

Standard Test Method for Vertical Holding Strength of Rafter-to-Sheathing Attachments in Light Wood Frame Roof Systems

Significance and Use

1.1 This test method was designed to assess the tensile strength of sheathing attachments to rafters in residential wood-frame construction, simulating uplift forces such as those caused by wind.

1.2 Failures of roof sheathing under wind loads are a common mode of structural failure that can lead to further rafter damage and allow water intrusion into the building envelope.

1.3 Typical fastening practices—such as using 6d or 8d nails spaced at 24 inches—may be inadequate in high wind zones, particularly when adhesive is not used in conjunction with mechanical fasteners.

1.4 The use of structural adhesives at the sheathing-to-rafter joint has the potential to substantially increase uplift resistance. This test evaluates the comparative performance of adhesive-reinforced versus nailed-only assemblies.

1.5 The method emphasizes tensile loading in a direction perpendicular to the plane of the sheathing, which is representative of wind suction effects acting on the roof surface.

1.6 The test results can inform product specification, fastening schedules, and construction best practices, especially in hurricane-prone regions or where higher safety margins are desired.

2. Scope

2.1 This standard describes a testing method for rafter-to-sheathing attachment assemblies using 1-foot-long rafter sections connected to 1-square-foot, 5/8-inch-thick sheathing panels. The joints are tested in direct tension perpendicular to the sheathing face.

3. Material

3.1 All test specimens are constructed using Douglas Fir 2x4 lumber, arranged in three-member assemblies.

3.2 Three types of sheathing substrates shall be used:

3.2.1 CD 5/8" Plywood (C side up)

3.2.2 5/8" OSB (ZIP System) – smooth side

3.2.3 5/8" OSB – rough side

3.3 Each adhesive-reinforced assembly receives a 3/8-inch bead of construction adhesive applied at the connection interface.

3.4 Tensile testing shall be conducted using an Instron tensile testing machine (or equivalent), at a separation rate of 0.2 inches per minute.

3.5 A custom-designed steel fixture (see Fig. 1) is used to grasp and stabilize the rafter for direct upward loading. A separate steel channel fixture (see Fig. 3) was developed to grip the rafter using 1/2 inch screw holes arranged through predrilled holes.

3.6 Each specimen included the use of two 8d nails.

4. Method

4.1 Each panel shall be joined with a 3/8 inch bead of construction adhesive placed using a controlled jig (See Fig. 2) and reinforced with 8d nails spaced at 10 inches. Nails are guided into position using pre-drilled pilot holes and driven flush after panel placement.

4.2 The rafter to sheathing test batches are as follows:

4.2.1 Nails only

- A. Two 8d nails to CD plywood
- B. Two 8d nails to smooth ZIP OSB
- C. Two 8d nails to rough OSB

4.2.2 Nails + Adhesive

- A. Nails and adhesive to CD plywood
- B. Nails and adhesive to rough OSB
- C. Nails and adhesive to ZIP OSB smooth

4.3 Test specimens shall be conditioned for 28 days in ambient conditions before testing to reflect fully cured adhesive performance.

4.4 Each specimen is placed and screwed into a custom-designed steel fixture (see Fig. 1) to prepare for testing.

4.5 With the specimen mounted within the steel fixtures, the crosshead is moved vertically at a constant rate of 0.2 inches per minute, producing direct tensile loading perpendicular to the sheathing surface.

4.6 Each test batch included ten identical specimens, and all tests were monotonic (non-cyclic).

4.7 After testing, specimens are visually inspected to assess failure mode, such as substrate tear-out or adhesive debonding.

Preliminary Results and Observations

5.1 Rafter to sheathing nails only:

5.1.1 Two 8d nails to CD plywood: **165 – 275 lbs**

5.1.2 Two 8d nails to smooth ZIP OSB: **175 – 225 lbs**

5.1.3 Two 8d nails to rough OSB: **180 – 205 lbs**

5.2 Rafter to sheathing nails + adhesive:

5.2.1 Nails and adhesive to CD plywood : **1,900 – 2,400 lbs**

5.2.2 Nails and adhesive to rough OSB: **775 – 850 lbs**

5.2.3 Nails and adhesive to ZIP OSB smooth: **1,300 – 1,635 lbs**

5.3 Both plywood and OSB specimens showed extensive substrate failure above the rafter glueline. This suggests that stronger grades of plywood would increase overall tensile performance.

Notes

Note 1: The unique focus of this test on the sheathing-to-rafter connection addresses a gap in current ASTM standards and provides actionable data for roof system improvement.

Note 2: Adjustments to fastener type, adhesive brand, panel thickness, or environmental exposure can be incorporated by agreement between project stakeholders.

Note 4: For long-term strength development and durability, manufacturers' full adhesive cure times and product-specific handling instructions should be followed when applying this method in performance testing.

Note 5: Pound units are used as the standard.

Note 6: This document does not address all potential safety hazards. Users are responsible for implementing appropriate safety procedures and verifying compliance with applicable laws.

Figures:

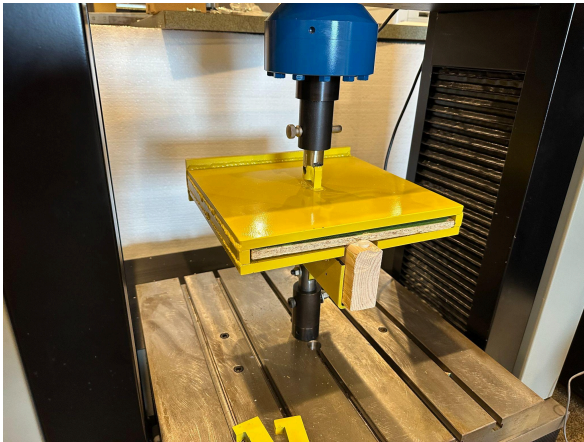


Fig. 1 Designed steel fixture and rafter to sheathing connection



Fig. 2 Wood channel for rafter to sheathing adhesion

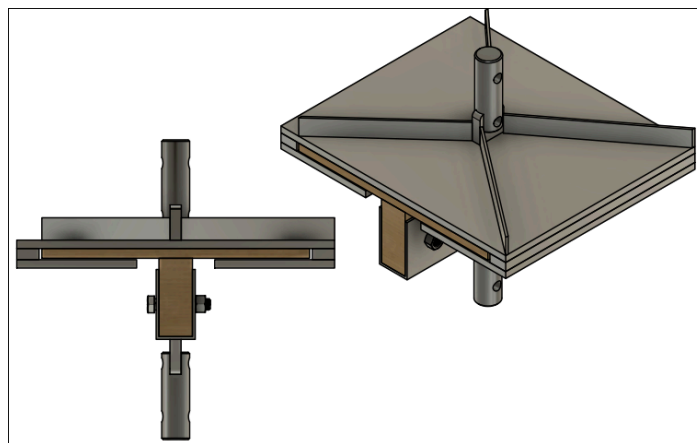


Fig. 3 Steel fixture and rafter to sheathing connection sketch

Test Procedure for Vertical Tensile Resistance of Bird Mouth and Truss Chord Roof-to-Wall Connections

Significance and Use

1.1 This test method was developed to evaluate the vertical holding strength of two frequently used wall-to-rafter connection types in light-frame wood construction: the “Bird Mouth” and the “Truss Chord” joint. These joints are critical in resisting roof uplift during extreme wind events.

1.2 Observational data from residential structures indicate that failures often initiate at the wall-to-roof interface, making these joints primary candidates for mechanical improvement.

1.3 Building codes commonly specify three 8d nails for these connections, but field performance has shown that such fastening is often insufficient to resist vertical separation forces.

1.4 This method allows for a side-by-side comparison of nailed-only joints versus joints reinforced with structural adhesives, providing insight into the enhanced performance adhesives may offer.

1.5 The methodology isolates the joint behavior from full structural framing, providing targeted data useful for structural engineers, builders, and code officials interested in improving connection integrity.

Scope

2.1 This procedure outlines a method for testing the tensile strength of wall-to-roof rafter connections under upward loads applied perpendicularly to the plane of the wall-top plate. The two connection types tested are the “Bird Mouth” and “Truss Chord” configurations.

Material

3.1 All specimens utilize 2x4 sections of Douglas Fir as a rafter substrate.

3.2 For adhesive-reinforced specimens, Adhesive shall be applied as a continuous 3/8" bead. Both the “Truss Chord” and “Bird Mouth” configurations contained three 8d nails.

3.3 Nailed specimens shall be assembled according to code using two nails inserted at a 30-degree angle at the rafter, and one nail on the opposite side of the rafter. Nails are maintained at a 30-degree angle with a fixture to ensure the angle.

3.4 Testing shall be conducted using an Instron tensile testing machine at a separation rate of 0.2 inches per minute. A designed steel fixture (see Fig. 1) is used to grasp and stabilize the rafter for direct upward loading. All tests are monotonic (non-cyclic).

Method

4.1 A precision fixture shall be used to ensure consistency in the nails angle across all specimens. Ten specimens per connection type shall be constructed and tested.

4.2 Adhesive-reinforced specimens are cured at ambient room temperature for 28 days before testing to achieve full bond strength. Nailed-only joints are tested after 24 hours.

4.3 The top plate wall configuration is composed of two 2x4 pieces cut to a 12 in. length and nailed together. The top plate is then nailed and or adhered to a single 2x4 rafter cut at 18in. length prior to testing.

4.4 The “Bird Mouth” configuration follows the same orientation as the “Truss Chord” configuration accompanied by a machined notch at the bottom end of the rafter. This notch was then used as the bearing point for the top plate and rafter connection (see Fig. 3).

4.5 Following assembly, cured “Truss chord” specimens shall be placed in a designed steel fixture to ensure vertical separation in the tensile tester (see Fig. 2).

Notes

Note 1: This test method was developed due to the lack of existing ASTM procedures for evaluating vertical tension resistance in these specific joint configurations. It may serve as a basis for future standardized evaluations.

Note 2: Where alternate adhesives, nails, or environmental conditions are expected in service, the parameters of this test—such as cure time, angle of the nail, or test rate—can be modified by mutual agreement between relevant stakeholders.

Preliminary Conclusions

5.1 Results of tensile performance are as follows:

5.11 Bird mouth & Truss Chord (nails only):	225-275 lbs
5.12 Bird mouth (nails + adhesive):	900-1100 lbs
5.13 Truss Chord (nails + adhesive):	550-650 lbs

5.2 All specimens exhibited observable nail damage to the top plate wood substrate.

5.3 Bird mouth specimens produced higher test performance as a result of the small vertical shear surface and greater bonded surface area.

5.4 Joints reinforced with Climate NS Adhesive demonstrated 3 to 4 times greater vertical tensile capacity than their nailed-only counterparts, suggesting that adhesive use significantly enhances uplift resistance in roof-to-wall connections.

5.5 These findings may serve as the basis for future code recommendations or engineered solutions that go beyond minimum property standards, particularly in hurricane- or tornado-prone areas.

Figures:



Fig. 1 Designed steel fixture and bird mouth



Fig. 2 Designed steel fixture and truss chord

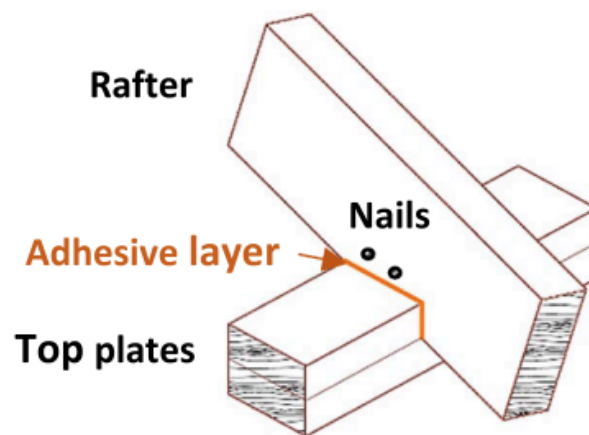
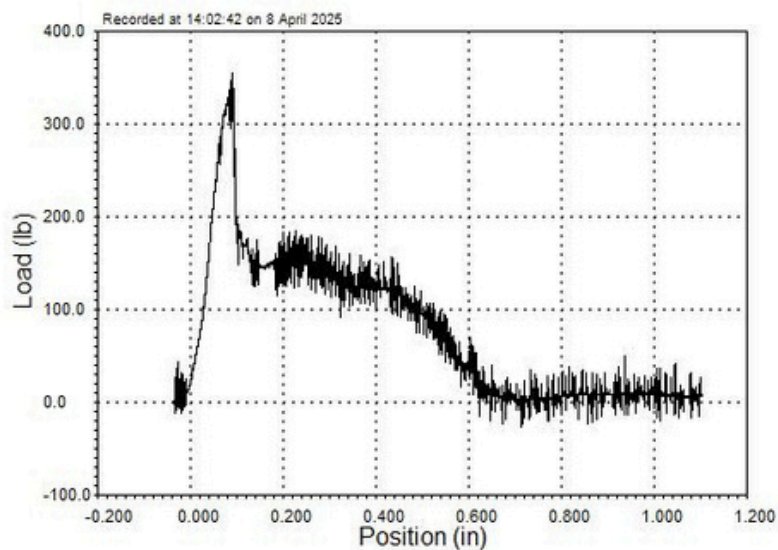


Fig. 3 Bird mouth connection sketch

Rafter to Sheathing - OSB
Nails Only_1



Specimen Identifier:
Material :
Operator:

OSB_N1
Climate NS
OP

Test Date:
Start Time:
End Time:

8 April 2025
14:02:42
14:08:24

Geometry:
Area:

Area
18.0000 sq in

Analysis Results

Extension at Maximum Load

Extension at Maximum Load

0.091 in

Load At Break

Load

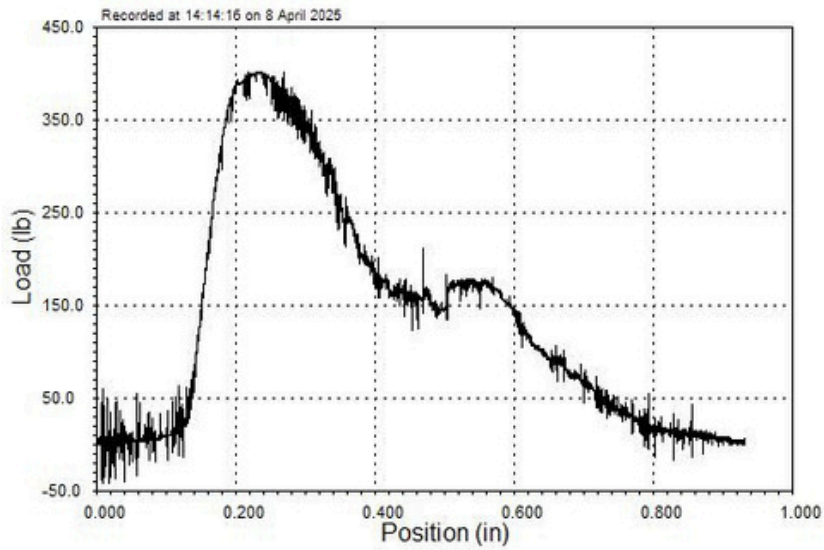
N/A

Maximum Load

Load

355 lb

Rafter to Sheathing - OSB
Nails Only_2

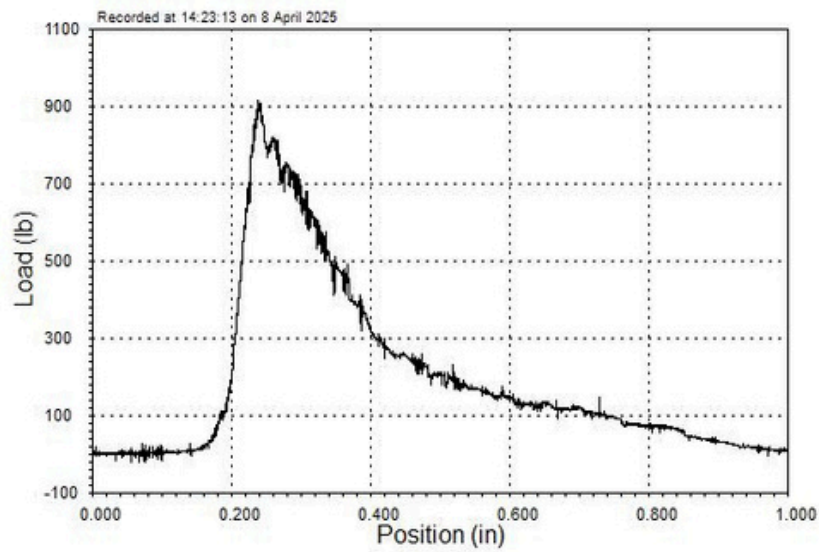


Specimen Identifier:	OSB_N2
Material :	Climate NS
Operator:	OP
Test Date:	8 April 2025
Start Time:	14:14:16
End Time:	14:18:56
Geometry:	Area
Area:	18.0000 sq in

Analysis Results

<u>Extension at Maximum Load</u>	
Extension at Maximum Load	0.218 in
<u>Load At Break</u>	
Load	N/A
<u>Maximum Load</u>	
Load	402 lb

Rafter to Sheathing - OSB
Nails and Adhesive_1



Specimen Identifier:
Material :
Operator:

OSB_A1
Climate NS
OP

Test Date:
Start Time:
End Time:

8 April 2025
14:23:13
14:28:13

Geometry:
Area:

Area
18.0000 sq in

Analysis Results

Extension at Maximum Load

Extension at Maximum Load

0.239 in

Load At Break

Load

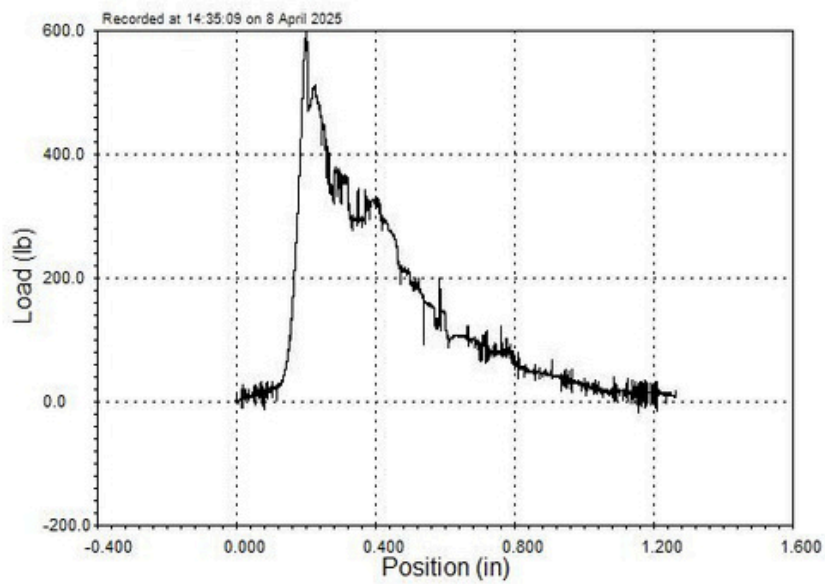
N/A

Maximum Load

Load

912 lb

Rafter to Sheathing - OSB Nails and Adhesive_2



Specimen Identifier:
Material :
Operator:

OSB_A1
Climate NS
OP

Test Date:
Start Time:
End Time:

8 April 2025
14:35:09
14:41:29

Geometry:
Area:

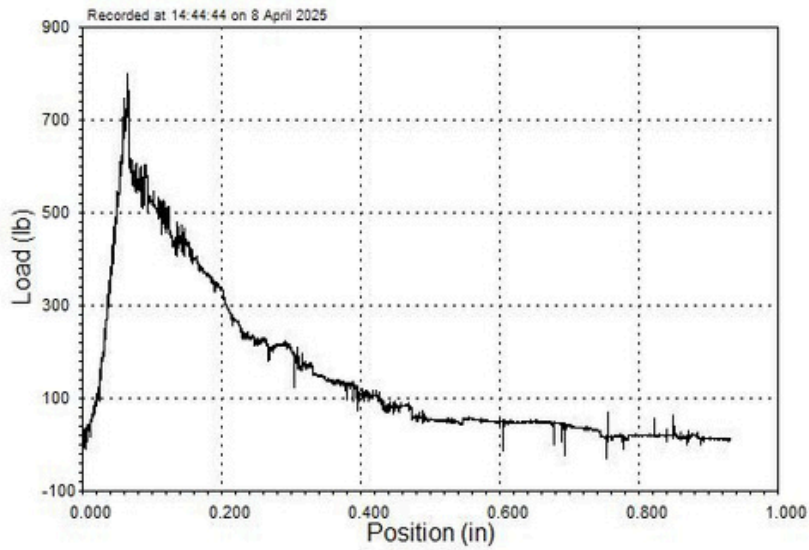
Area
18.0000 sq in

Analysis Results

Extension at Maximum Load
Extension at Maximum Load
Load At Break
Load
Maximum Load
Load

0.203 in
N/A
597 lb

Rafter to Sheathing - OSB
Nails and Adhesive_3

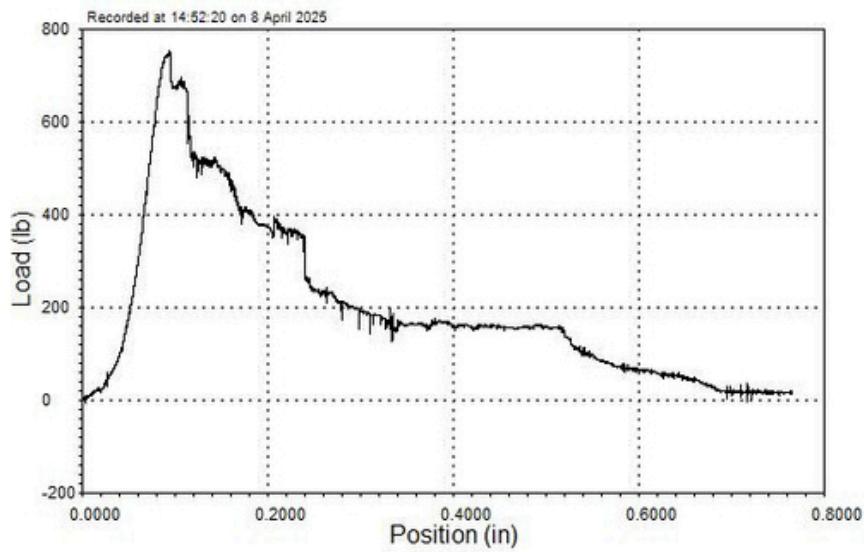


Specimen Identifier:	OSB_A3
Material :	Climate NS
Operator:	OP
Test Date:	8 April 2025
Start Time:	14:44:44
End Time:	14:49:24
Geometry:	Area
Area:	18.0000 sq in

Analysis Results

<u>Extension at Maximum Load</u>	
Extension at Maximum Load	0.067 in
<u>Load At Break</u>	
Load	N/A
<u>Maximum Load</u>	
Load	798 lb

Rafter to Sheathing - OSB
Nails and Adhesive_4

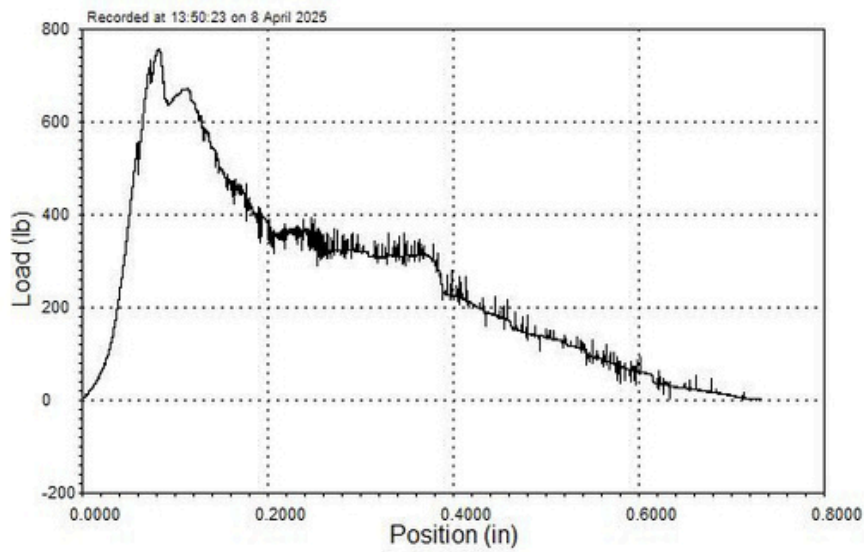


Specimen Identifier:	OSB_A4
Material :	Climate NS
Operator:	OP
Test Date:	8 April 2025
Start Time:	14:52:20
End Time:	14:56:10
Geometry:	Area
Area:	18.0000 sq in

Analysis Results

<u>Extension at Maximum Load</u>	
Extension at Maximum Load	0.094 in
<u>Load At Break</u>	
Load	N/A
<u>Maximum Load</u>	
Load	752 lb

Rafter to Sheathing - OSB
Nails and Adhesive_5

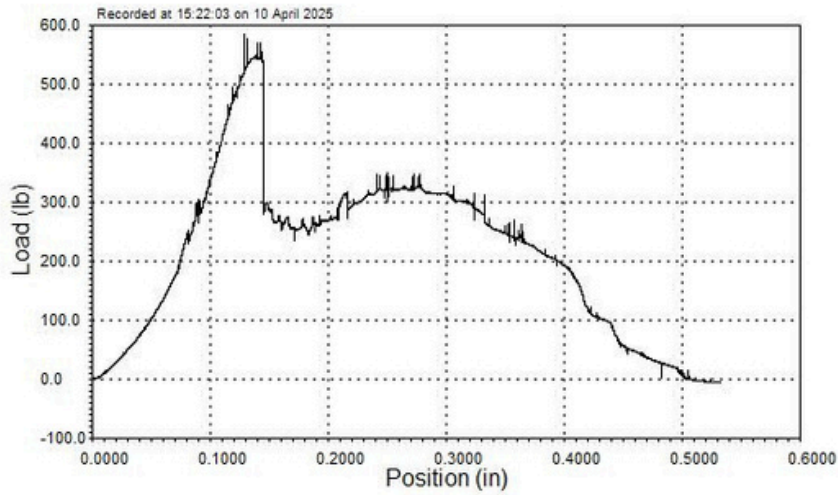


Specimen Identifier:	OSB_A5
Material :	Climate NS
Operator:	OP
Test Date:	8 April 2025
Start Time:	13:50:23
End Time:	13:54:03
Geometry:	Area
Area:	18.0000 sq in

Analysis Results

<u>Extension at Maximum Load</u>	
Extension at Maximum Load	0.083 in
<u>Load At Break</u>	
Load	0 lb
<u>Maximum Load</u>	
Load	756 lb

Rafter to Sheathing - PW
Nails Only_1



Specimen Identifier:
Material :
Operator:

PW_N1
Climate NS
OP

Test Date:
Start Time:
End Time:

10 April 2025
15:22:03
15:24:43

Geometry:
Area:

Area
18.0000 sq in

Analysis Results

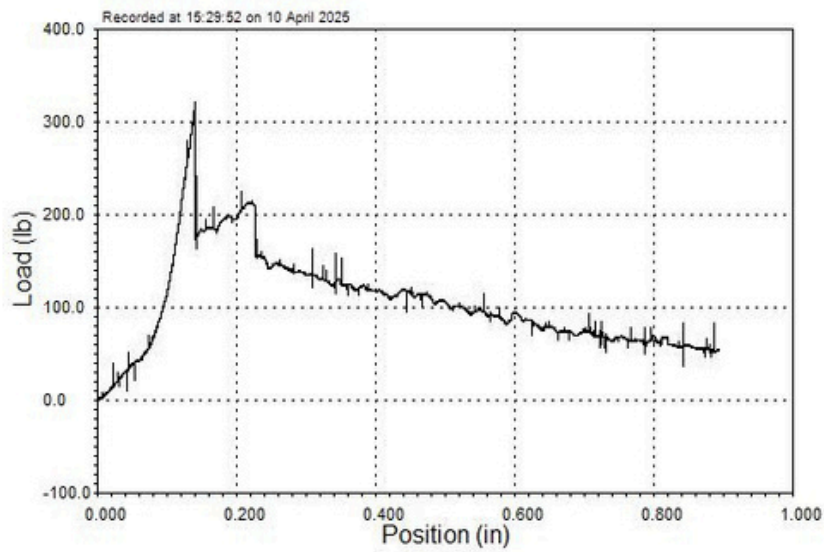
Extension at Maximum Load
Extension at Maximum Load
Load At Break
Load
Maximum Load
Load

0.130 in

0 lb

584 lb

Rafter to Sheathing - PW
Nails Only_2



Specimen Identifier:
Material :
Operator:

PW_N2
Climate NS
OP

Test Date:
Start Time:
End Time:

10 April 2025
15:29:52
15:34:20

Geometry:
Area:

Area
18.0000 sq in

Analysis Results

Extension at Maximum Load

Extension at Maximum Load

0.142 in

Load At Break

Load

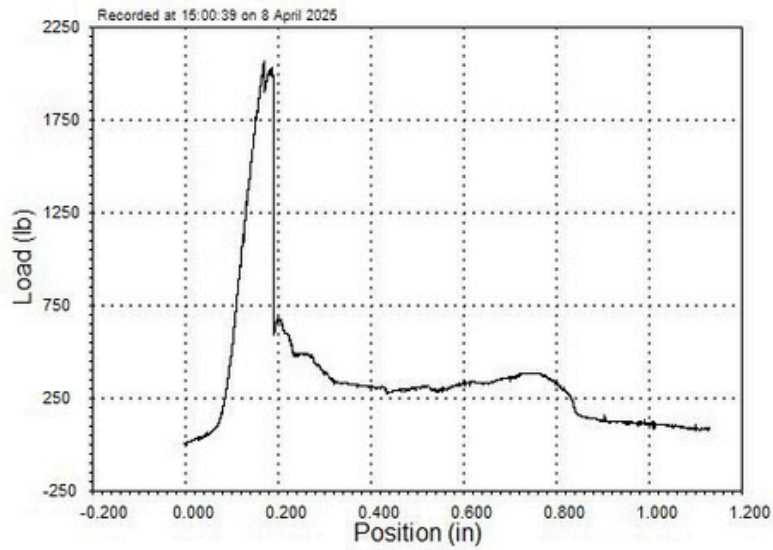
N/A

Maximum Load

Load

320 lb

Rafter to Sheathing - PW
Nails and Adhesive_1



Specimen Identifier:
Material :
Operator:

PW_A1
Climate NS
OP

Test Date:
Start Time:
End Time:

8 April 2025
15:00:39
15:06:19

Geometry:
Area:

Area
18.0000 sq in

Analysis Results

Extension at Maximum Load

Extension at Maximum Load

0.171 in

Load At Break

Load

N/A

Maximum Load

Load

2062 lb

Rafter to Sheathing - PW
Nails and Adhesive_2

Specimen Identifier:
Material :
Operator:

PW_A2
Climate NS
OP

Test Date:
Start Time:
End Time:

10 April 2025
15:12:22
15:13:42

Geometry:
Area:

Area
18.0000 sq in

Analysis Results

Extension at Maximum Load

Extension at Maximum Load

0.183 in

Load At Break

Load

N/A

Maximum Load

Load

871 lb

