World Conference on
Timber Engineering
Oslo 2023

NUMERICAL AND EXPERIMENTAL EVALUATION OF WOOD-NAILER OPEN WEB STEEL JOISTS

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ABSTRACT: The wood-nailer open web steel joist is a steel truss intended for use with a wood roof or floor deck. The wood-nailer is attached via mechanical shear connectors (self-drilling screws) to the full width and length of the top chord of steel joist. Current engineering practice does not consider the contribution of the wood-nailer to the strength and stiffness of the steel and wood hybrid system. This paper investigates the composite behavior of wood-steel joist systems through full-scale experimental testing and comprehensive 3-D finite element (FE) modelling. The FE model was calibrated by comparing results to full-scale experimental results on the wood-nailer steel joist system. The validated FE model of the wood-nailer-steel joist system is then used to conduct parametric studies that investigate the influence of screw spacing and wood-nailer thickness on the structural performance of the wood-nailer joist. This information is critical for developing a comprehensive composite design procedure.

KEYWORDS: wood-nailer, finite element modelling, composite behavior, full-scale testing

1 INTRODUCTION

An open web steel joist is a standard steel truss that consists of three components: the top chord (TC), the bottom chord (BC), and the web members, which are connected to the top and bottom chord by welds [1]. Chord members are typically double angles, with a gap in between, while web members can be either angles, channels, or rods. The conventional wood-nailer open web steel joist (WNOWSJ) is a standard steel joist with a wood-nailer attached to the top chord, as shown in Figure 1.

Figure 1: Hybrid Wood-on-Steel Roof System

The wood-nailer (WN) acts as a filler to attach the wood deck to the steel joist using mechanical fasteners. It consists of several wood-nailer segments, butted but not joined, attached to the joist's top chord steel angles via mechanical shear connectors (self-drilling screws), as shown in Figure 2.

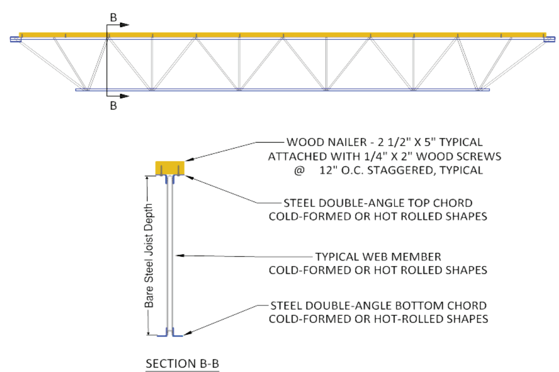

Figure 2: Wood-Nailer Steel Joist

Holes are punched in a staggered pattern into the horizontal legs of the top chord angles so self-drilling ¼-in (6.35 mm) diameter screws can be installed in pre-cut holes. The screw is then driven into the wood to attach the wood-nailer. A WNOWSJ is used in the panelized hybrid wood /steel roof system offering an attractive alternative to conventional timber joists. The conventional wood-nailer open web steel joist structural performance can be improved by making the wood-nailer structurally continuous and an integral component of the steel joist [2]. The structural continuity of the wood-nailer is achieved either through splicing the wood segments together along the length of the joist or by providing a

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https://doi.org/10.52202/069179-0003

single full-length wood member for each joist. As a structurally continuous wood-nailer, the strength of the wood-nailer can be incorporated in the steel joist design as either non-composite, partial composite, or fully composite with the joist steel top chord, depending on the shear connection behaviour. This paper investigates the composite behaviour of wood-steel joist systems through full-scale experimental testing conducted by Martignetti [4] and comprehensive 3-D non-linear finite element (FE) modelling. The FE model was validated by comparing the FE results to full-scale experimental data on the wood-nailer steel joist system. The validated FE model of the wood-nailer-steel joist system is then used to conduct a parametric study that investigates the influence of wood-nailer thickness and screw spacing on the structural performance of the wood-nailer joist.

2 EXPERIMENTAL

Martignetti et.al. [4] experimentally evaluated wood-nailer steel joist marks (J1) and bare steel joists (J3) performances. A total of four full-scale wood-nailer joist pair tests were conducted. Two full-scale joist pair tests involved a wood decking system, and the other two full-scale bare steel joist pair tests involved a steel decking system. The steel joists were 40 ft (12.19 m) long. Both joist marks J1 and J3 had a bare steel depth of 28-in (711 mm). J1 also had a 2 ½ in (64 mm) thick wood-nailer on the top chord for a total depth of 30.5 in (775 mm). The joist top and bottom chord angle sizes are described in

Table 1.

Table 1: Wood-nailer Steel Joist Dimensions

Joist Mark	J1
Steel Joist Type	Wood-Nailer
Deck Type	Plywood
WN Thickness in (mm)	2.5 (64)
WN Steel Joist Overall Depth in (mm)	30.5 (775)
Length ft (m)	40 (12.19)
Top Chord in (mm)	LL 2 x 3/16 (LL 51 x 5)
Bottom Chord in (mm)	LL 1.75 x 0.17 (LL 44 x 4)
Joist Mark	J3
Steel Joist Type	Steel Joist
Deck Type	Steel
Bare Steel Joist Depth in (mm)	28 (711)
Length ft (m)	40 (12.19)
Top Chord in (mm)	LL 2 x 3/16 (LL 51 x 5)
Bottom Chord in (mm)	LL 1.75 x 0.17 (LL 44 x 4)

All wood-nailer steel joists used in the experimental study had a wood-nailer 2.5-in (64-mm) thick x 5-in (127 mm) wide, attached to the top of the steel top chord angles with ¼-in (6.35 mm) diameter x 2-in (51 mm) long self-drilling screws staggered at 24-in (610 mm) on center. Figure 3 shows the attachment between the wood-nailer and the steel joist [2].

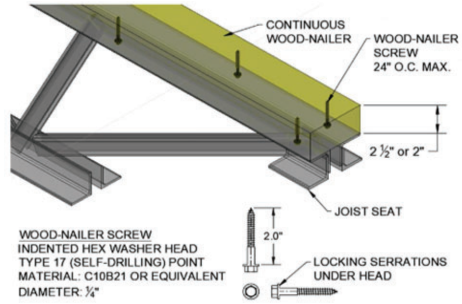


Figure 3: Wood-nailer Attachment to Steel Joist [2]

2.1 JOIST TEST SETUP

The wood-nailer steel joist pair was positioned 8 ft (2.44 m) apart to accurately simulate the joist's behaviour in a floor or roof system. Wood sub-purlins with nominal dimensions 2-in (51-mm) by 4-in (102-mm), and 24-in (610-mm) on center, are installed between the joists, and ½-in (13-mm) thick plywood sheathing is nailed to the sub purlins and joist wood-nailer by standard nailing techniques, creating a section of the roof. Figure 4 shows the wood-nailer joist (J1) specimen [4]. Steel joists (J3) were set up similarly to (J1). Figure 5 shows the steel joists (J3) and deck setup [3].

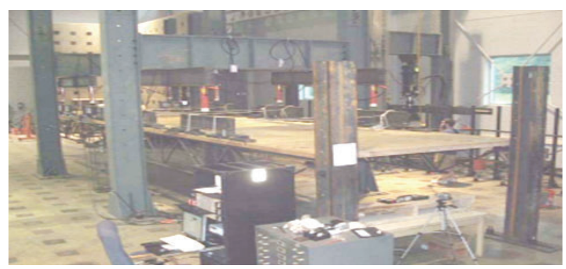


Figure 4: Wood-nailer Joist and Plywood Deck[4]

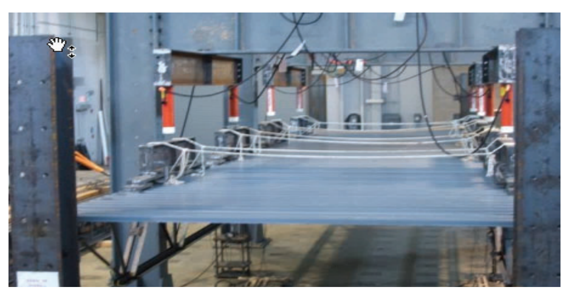


Figure 5: *Steel Joist and Deck [4]*

2.2 LOADING

A loading pyramid was used to create a distributed load over the middle 32 ft (9.75-m) of the wood-nailer steel joist span. The load was applied to the wood deck directly above the top chord of the joists. Figure 6 illustrates the

https://doi.org/10.52202/069179-0003

distributed loading pattern. A 10,000-psi (69 MPa) manual hydraulic pump was used to apply a static load.

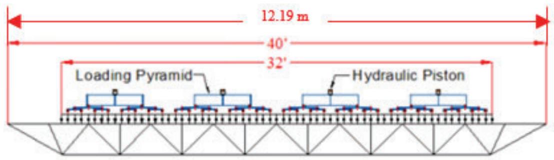


Figure 6: *Load Distribution Setup [4]*

2.3 DATA ACQUISITION

Linear variable displacement transducers (LVDTs) were used to measure the displacement near the mid-span of each joist. Eighteen strain gages were placed at the mid-span of each joist chord and wood-nailer to measure the strains and stresses in each component. Three Vishay Micro-Measurements scanners and the associated computer software recorded the signals from the load cells, LVDTs, and strain gages. Figure 7 shows strain gauge locations described in [4].

Figure 7: *Wood-Nailer Steel Joist Strain Gage Locations*

2.4 WOOD-NAILER MATERIAL TESTING

Martignetti [4][4] conducted a total of 28 tests per ASTM D4761 [5] to verify the modulus of elasticity of the Douglas-Fir wood-nailers. The statistical analysis of the test data shows that the median and the mean for the wood-nailer modulus of elasticity were both 1600 ksi (11000 MPa). The standard deviation was 314 ksi (2165 MPa)[4].

2.5 DETERMINATION OF STEEL PROPERTIES

Forty-eight steel coupons, one coupon per chord, were taken from all steel joists, then tested per ASTM E8-04 [6] for tensile testing. The statistical analysis of the test data shows that the median and the mean for the steel yield strength were both about 56 ksi (386 MPa), and the ultimate strength was about 81 ksi (559 MPa). The standard deviation for yield strength was 1.66 ksi (11.6 MPa), and for ultimate strength was 2.23 ksi (15.6 MPa)[4].

3 FINITE ELEMENT MODELLING

The finite element (FE) software package ANSYS [1][7] was used to develop a comprehensive 3-D non-linear finite element modelling (FEM) capable of replicating the experimental studies conducted on (J1) by Martignetti [4]. In addition, a bare steel joist (J3) was also simulated to serve as a reference structure against which the partial composite wood-nailer steel joist (J1) could be compared. The geometry, loads, and support conditions were applied to the numerical models. Steel joists were modelled as simply supported and subjected to a uniformly distributed load to simulate the experimental conditions.

3.1 MODELLING PROCEDURE

The following sections will describe the modelling procedure for material, geometry, shear connectors, boundary conditions, and mesh.

3.2 MATERIAL MODELLING

3.2.1 Hot-Rolled Steel

A simplified bi-linear stress-strain curve is used. The following mechanical properties were used:

Table 2: *Hot-Rolled Steel Mechanical Properties*

Property	Strength ksi (MPa)
Yield Strength	56 (386)
Modulus of Elasticity	29000 (199948)
Tangent Modulus	1450 (9997)

3.2.2 Shear Connector

The screw material is AISI-1021(C10B21). A simplified bi-linear stress-strain curve is used. Table 3 shows the mechanical properties that were used in the FE model.

Table 3: *Shear Connector Mechanical Properties*

Property	Strength ksi (MPa)
Yield Strength	57.3 (395)
Tensile Strength	68.2 (470)
Tangent Modulus	1450 (9997)

The AISI 1021 carbon steel is equivalent to ASTM 29.

3.2.3 Wood-Nailer

The variability of wood mechanical properties can significantly influence the structural performance of wood and steel-wood connections. Wood is an orthotropic material with unique and independent properties in different directions. However, since the primary strains and stresses are along the length of the joist, an isotropic material model using material properties for this direction are assumed. A simplified bi-linear stress-strain curve is used. Dowel bearing strength is used for the wood-nailer yield strength. Table 4 shows the Douglas-Fir wood's physical properties used in the FE model.

Table 4: *Douglas-Fir Wood-Nailer Mechanical Properties*

Property	Strength ksi (MPa)
Yield Strength	5 (34)
Modulus of Elasticity	1600 (11000)

Tangent Modulus	0.25 (1.73)

3.3 GEOMETRY

Symmetry constraints were used at the steel joist mid-length, as shown in Figure 8, to reduce the model size.

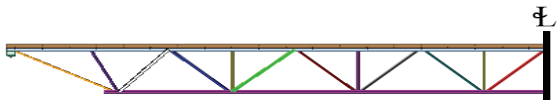


Figure 8: *One-Half FE Model of Wood-Nailer Steel Joist Span*

3.4 BOUNDARY CONDITIONS

Boundary Conditions in FEA are critical and significantly impact the outcomes. The wood-nailer steel joist has several components, and the contact types among the parts can significantly affect the results and require special consideration.

3.4.1 Support Conditions

Wood-nailer steel joists were modelled as simply supported at the ends of the span, as shown in Figure 9.

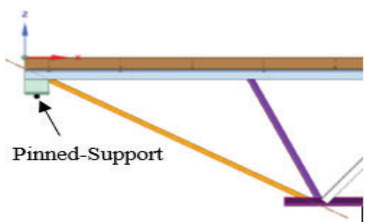


Figure 9: Pinned- Support

3.4.2 Shear Connector

The self-drilling screws acting as shear connectors between the steel joist and wood nailer were modelled as solid bodies, as shown in Figure 10.

Figure 10: Screw Model

Threads on the shear connector were removed to reduce computational time and avoid convergence issues. Root diameter or the solid core of the screw was used. A pretension load of 150 lb (445 N) was applied to each shear connector.

3.4.3 Contact

ANSYS offers five different contact formulations [7]. In the FE model, bonded and frictional contacts were used. In bonded contact, separation, sliding, or penetration are not allowed. However, in frictional contact, the bodies in contact can slide relative to one another in the tangential direction and also can translate in the normal direction [8]. Bonded contacts were used to model the contact between the screw shank and the wood-nailer. In addition, frictional contact was used between screw shanks and the inner walls of the holes in the steel joist top chord. The fillet-welded connection between each web member end and the chord member was modelled with edge-bonded contacts.

3.4.4 Applied Load

A uniform load was applied directly over 16 ft (4.88 m) of the top surface area wood-nailer steel joist one-half FE model to replicate the applied distributed load, as shown in Figure 11.

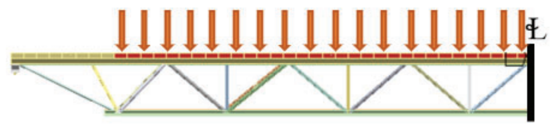


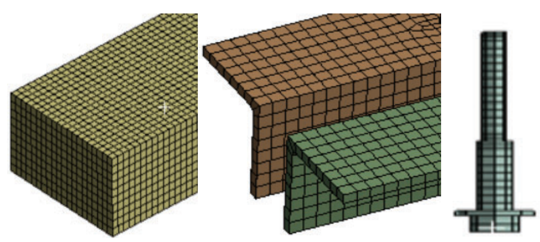
Figure 11: *Load Applied Directly to the Wood-Nailer*

3.4.5 Bracing

In the FE model, the wood-nailer was constrained laterally, in the perpendicular direction to the length of the steel joist, every 6 inches to simulate the lateral bracing provided by the wood deck to the steel joist top chord.

3.5 MESH

A rigorous mesh sensitivity analysis was conducted to determine the model discretization that provides the best cost-effectiveness and accuracy combination. The wood-nailer, top and bottom chords, and webs were meshed by quadratic hexahedral elements. For screw fasteners, axisymmetric hexahedra mesh with sweep method was used. Contact sizing was used to increase the number of elements to minimize mesh transitions. Figure 12 shows the FE mesh elements for different components.



(a) *(b)* *(c)*

Figure 12: *FE mesh for (a) Wood-Nailer, (b) Top and Bottom Chords, (c) Screw*

3.6 VALIDATION OF THE DEVELOPED FINITE ELEMENT MODEL

3.6.1 (J1) Experimental and Numerical Deflection Results

Figure 13 shows the experimental load-deflection plots for the wood-nailer steel joists (J1) [4]

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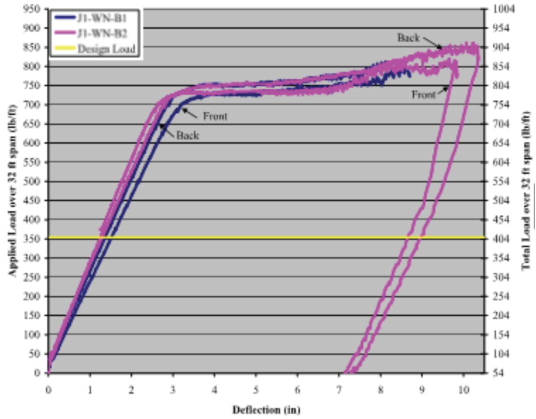

Figure 13: *(J1) Experimental Load (lb/ft) vs. Deflection [4]*

The experimental and finite element model mid-length deflection for wood-nailer steel joist (J1) mid-length is shown in Table 5.

Table 5: *J1 Experimental vs. FE Model Deflection*

Wood-nailer thickness- in (mm)		2.5 (64)
Screw Spacing- in (mm)		24 (610)
Uniform Load- lb/ft (kN/m)		700 (10.22)
Load Length- ft (m)		16 (4.88)
Wood-nailer Steel Joist Mid-Length Deflection		
Joist Mark	Experimental in (mm)	FE Model in (mm)
J1	2.61-3.15 (66-80)	2.71(69)

(J1) FE load-deflection plot is shown in Figure 14. At a point load of 11.2 kip (49.82 kN), the wood-nailer steel joist mid-length deflection is 2.71-in (69 mm).

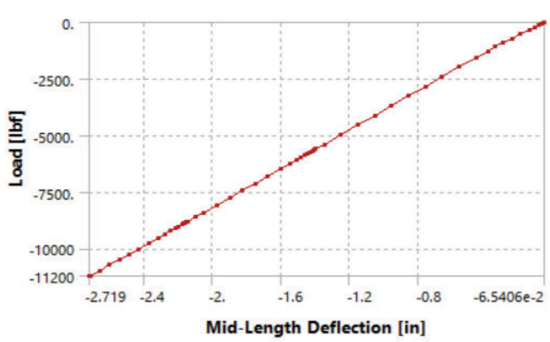

Figure 14: *(J1) FE Model Load(N) vs. Deflection*

As shown in Figure 15, (J1) FE model deflection prediction in the linear range shows a reasonably good agreement with the experimental data.

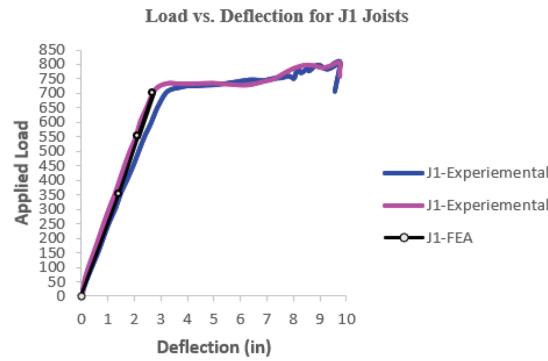

Figure 15: *(J1) Experimental vs. FE Load-Deflection Curves*

(J3) Experimental and Numerical Deflection Results
Figure 16 shows the experimental load-deflection plots for the bare steel joists (J3) [4].

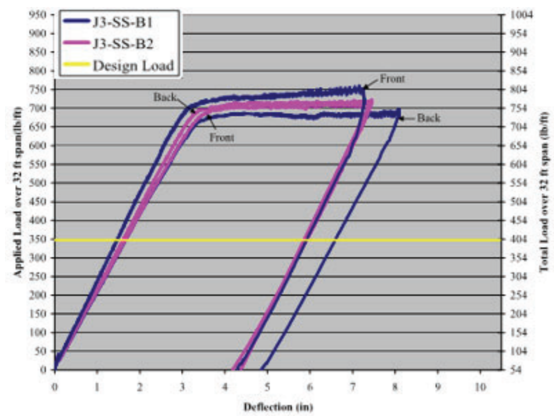

Figure 16: *(J3) Experimental Load (lb/ft) vs. Deflection [4]*

The experimental and finite element model mid-length deflection for bare steel joists (J3) is shown in Table 6.
Table 6: *J3 Experimental vs. FE Model Deflection*

Uniform Load- lb/ft (kN/m)		700 (10.22)
Load Length- ft (m)		16 (4.88)
Bare Steel Joist Mid-Length Deflection		
Joist Mark	Experimental in (mm)	FE Model in (mm)
J3	3.08-3.42 (78-87)	3.19 (81)

(J3) FE model load-deflection plot is shown in Figure 17. At a concentrated load of 11.2 kip (49.82 kN), the bare steel joist deflection at mid-length is 3.19-in (81 mm).

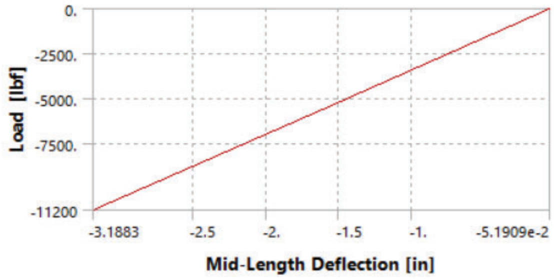

Figure 17: *(J3) FE Model Load-Deflection Plot*

Figure 18 depicts (J3) deflection at mid-length from the FE model.

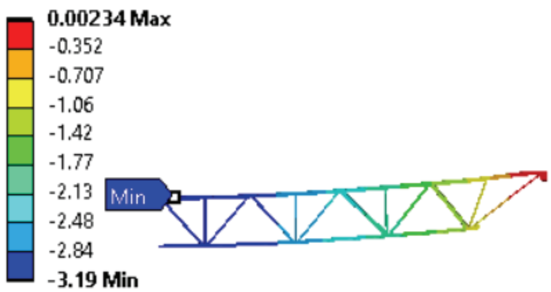

Figure 18: *(J3) FE Model Deflection in (in)*

As shown in Figure 19, (J3) FE model deflection prediction in the linear range shows a reasonably good agreement with the experimental data. Furthermore, as the FE model deflection data shows, the deflection of (J1) is less than (J3), indicating that the wood-nailer steel joist (J1) has a higher flexural stiffness than (J3). The higher flexural stiffness confirms that some level of partial composite action was attained in the wood-nailer steel joist.

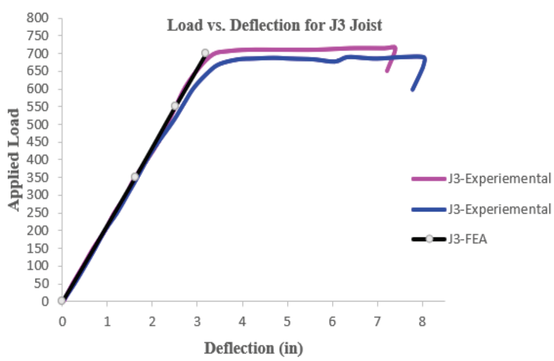

Figure 19: *(J3) Experimental vs. FE Load-Deflection Curves*

3.6.2 (J3) Experimental and Numerical Normal Strain Results

Figure 20 shows the applied-strain plots for the top chord of bare steel joist (J3) [3].

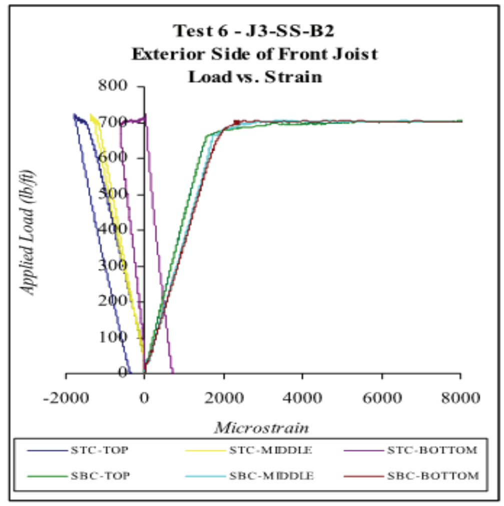

Figure 20: *(J3) Exterior Side of Front Joist Strain Plots. Experimental data from [4]*

Figure 21 shows (J3) normal strains in the top chord from the FE model.

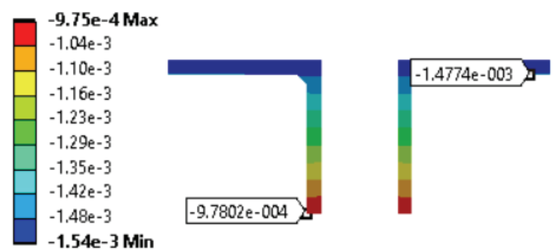

Figure 21: *(J3) Top Chord (TC) Normal Strains*

Table 7 shows the experimental vs. FE model normal strains at the top and bottom of (J3) top chord. The FE model analysis agrees well with the experimental strain results.

***Table** 7: (J3) FE Model vs. Experimental Normal Strains*

Uniform Load- lb/ft (kN/m)			700 (10.22)
Load Length- ft (m)			16 (4.88)
WN Steel Joist Mid-Length Normal Strains			
Member	Strain Gauge Location	Experimental (microstrain)	FE Model (microstrain)
TC	Top	1400-1500	1480
	Bottom	600-700	978

3.7 (J1) WOOD-NAILER STEEL JOIST STRAINS

3.7.1 Experimental and Numerical Strain Results

Figure 22 shows the applied load-strain plots for the wood-nailer, top chord, and bottom chord at the locations described in Figure **7**.

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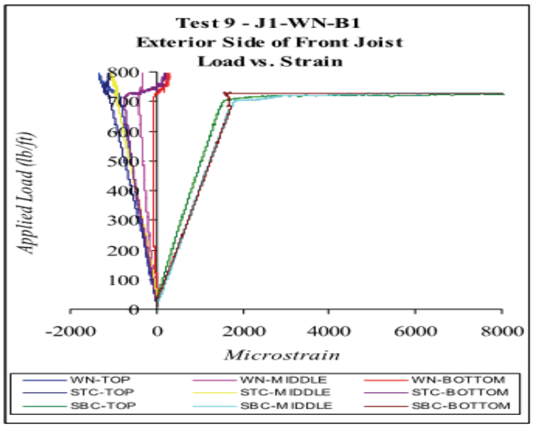

Figure 22: *J1-B1 Exterior Side of Front Joist Strain Plots. Experimental data from [4]*

3.7.2 (J1) Finite Element Model vs. Experimental Strains at the Top and Bottom of Each Member

Table 8 shows the experimental vs. FE model normal strains at the top and bottom of each component. The FE model analysis agrees well with the experimental strain results.

Table 8: *(J1) FE Model vs. Experimental Normal Strains*

Wood-nailer thickness- in (mm)			2.5 (64)
Screw Spacing- in (mm)			24 (610)
Uniform Load- lb/ft (kN/m)			700 (10.22)
Load Length- ft (m)			16 (4.88)
WN Steel Joist Mid-Length Normal Strains			
Member	Strain Gauge Location	Experimental (microstrain)	FE Model (microstrain)
WN	Top	600 - 000	980 - 1000
	Bottom	130-170	520-540
TC	Top	1080-1100	930
	Bottom	300-960	730-770
BC	Top	1500-1800	1700
	Bottom	1790-1820	1800

Figure 23 through **Figure 25** shows the normal strains in the wood-nailer, top chord, and bottom chord from the FE model.

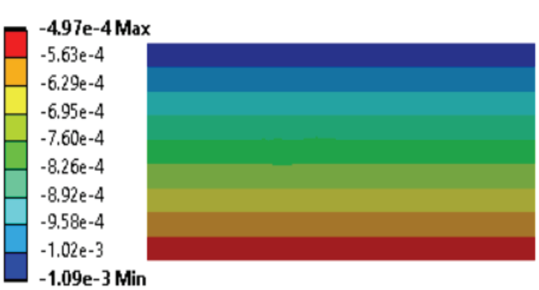

Figure 23: *(J1) Wood- Nailer (WN) Normal Strains*

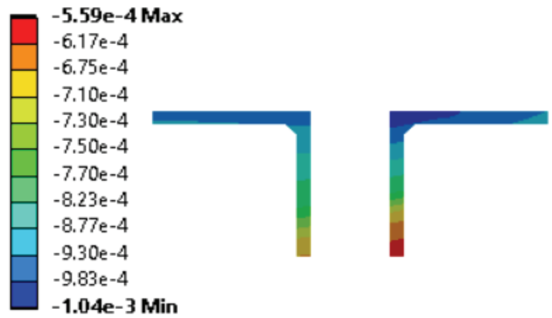

Figure 24: *(J1) Top Chord (TC) Normal Strains*

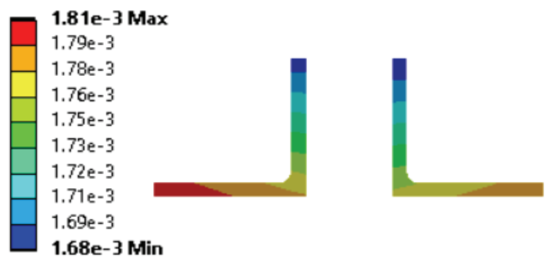

Figure 25: *(J1) Bottom Chord (BC) Normal Strains*

Table 7 and Table 8 show that the top chord combined normal strains in the wood-nailer steel joist (J1) are smaller than the bare steel joist (J3), which confirms that the wood nailer reduces the axial and bending stresses in the joist top chord through load-sharing under design loading.

3.7.3 Wood-Nailer Steel Joist (J1) And Steel Joist (J3) Component Axial Forces

Table 9 shows the FE model component axial forces for wood-nailer steel joist (J1) and steel joist (J3).

Table 9: J1 and J3 Component Forces

Wood-Nailer Thickness- in (mm)			2.5 (64)
Screw Spacing- in (mm)			24 (610)
Load- lb/ft (kN/m)			700 (10.22)
Load Length- ft (m)			16 (4.88)
FE Model Mid-Length Component Axial Forces			
Mark	WN kip (kN)	TC kip (kN)	BC kip (kN)
J1	19.9 (88.3)	37.5 (166.9)	57.8 (257.6)
J3	N/A	58.3 (259.5)	59.1(262.7)

The reduction in the bottom chord axial forces demonstrates that the wood-nailer steel joist's effective depth has increased. The increased joist effective depth with identical steel joist and added wood-nailer is evidence of the top chord elastic neutral axis moving upward due to composite behaviour between the steel top chord and the wood-nailer. The combined effect of the wood-nailer composite behaviour with the steel top chord, the resulting change in the top chord neutral axis, and the resulting increased joist effective depth increase the overall joist moment capacity. Figure 26 shows the FE model axial load in the wood-nailer, top, and bottom chords.

Figure 26: Wood-Nailer, Top and Bottom Chord Axial Forces

4 PARAMETRIC STUDIES

An essential part of a numerical study is conducting a parametric study. The validated FE model was used to conduct a parametric analysis to investigate the effect of screw spacing and wood-nailer thickness on the structural performance of the wood-nailer steel joist. First, for the standard screw spacing of 24-in, two alternative wood-nailer thicknesses, 2.25-in and 2-in, were modelled. Second, for a wood-nailer, 2.5-in thick, two alternative screw spacings, 20-in (508 mm) and 16-in (406 mm), were modelled.

4.1 WOOD-NAILER THICKNESS

The first parameter investigated was the effect of wood-nailer thickness on the joist component axial forces and the joist stiffness or deflection.

4.1.1 Wood-Nailer Steel Joist Deflection

FE model deflection results for two alternative wood-nailer thicknesses, 2.25-in and 2-in, are shown in Table 10. As expected, increasing the wood-nailer thickness resulted in a reduction in the wood-nailer steel joist deflection.

Table 10: (J1) FE Model Deflections

Screw Spacing- in (mm)	24 (610)
Load- lb/ft (kN/m)	700 (10.22)
Load Half Joist Length- ft (m)	16 (4.88)
FE Model Deflection at Joist's Mid-Length	
WN Thickness- in (mm)	Deflection- in (mm)
2.5 (64)	2.71 (69)
2.25 (57)	2.76 (70)
2.0 (51)	2.80 (71)

4.1.2 Wood-Nailer Steel Joist Component Axial Forces

Table 11 shows the FE model component axial forces for two alternative wood-nailer thicknesses, 2.25-in (57 mm) and 2-in (51 mm).

***Table 11**: FE Model Component Axial Forces*

Screw Spacing- in (mm)			24 (610)
Load- lb/ft (kN/m)			700 (10.22)
Load Length- ft (m)			16 (4.88)
FE Model Mid-Length Component Axial Forces			
WN Thickness in (mm)	WN kip (kN)	TC kip (kN)	BC kip (kN)
2.5 (64)	19.9 (88)	37.5 (167)	57.8 (257)
2.25 (57)	18.5 (82)	39.1 (174)	58.1 (258)
2.0 (51)	17.5 (78)	40.3 (179)	58.2 (259)

The FE model component axial force results shown in Table 11 demonstrate that increasing the wood-nailer thickness resulted in the following:

- An increase in the wood-nailer steel joist's effective depth decreases the axial force in the bottom chord.
- An increase in the axial force resisted by the wood-nailer and a decrease in the axial force resisted by the top chord. The shear strength of the screws limits the axial force transferred to the wood-nailer.

The FE analysis results demonstrate that there is a partial composite action in the wood-nailer steel joist system.

4.2 SCREW SPACING

The second parameter was to investigate the effect of screw spacing on the joist stiffness or deflection and component axial forces. Two alternative screw spacings, 20-in (508 mm) and 16-in (406 mm), were used, while the wood-nailer thickness is the standard 2.5-in (64-mm).

4.2.1 Wood-Nailer Steel Joist Deflection

Table 12 shows (J1) FE model deflections at mid-length using two alternative screw spacings, 20-in (508 mm) and 16-in (406 mm).

***Table 12:** FE Model Wood-Nailed Steel Joist Deflection*

Wood-Nailer Thickness- in (mm)	2.5 (64)
Load- lb/ft (kN/m)	700 (10.22)
Load Half Joist Length- ft (m)	16 (4.88)
FE Model Mid-Length Deflection	
Screw Spacing- in (mm)	Deflection- in (mm)
24 (610)	2.71 (69)
20 (508)	2.64 (67)
16 (406)	2.55 (65)

Figure 27 and Figure 28 depict the FE model deflection when the screw fasteners are spaced at 16-in (406 mm) and 24-in (610 mm) on center, respectively.

https://doi.org/10.52202/069179-0003

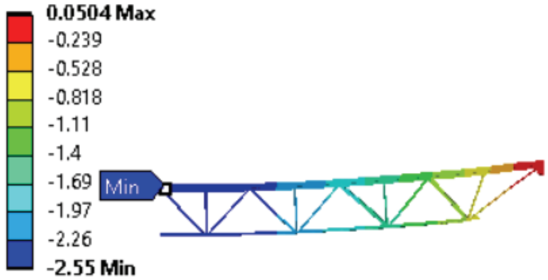

Figure 27: *FE Model Deflection (in) for screw spacing 16-in (406 mm)*

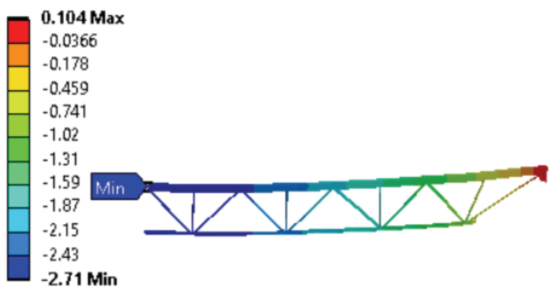

Figure 28: *FE Model Deflection (in) for screw spacing 24-in (610 mm)*

The FE model deflection results indicate that as the shear connector spacing decreases, the wood-nailer steel joist attains a higher level of composite action leading to 6% higher flexural stiffness.

4.2.2 Wood-Nailer Steel Joist Component Axial Forces

Table 13 shows the FE model component axial forces using two alternative screw spacings, 20-in (508 mm) and 16-in (406 mm).

Table 13: *FE Model Component Axial Forces for Screw Spacings 20-in(508-mm) and 16-in (406 mm)*

Wood-Nailer Thickness- in (mm)		2.5 (64)	
Load- lb/ft (kN/m)		700 (10.22)	
Load Length- ft (m)		32 (9.75)	
FE Model Mid-Length Axial Forces			
Spacing in (mm)	WN Kip (kN)	TC Kip (kN)	BC kip (kN)
24 (604)	19.9 (88)	37.5 (167)	57.8 (257)
20 (508)	21.8 (97)	34.4 (153)	56.4 (251)
16 (406)	23.5 (105)	31.6 (141)	55.3 (246)

As expected, the FE model component axial force results indicate that a 33% reduction in the shear connector spacing results in an 18% increase in the axial force transferred to the wood-nailer. The axial force transferred to the wood-nailer is limited by the shear strength of the screws. In addition, the wood-nailer steel joist attains a higher level of composite action leading to an increase in the effective joist depth, which results in a larger moment capacity.

5 CONCLUSIONS

The structural performance of wood-nailer steel joists was numerically investigated. The non-linear finite element (FE) models were developed and analysed using Ansys software. The FE model developed was verified against available experimental data. The numerical predictions showed reasonably good agreement with the experimental data. Parametric analyses were conducted using the validated FE models, and the following conclusions can be drawn from the results of FE analyses.

- The wood-nailer acts partially compositely with the steel top chord and the transformed wood-nailer increases the effective depth of the steel joist.
- The continuous wood-nailer reduces bending stresses in the joist top chord through load-sharing under design loading.
- The combined effect of the wood-nailer composite behaviour with the steel top chord, the resulting change in the top chord neutral axis, and the resulting increased joist effective depth, increase the overall joist moment capacity and flexural stiffness.
- A higher level of composite action is achieved with a larger shear connector density.

6 FUTURE RESEARCH

There is a need to conduct push-out research to investigate the strength and ductility of the screw connection. The push-out tests would allow a direct data analysis of the connection itself, without the additional variables of truss load paths, composite behaviour, and relative stiffness of different materials. The load-slippage data collected from the push-out test will provide valuable connection strength and stiffness data to refine the current finite element model of the wood-nailer steel joist.

ACKNOWLEDGEMENT

The authors are grateful to New Millennium Building Systems for providing the financial support of this research and Joe Pote for his technical guidance.

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