.1 |
| C-15/18-50-4-64-SSL | 11.5 | 13.0 | 11.2 | 18.7 | 1.0 |
| C-15/18-50-8-64-SSL | 13.2 | 14.1 | 12.9 | 20.4 | 1.0 |
| C-15/18-50-8-89-SSL | 14.2 | 9.6 | 15.3 | 10.2 | 0.9 |

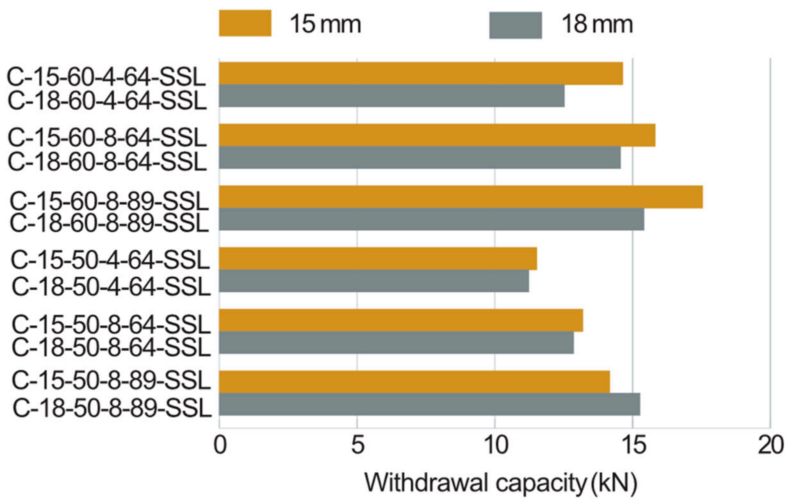



**Figure 14.** Withdrawal capacity and difference in specimens with two OSB thicknesses.

*5.3. Effect of Screw Quantity*

As shown in Table 8 and Figure 15, the withdrawal capacity of specimens with eight screws is not two times larger than those with four screws and their capacities barely increase by 10% to 20%. Unexpectedly, for the specimens with the anchor plate rotated and only four out of eight screws on the flange, the withdrawal capacity was even smaller compared to the standard four-screw configurations. This indicates that the rotation of the anchor plate significantly reduces the withdrawal capacity of the rigging device.

**Table 8.** Withdrawal capacity and difference in specimens with three screw arrangements.

| Label | Withdrawal Capacity | | | | | | Comparison | |
|---|---|---|---|---|---|---|---|---|
| | 4 Screws | | 8 Screws | | 8 Screws (4 on OSB) | | | |
| | Mean $P_4$ (kN) | COV (%) | Mean $P_8$ (kN) | COV (%) | Mean $P_{84}$ (kN) | COV (%) | $\frac{P_8}{P_4}$ | $\frac{P_{84}}{P_4}$ |
| C/R-15-60-4/8-64-SSL | 14.6 | 14.3 | 15.8 | 10.7 | 12.7 | 20.2 | 1.08 | 0.87 |
| C-18-60-4/8-64-SSL | 12.5 | 9.7 | 14.6 | 14.8 | N.A. | N.A. | 1.16 | N.A. |
| C-18-50-4/8-64-SSL | 11.2 | 18.7 | 12.9 | 20.4 | N.A. | N.A. | 1.15 | N.A. |
| C/R-15-50-4/8-64-SSL | 11.5 | 13.0 | 13.2 | 14.1 | 9.8 | 19.3 | 1.15 | 0.85 |

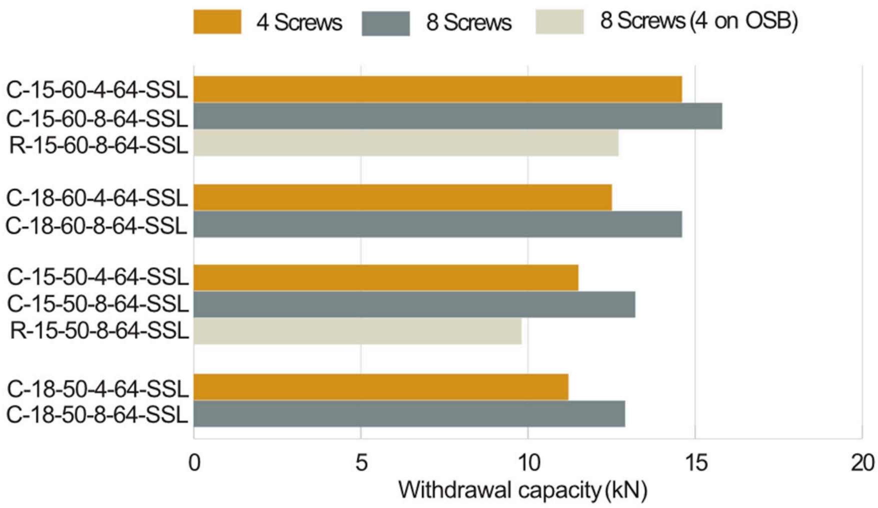



**Figure 15.** Withdrawal capacity for specimens with three screw arrangements.

### *5.4. Effect of Flange Width*

Table 9 and Figure 16 demonstrate that I-joist specimens with wider SSL flanges (89 mm) exhibited higher withdrawal capacities compared to those with narrower SSL flanges (64 mm). This enhancement is likely attributed to the increased distance between the flange edges and screw locations.

**Table 9.** Withdrawal capacity and difference in specimens with two different flange widths.

| Label | Withdrawal Capacity | | | | Comparison $P_{89}/P_{64}$ |
|---|---|---|---|---|---|
| | 64 mm (IJSSL64) | | 89 mm (IJSSL89) | | |
| | Mean $P_{64}$ (kN) | COV (%) | Mean $P_{89}$ (kN) | COV (%) | |
| C-15-60-8-64/89-SSL | 15.8 | 10.7 | 17.5 | 12.5 | 1.11 |
| C-18-60-8-64/89-SSL | 14.6 | 14.8 | 15.4 | 10.7 | 1.06 |
| C-15-50-8-64/89-SSL | 13.2 | 14.1 | 14.2 | 9.6 | 1.07 |
| C-18-50-8-64/89-SSL | 12.9 | 20.4 | 15.3 | 10.2 | 1.19 |

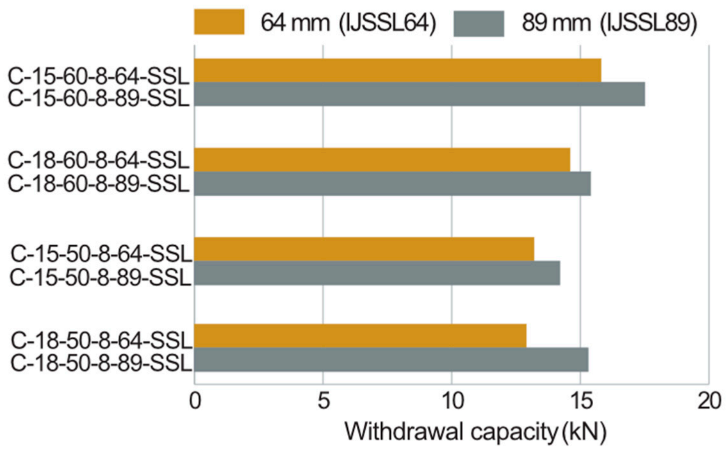



**Figure 16.** Withdrawal capacity of specimens with two different flange widths.

## *5.5. Effect of Flange Materials*

As illustrated in Table 10 and Figure 17, comparisons of the withdrawal capacity between IJLVL and IJSSL specimens show that those with the SSL flange exhibit higher withdrawal capacity than those with the LVL flange. A significant increase in more than 20% was observed for C-15-60-4-64-SSL compared to C-15-60-4-53-LVL and for C-15-50-4-64-SSL to C-15-50-4-53-LVL specimens. While the wider flange width contributes to capacity increase, as discussed in the preceding section, this effect was less than 20% as shown in Table 9. Therefore, it can be concluded that the SSL flange specimens exhibit higher withdrawal capacity compared to the LVL flange specimens.

**Table 10.** Withdrawal capacity of specimens with two different flange materials.

| **Label** | **Withdrawal Capacity** | | | | **Comparison $P_{SSL}/P_{LVL}$** |
|---|---|---|---|---|---|
| | **IJLVL** | | **IJSSL** | | |
| | **Mean $P_{LVL}$ (kN)** | **COV (%)** | **Mean $P_{SSL}$ (kN)** | **COV (%)** | |
| C-15-60-4-53-LVL/C-15-60-4-64-SSL | 11.6 | 10.2 | 14.6 | 14.3 | 1.26 |
| C-15-60-8-89-LVL/C-15-60-8-89-SSL | 17.6 | 8.3 | 17.5 | 12.5 | 1.00 |
| C-15-50-4-53-LVL/C-15-50-4-64-SSL | 7.9 | 3.6 | 11.5 | 13.0 | 1.46 |
| C-15-50-8-89-LVL/C-15-50-8-89-SSL | 12.5 | 10.5 | 14.2 | 9.6 | 1.13 |

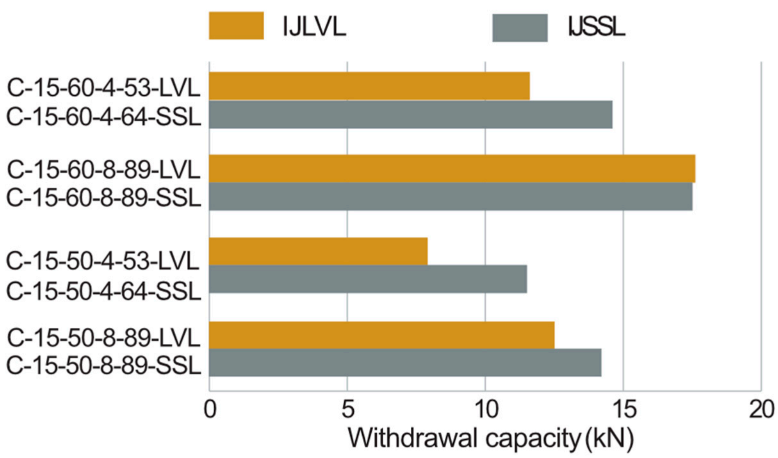



**Figure 17.** Withdrawal capacity of specimens with two different flange materials.

## 6. Conclusions

In this study, a novel rigging device for prefabricated wood I-joist floor panels was developed and evaluated through withdrawal testing. The device can be installed on the panel surface using self-tapping screws, eliminating the need for predrilled holes in the sheathing panels and framing members. The tests evaluated the influence of anchor plate placements, flange materials and width, screw quantity, and OSB thickness on the withdrawal capacity.

Test results indicate that both the screw penetration depth (not just the threaded length) within the joist flange and the number of screws significantly affect the withdrawal capacity. The longer the penetration length and the greater the number of screws, the higher the capacity the rigging device exhibits. However, the capacity does not increase proportionally with the number of screws. Anchor plates with eight screws centered on the flange show up to a 20% increase compared to those with four screws. Additionally, thinner OSB panels resulted in higher withdrawal capacities and rotating the anchor plate significantly reduces the withdrawal capacity. A wider flange slightly increases the capacity and I-joists with SSL flanges exhibit higher capacity compared to those with LVL flanges.

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