Engineering Analysis

Subject: Stud Shoe

ATI Report 65019.01-122-34

Rendered to:

GREENFIELD MANUFACTURING COMPANY
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Revision 1: 06/30/06

Scope

Architectural Testing, Inc. (ATI) was contracted to perform an engineering analysis of three stud shoes based on structural performance testing (see ATI Report 63768.01-122-31) and the *National Design Specification for Wood Construction, NDS-2001* (ANSI/AF&PA, 2001). For this evaluation, the allowable design capacity of the stud shoe was established as the lesser of ultimate test loads with applied factors of safety, average test loads at 0.125" movement between the stud and stud shoe, or allowable wood member or fastener capacities as established by NDS-2001.

The following reference standards are used:

National Design Specification for Wood Construction, NDS -2001 (ANSI/AF&PA, 2001)

Acceptance Criteria for Joist Hangers and Similar Devices (AC 13), ICC Evaluation Services, Inc., October 2003

Cold-Formed Steel Design Manual, American Iron and Steel Institute (AISI), 1996 Edition

Product Description

Samples were submitted by Greenfield Manufacturing Company of a nominal 3-1/2" by 5-1/2" stud shoe manufactured from 16 gage steel. A 2-1/4" circular notch for passing conduit or piping was located in the center of the product and each of the stud shoes were anchored with 0.135" diameter by 1-1/2" long joist hanger nails. The steel was assumed to be cold-formed with minimum yield strength of 36 ksi. This analysis considers the fasteners to be loaded parallel to the grain in dry Douglas Fir-Larch with a specific gravity of 0.49 at a sustained temperature less than 100ºF. The analysis also considered Hem-Fir with a specific gravity of 0.43 as an alternate stud material.

Analyses

The stud shoe was analyzed using three different stud arrangements, a single, double and triple stud configuration. Since tensile testing was not performed on any of these assemblies, the load capacity will be based on compressive strength only.

Direct Load Capacity Tests

Structural performance tests were conducted by ATI and reported in ATI Report 63768.01-122-31. Analysis of the test results confirms the testing meets the requirements of Section 3.2 *Test and Performance Requirements* of AC13. Therefore, it is appropriate to use the reported results to establish a working load limit for the stud shoe.

For compression loading, ultimate strengths were achieved after 0.125" vertical movement (slip) of the stud shoe with respect to the stud occurred or the lowest peak load with the appropriate safety factor applied. The results are detailed in the following table.

Installation Description	Average Load at 0.125" Movement	(Lowest Peak Load) / 3
Single 2x4 Stud with 2-1/4" notch	3,255 lbs	962 lbs
Double 2x4 Stud with 2-1/4" notch	6,568 lbs	1,870 lbs
Triple 2x4 Stud with 2-1/4" notch	7,489 lbs	2,222 lbs

Note: Stud Shoe assemblies were tested in compression only.

NDS-2001 Analysis

Section 3.2.11.3 of AC 13 states the device shall have a direct load capacity rating no greater than the allowable design load determined in accordance with the NDS for the wood members forming the connection. The connection of the stud shoe to the stud is evaluated on Pages 5 through 12 and considers bearing strength of the timber stud and bending and bearing strength of the stud shoe.

Installation Description	Load Capacity Rating Calculated per NDS-2001 (Compression Only)
Single 2x4 Stud with 2-1/4" notch (Douglas Fir)	552 lbs
Double 2x4 Stud with 2-1/4" notch (Douglas Fir)	810 lbs
Triple 2x4 Stud with 2-1/4" notch (Douglas Fir)	945 lbs
Single 2x4 Stud with 2-1/4" notch (Hem-Fir)	498 lbs
Double 2x4 Stud with 2-1/4" notch (Hem-Fir)	732 lbs
Triple 2x4 Stud with 2-1/4" notch (Hem-Fir)	854 lbs

Summary

For this evaluation, the allowable design capacity (compression) of the stud shoe was established as the lesser of ultimate test loads with applied factors of safety, average test loads at 0.125" movement between the stud and stud shoe, or allowable wood member or fastener capacities as determined by NDS-2001. The results are presented in the following table.

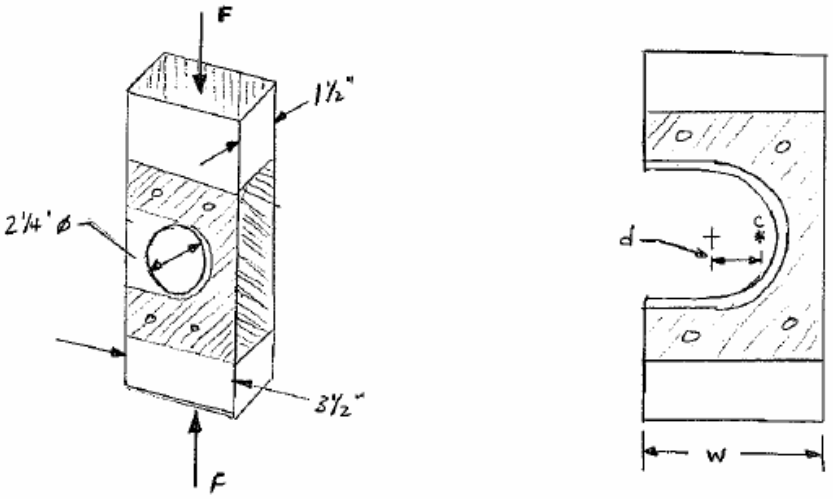
Installation Description	Load Capacity Rating, Compression Only	Limited By
Single 2x4 Stud with 2-1/4" notch (Douglas Fir)	552 lbs	NDS Calculations
Double 2x4 Stud with 2-1/4" notch (Douglas Fir)	810 lbs	NDS Calculations
Triple 2x4 Stud with 2-1/4" notch (Douglas Fir)	945 lbs	NDS Calculations

Reference Drawings (attached)

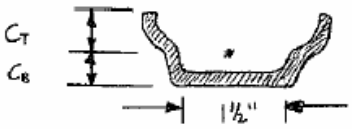
Fig. 533 Stud Shoe, Greenfield Manufacturing Company, 1/06

Calculations

STUD FIXER WITH 2½" HOLE IN STUD



AREA OF STUD FIXER AT HOLE FOR A SINGLE STUD:



FROM AUTOCAD: $A_{FIXER} = 0.156\ in^2$

$I = 0.069\ in^4$

$C_T = 0.402\ in$ $C_B = 0.132\ in$

MAXIMUM LOAD A SINGLE STUD WILL SUPPORT

$$\sigma_{ALLOW} = \frac{Mc}{I} + \frac{F}{A}$$

WHERE $M = Fd$ AND $d = (W/2) - C_B$

$$\sigma_{ALLOW} = \frac{F(W/2 - C_B)C_T}{I} + \frac{F}{A}$$

$$\therefore F = \frac{\sigma_{ALLOW}}{\frac{(W/2 - C_B)C_T}{I} + \frac{1}{A}}$$

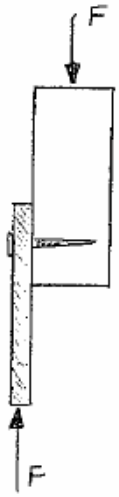
→ ASSUME A36 STEEL

$F_y = 36\ ksi = 36{,}000\ psi$ (COLD FORMED STEEL - 1996 EDITION)

$\nabla_{ALLOW} = .6F_y = 21{,}600\ psi$

$$F = \frac{21600\ psi}{\frac{(3\frac{1}{2}" - 0.132in)(0.402in)}{0.069\ in^4} + \frac{1}{0.156\ in^2}}$$

$F = 1363.91\ lbs$



SINGLE SHEAR CONNECTIONS FOR SINGLE STUD

→ DOUGLAS FIR WOOD $G = 0.49$

FOR 8D JOIST HANGERS $d = 0.113"$

$Z = 92\ lbs$ (NDS 2001 - TABLE 11P)

$Z' = Z C_D C_M C_t C_g C_{tn}$

ADJUSTMENT FACTORS (NDS-2001 TABLE 10.3.1 FOR ADJUSTMENTS)

$C_D = 1$
$C_M = 1$ – ASSUME NOT USED IN WET CONDITIONS
$C_t = 1$ → ASSUME $T \leq 100°F$
$C_g = 1$ – END GRAIN FACTOR NOT APPLICABLE
$C_{tn} = 1$ – NAILS NOT TOE NAILED TO STUD

$\therefore\ Z'_{TOT} = (92\ lbs)(1)(1)(1)(1)(1) \times 6\ NAILS$

$Z'_{TOT} = 552\ lbs$

SINGLE SHEAR CONNECTIONS FOR SINGLE STUD (CONT.)

⇒ FOR HEM-FIR WOOD $G = 0.43$

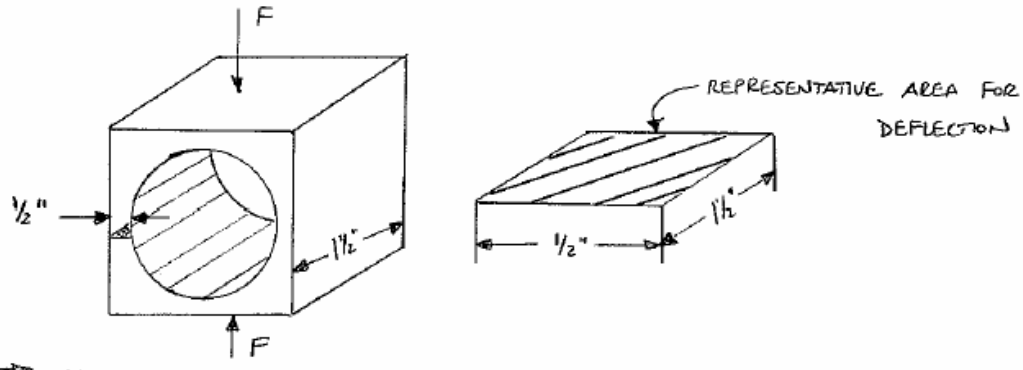
$Z = 83$ lbs (NDS 2001 - TABLE 11P)

$Z' = Z\, C_D C_M C_t C_g C_{tn}$

$Z' = (83 \text{ lbs})(1)(1)(1)(1)(1) \times 6$ NAILS

$Z' = 498$ lbs

CHECK FOR COMPRESSION OF REMOVED WOOD IN CALCULATION



⇒ CHECK FOR FORCE REQUIRED TO DEFLECT GIVEN AREA OF DOUGLAS FIR WOOD ⅛"

$\Delta = FL/AE$ $E = 1{,}400{,}000$ psi (NDS 2001 SUPPLEMENTAL - TABLE 4A)

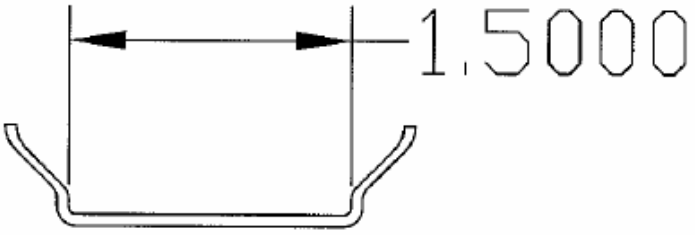
$FL = \Delta AE$

$F = \Delta AE / L$

$F = (1/8")(1/2" \times 1\,1/2")(1{,}400{,}000 \text{ psi}) / (2\,1/4")$

$F = 58333.3$ lbs

⇒ MAXIMUM FORCE GOVERNED BY SHEAR STRESS VALUE OF NAILS. THIS APPLIES FOR DOUBLE AND TRIPLE STUD FIXER.

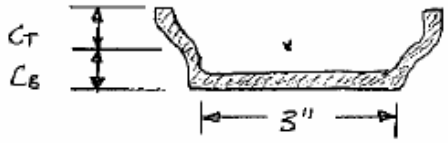


Area:	0.156		
Perimeter:	5.561		
Bounding box:	X: −1.092	--	1.092
	Y: −0.132	--	0.402
Centroid:	X: 0.000		
	Y: 0.000		
Moments of inertia:	X: 0.004		
	Y: 0.069		
Product of inertia:	XY: 0.000		
Radii of gyration:	X: 0.155		
	Y: 0.664		

Principal moments and X-Y directions about centroid:
I: 0.004 along [1.000 0.000]
J: 0.069 along [0.000 1.000]

MAXIMUM LOAD A DOUBLE STUD WILL SUPPORT

PROPERTY INFORMATION FOR CROSS SECTION FROM AUTO CAD



$A = 0.249\ in^2$ $\quad C_T = 0.441\ in$

$I = 0.310\ in^4$ $\quad C_B = 0.099\ in$

$$T_{ALLOW} = \frac{Mc}{I} + \frac{F}{A}$$

$$F = T_{ALLOW} \Big/ \frac{(W/2 - C_B)C_T}{I} + \frac{1}{A}$$

$$F = (21{,}600\ psi) \Big/ \frac{(3\frac{1}{2}"/2 - 0.099\ in)(0.441\ in)}{0.310\ in^4} + \frac{1}{0.249\ in^2}$$

$F = 3389.91$ lbs

SINGLE SHEAR CONNECTIONS FOR DOUBLE STUD

⇒ DOUGLAS FIR $G = 0.49$ 10D HANGERS $d = .148"$ $Z = 135$ lbs

$$Z'_{TOT} = Z\ C_D C_M C_t C_g C_{tn} (\#\ NAILS)$$

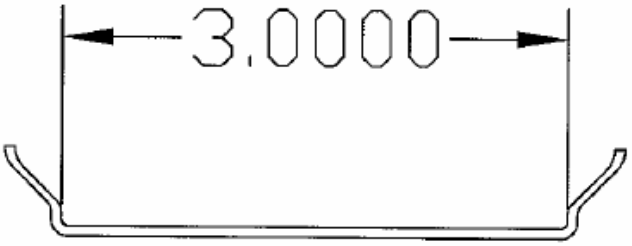
$$Z'_{TOT} = (135\ lb)(1)(1)(1)(1)(1)(6\ NAILS)$$

$Z'_{TOT} = 810$ lbs

⇒ HEM FIR $Z = 122$ lbs

$$Z'_{TOT} = (122\ lb)(1)(1)(1)(1)(1) \times 6\ NAILS$$

$Z'_{TOT} = 732$ lbs

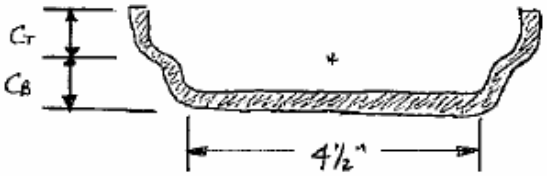


Area:	0.249		
Perimeter:	8.561		
Bounding box:	X: -1.842	--	1.842
	Y: -0.094	--	0.441
Centroid:	X: 0.000		
	Y: 0.000		
Moments of inertia:	X: 0.004		
	Y: 0.310		
Product of inertia:	XY: 0.000		
Radii of gyration	X: 0.132		
	Y: 1.117		

Principal moments and X-Y directions about centroid:
I: 0.004 along [1.000 0.000]
J: 0.310 along [0.000 1.000]

MAXIMUM LOAD A TRIPLE STUD WILL SUPPORT

PROPERTY INFORMATION FOR CROSS SECTION FROM AUTO CAD



$A = 0.342\ in^2$ $\quad C_T = 0.458\ in$

$I = 0.832\ in^4$ $\quad C_B = 0.077\ in$

$$\sigma_{ALLOW} = \frac{Mc}{I} + \frac{F}{A}$$

$$F = \sigma_{ALLOW} \Big/ \frac{(W/2 - C_B)C_T}{I} + \frac{1}{A}$$

$$F = (21{,}600\ psi) \Big/ \frac{(3\frac{1}{2}"/2 - 0.077\ in)(0.458\ in)}{0.832\ in^4} + \frac{1}{0.342\ in^2}$$

$F = 5617.79\ lbs$

SINGLE SHEAR CONNECTIONS FOR TRIPLE STUD

⇒ DOUGLAS FIR $Z = 135\ lbs$

$Z'_{TOT} = Z \times C_D C_M C_t C_g C_{tn} \times \#\ NAILS$

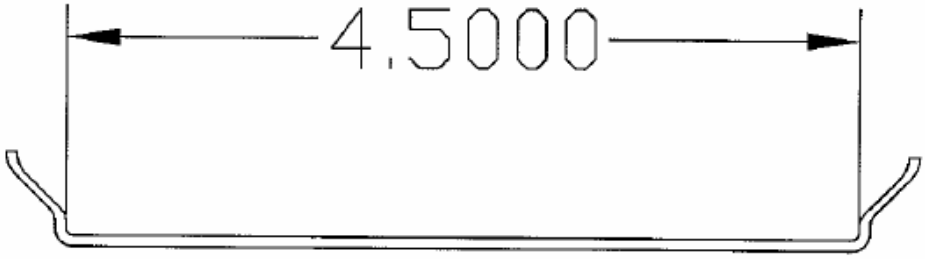
$Z'_{TOT} = (135\ lb)(1)(1)(1)(1)(1)(7\ NAILS)$

$Z'_{TOT} = 945\ lbs$

⇒ HEM FIR $Z = 122\ lbs$

$Z'_{TOT} = (122\ lb)(1)(1)(1)(1)(1)(7\ NAILS)$

$Z'_{TOT} = 854\ lbs$



Area:	0.342
Perimeter:	11.561
Bounding box:	X: -2.592 -- 2.592
	Y: -0.077 -- 0.458
Centroid:	X: 0.000
	Y: 0.000
Moments of inertia:	X: 0.005
	Y: 0.832
Product of inertia:	XY: 0.000
Radii of gyration:	X: 0.117
	Y: 1.560
Principal moments and X-Y directions about centroid:	
	I: 0.005 along [1.000 0.000]
	J: 0.832 along [0.000 1.000]

Revision Log

Rev. #	Date	Page(s)	Revision(s)
0	05/30/06	N/A	Original report issue
1	06/30/06	Pages 2, 4	Changed part description to 16 gage steel and reference drawing to Fig. 533 Stud Shoe, 01/06

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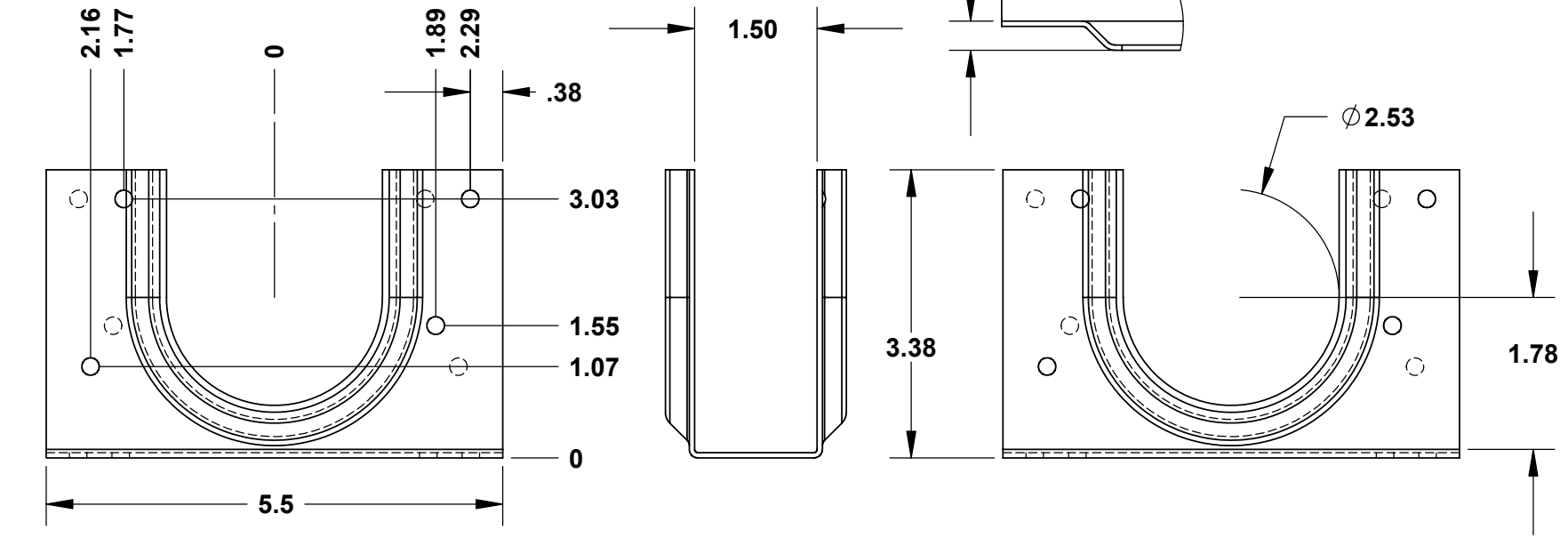

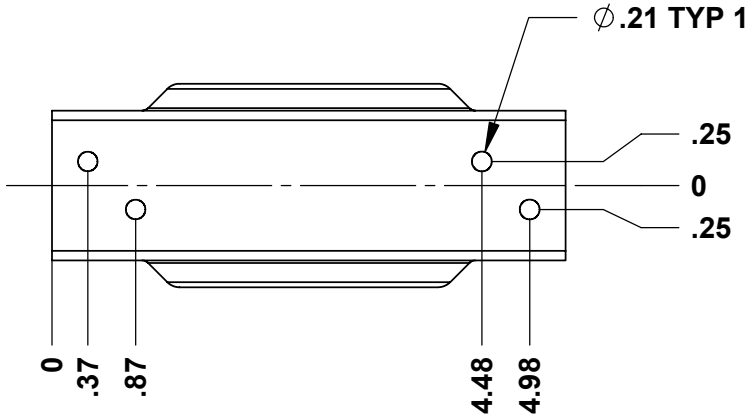

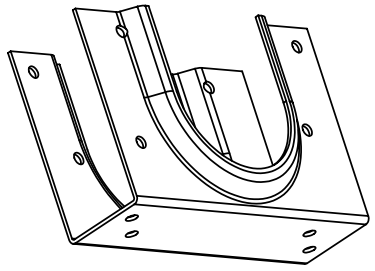

FILE:SINGLE STUD SHOE DIMENSIONED.SLDRW

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	APPROVALS DATE	
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MATERIAL 16 GA STEEL		P/N FIG 533
FINISH --		A REV.
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