It's More than "Just a Deck"

www.phrc.psu.edu

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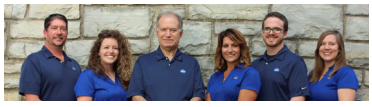
- The Pennsylvania Housing Research Center (PHRC) provides and facilitates education, training, innovation, research, and dissemination to the residential construction industry for the purpose of improving the quality and affordability of housing.
- Educational programs and publications by the PHRC address a wide range of topics relevant to the home building industry and are designed to reach a diverse audience: builders, code officials, remodelers, architects, developers, engineers, planners, landscape architects, local government officials, educators, etc. to provide professional development and continuing education



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Program Description

In this Residential Deck webinar we will look at past deck failures and briefly review the potential root cause of that failure. We will then look through the provisions in chapter 5 of the 2015 IRC, along with some additional guidelines to see how current codes and guidelines have evolved in response to previous failures.

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Program Objectives

- Review past residential deck failures and how the failures led to occupant injury or death.
- Review provisions in chapter 5 of the 2015 IRC that relates to the design and construction of a code compliant residential deck.
- Understand that there are additional guidelines available to assist in the design and construction of a residential deck.
- Review residential deck guard rail testing results and review additional guidelines that can help in the design and construction of safer system for the occupant.

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Why Are You Here?

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Normal Deck Loading

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Excessive Deck Loading and ?

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Source – www.deckmagazine.com

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Source – www.thatshouldhold.com

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News Report July 4, 2016

- Links to NBC News report:
  - https://www.nbcnews.com/nightly-news/video/deck-disaster-how-to-protect-from-potential-danger-under-your-feet-718376003870
  - https://www.nbcnews.com/news/embedded-video/mmvo42490949513

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Guardrail Loading

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Guardrail failure

- Improper railing attachments resulted in a lady falling 14 feet to her death.

Photo courtesy of – Darin Clements

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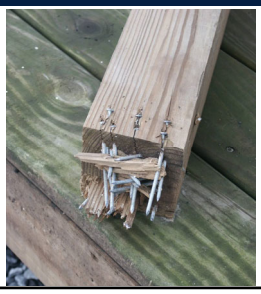
Post attachment

- Toe-nailed post?



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Compliant?

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They are EVERYWHERE!

- In 2009, "The Forestry Chronicle" stated there are approximately 30 million residential decks
- In 2019, NAHB's Eye On Housing referenced 25% of new construction homes receive a deck at the time of construction.

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Source: JANUARY/FEBRUARY 2009, VOL. 85, NO. 1 – THE FORESTRY CHRONICLE
Source: http://eyeonhousing.org/2019/11/share-of-new-homes-with-decks-declines-in-2018/

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Personal Injuries or Deaths are of Major Concern – Common Root Cause

- Ledger failure - total collapse of deck
  - Inadequate connection to primary structure
  - Inadequate protection from moisture
- Guardrail failure – falling hazard
  - Inadequate connection to deck frame
  - Notched post failure
- Risk increases with age due to environmental exposure causing degradation

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Injuries

- More injuries may be connected to deck failures than all other wood building components and loading cases combined!

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Source – Washington State Magazine, Tina Hilding
https://magazine.wsu.edu/2009/10/07/making-decks-safer/

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Structural Review – House vs. Deck

- **Different structural systems**
  - House – Platform frame
  - Deck - Post and beam
    - (Now covered by the IRC – See R507.1 Decks)
- **Less structural redundancy**
- **Larger loads on members and connections**
- **Lower lateral stability**
  - Both horizontal and vertical

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Structural Review – House vs. Deck

- **Increased exposure (wet service – UV)**
  - Wood durability
  - Fasteners
- **Uncertain (unexpected) service load during the life of the structure**
- **Design life expectancy**
  - House = 50 years
  - Deck = ?
    - Deck Planks (wood) = 15 years
    - Deck Planks (composite) = 8-25 years
    - Structural Wood = 10-30 years
    - Fasteners (galvanized) = 10+ years
    - Fasteners (hot-dipped galvanized = 35-60 years
      - Source – www.nachi.org
- **Failure**
  - House failure is not catastrophic
  - Deck failure usually are

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Big Take Away!

It is much more than “just a deck”!

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Structural Requirements

2015 International Residential Code, Chapter 3 & 5

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Objective

- Provide a summary of the general structural requirements related to deck design and construction in the IRC
- Review additional resources that can help achieve the minimum design criteria for guardrails. (DCA-6 2015 IRC Version)

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Decks Supported by Exterior Walls

- Wood-framed decks shall be in accordance with this Section (2015 IRC R507) or Section 301 for materials and conditions
- Positively anchored to primary structure
- Designed for lateral & vertical loads
- Cannot use toenails or nail subject to withdrawal
- Cantilever floors must resist uplift at backspan
- Must be free-standing (self supporting) if positive anchoring cannot be verified

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Design Criteria

- **Minimum Design Criteria**

	Live loads	
Table R301.5	Sleeping rooms	30 psf
	Rooms other than sleeping	40 psf
	Exterior balconies and decks	40 psf
	Guardrails & handrails	200 lbs [d, h]
	Guardrails infill components	50 lbs [h]
	Stairs	40 psf [c]
	Allowable Deflection	
Table R 301.7	Floors	L/360

- **Footnotes**
  - [d] A single concentrated load applied in an direction at any point along the top.
  - [h] Glazing used in handrail assemblies and guards shall be designed with a safety factor of 4

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Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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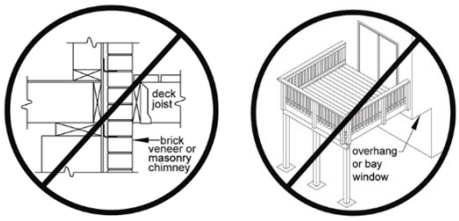
Deck Attachment "Don'ts"



courtesy, American Wood Council, Leesburg, VA

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Prescriptive Deck Design Through the IRC

2015 IRC Code Requirements

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Deck Ledger Board Connection

- For decks supporting a total design load of 50 lbs. per square foot, the connection must be of pressure-preservative-treated Southern Pine, or approved decay-resistant species, 2" nominal lumber band joist bearing on a sill plate or wall and be attached with ½" lag screws or bolts with washers. Attachment materials shall be hot-dipped galvanized or stainless steel.

Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Deck Ledger Board Connection

- Ledgers shall be flashed in accordance with Section R703.8 to prevent water from contacting the house band joist.
- Snow load shall not be assumed to act concurrently with live load.
- The tip of the lag screw fully extend beyond the inside face of the band joist.
- Sheathing shall be wood structural panel or solid sawn lumber.
- Sheathing shall be permitted to be wood structural panel, gypsum board, fiberboard, lumber or foam sheathing. Up to ½" inch thickness of stacked washers shall be permitted to substitute for up to ½ inch of allowable sheathing thickness where combined with wood structural panel or lumber sheathing.

TABLE R507.2 DECK LEDGER CONNECTION TO BAND JOIST [a, b]

JOIST SPAN	6' and less	6'1" to 8'	8'1" to 10'	10'1" to 12'	12'1" to 14'	14'1" to 16'	16'1" to 18'
Connection details	On-center spacing of fasteners[d, e]						
½ inch diameter lag screw with ½ inch maximum sheathing	30	23	18	15	13	11	10
½ inch diameter bolt with ½ inch maximum sheathing	36	36	34	29	24	21	19
½ inch diameter bolt with 1 inch maximum sheathing	36	36	29	24	21	18	16

Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Ledger Attachment Detail

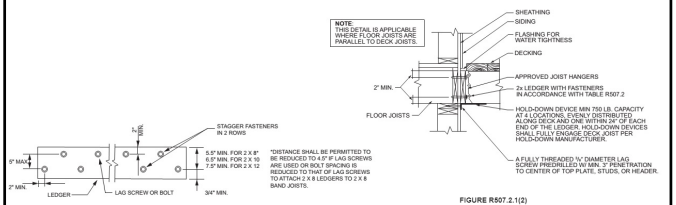

FIGURE R507.2.1(1)
PLACEMENT OF LAG SCREWS AND BOLTS IN LEDGERS

*DISTANCE SHALL BE PERMITTED TO BE REDUCED TO 4.5" IF LAG SCREWS ARE USED OR BOLT SPACING IS REDUCED TO THAT OF LAG SCREWS TO ATTACH 2 X 8 LEDGERS TO 2 X 8 BAND JOISTS.

FIGURE R507.2.1(2)
PLACEMENT OF LAG SCREWS AND BOLTS IN BAND JOISTS

Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Deck Lateral Load Connection

- **R507.2.4 Deck lateral load connection.** The lateral load connection required by Section R507.1 shall be permitted to be in accordance with Figures R507.2.3(1) or R507.2.3(2). Where the lateral load connection is provided in accordance with Figure 507.2.3(1), hold-down tension devices shall be installed in not less than two locations per deck, within 24 inches of each end of the deck. Each device shall have an allowable stress design capacity of not less than 1500 pounds (6672 N). Where the lateral load connections is provided in accordance with Figure R507.2.3(2), the hold-down tension devices shall be installed in not less than 4 locations per deck, and each device shall have an allowable stress design capacity of not less than 750 pounds (3336 N).

Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Deck Lateral Load Connection

- (2) 1500 pound tension devices located within 24" of each end of the deck

Or

- (4) 750 pound tension devices installed in not less than 4 locations

Or

- Other method approved by the code official?

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Deck Lateral Load Connection – R507.2.3(1)

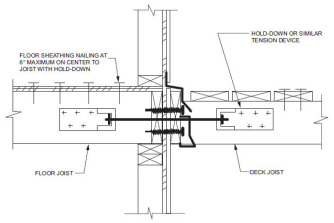

Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Deck Lateral Load Connection – R507.2.3(2)

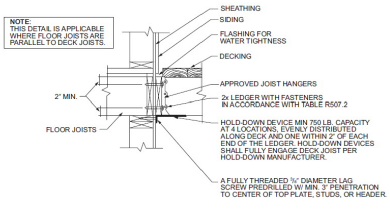

Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Deck Joist Design

- Maximum allowable spans for wood deck joists are as shown in 2015 IRC Figure R507.5 and shall be in accordance with 2015 IRC Table R507.5

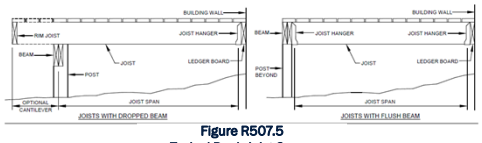

Figure R507.5
Typical Deck Joist Spans

Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Deck Joist Design

Table 3 - DECK JOIST SPANS FOR COMMON LUMBER SPECIES

SPECIES	SIZE	SPACING OF DECK JOISTS WITH NO CANTILEVER			SPACING OF DECK JOISTS WITH CANTILEVERS		
		12"	16"	24"	12"	16"	24"
Sothern Pine	2 X 6	9-11	9-0	7-7	6-8	6-8	6-8
	2 X 8	13-1	11-10	9-8	10-1	10-1	9-8
	2 X 10	16-2	14-0	11-5	14-6	14-0	11-5
	2 X 12	18-0	16-6	13-6	18-0	16-6	13-6

2015 IRC Table 507.5

Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Bearing for Joists – R507.7

- The ends of each joist, beam or girder
  - ≥ 1.5 inches of bearing on wood or metal, and
  - ≥ 3 inches of bearing on masonry or concrete.
  - Approved joist hanger
  - Joist bearing on beam shall be connected to resist lateral displacement

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Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Decking Requirements and Design

- Maximum allowable spacing for joist supporting decking shall be in accordance with 2015 IRC Table R507.4
- Wood decking shall be attached to each supporting member with minimum (2) threaded nails or screws

Table 2 - Maximum Joist Spacing

Connection Details	MAXIMUM ON-CENTER JOIST SPACING	
	Perpendicular to joist	Diagonal to joist
1/2" diameter lag screw with 1/2" maximum sheathing	16 inches	12 inches
2-inch-thick wood	24 inches	16 inches
Plastic Composite	Manufacturer installation instructions	Manufacturer installation instructions

2015 IRC Table 507.4

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Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Deck Beam Design

- Maximum allowable spans for wood deck beams, as shown in Figure R507.6, shall be in accordance with Table R507.6.
  - Plies shall be fastened with 2 rows of nails @19" o.c. along each edge
  - Beam can cantilever up to ¼ actual beam span
  - Splices shall be located at interior post

Figure R507.6
Typical Deck Beam Spans

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Image Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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2018 Table R507.5 Deck Beam Span Lengths

TABLE R507.5
DECK BEAM SPAN LENGTHS[a, b, c, d, e, f, g] (ft. - in.)

SPECIES[f]	SIZE[d]	DECK JOIST SPAN LESS THAN OR EQUAL TO: (feet)						
		6	8	10	12	14	16	18
Southern pine	1 - 2 X 6	4-11	4-0	3-7	3-3	3-0	2-10	2-8
	1 - 2 X 8	5-11	5-1	4-7	4-2	2-10	3-7	3-5
	1 - 2 X 10	7-0	6-0	5-5	4-11	4-7	4-3	4-0
	1 - 2 X 12	8-3	7-1	6-4	5-10	5-5	5-0	4-9
	2 - 2 X 6	6-11	5-11	5-4	4-10	4-6	4-3	4-0
	2 - 2 X 8	8-9	7-7	6-9	6-2	5-9	5-4	5-0
	2 - 2 X 10	10-4	9-0	8-0	7-4	6-9	6-4	6-0
	2 - 2 X 12	12-2	10-7	9-5	8-7	8-0	7-6	7-0
	3 - 2 X 6	8-2	7-5	6-8	6-1	5-8	5-3	5-0
	3 - 2 X 8	10-10	9-6	8-6	7-9	7-2	6-8	6-4
	3 - 2 X 10	13-0	11-3	10-0	9-2	8-6	7-11	7-6
	3 - 2 X 12	15-3	13-3	11-10	10-9	10-0	9-4	8-10

a. Ground snow load, live load = 40 psf, dead load = 10psf, L/Δ = 360 at main span, L/Δ = 180 at cantilever with a 220-pound load applied to end.
b. Beams supporting deck joists from one side only.
c. No. 2 grade, wet service factor.
d. Beams depth shall be greater than or equal to depth of joists with a flush beam condition.
e. Includes incising factor.
f. Northern species. Incising factor not included.
g. Beam cantilevers are limited to the adjacent beam's span divided by 4.

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.

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2015 IRC Section R507.8.1 Deck Posts to Deck Footing

- Posts shall bear on footings in accordance with Section R403 and Figure R507.8.1. Posts shall be restrained to prevent lateral displacement at the bottom support. Such lateral restraint shall be provided by manufactured connectors installed in accordance with Section R507 and the manufacturers' instructions or a minimum post embedment of 12 inches in surrounding soils or concrete piers.

Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Deck Post to Deck Footing Design

- **Posts shall be designed as followed:**
  - Bear on footings in accordance with 2015 IRC Figure R507.8.1
  - Be restrained to prevent lateral displacement at the bottom
    - Per connectors manufacturers' instructions
    - Minimum post embedment of 12" in surrounding soils or concrete piers

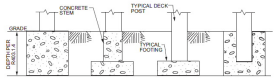

Figure R507.8.1
Typical Deck Posts to Deck Footings

Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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Deck Post to Beam Design

- **Deck beams shall be attached to deck posts**
  - In accordance with Figure R507.7.1
  - By equivalent means capable to resist lateral displacement
  - Connectors shall be sized for the post and beam sizes
  - Bolts to have washers
    - Exception –
      - Beam bears directly on footing in accordance with 2015 IRC R507.8.1

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Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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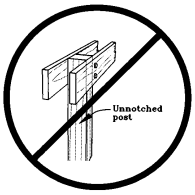
Bolted connections?

- **Bolted connections have limited capacity and does not meet bearing requirements of the IRC.**



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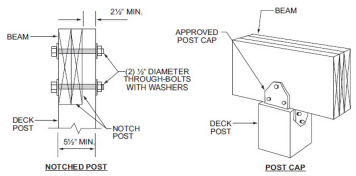
Deck Post to Beam Design – R507.7.1



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Source: International Code Council (ICC). (2014). 2015 International Residential Code, Country Club Hill, Ill.

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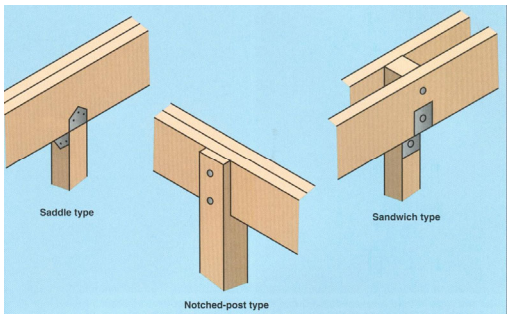

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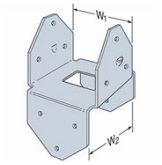
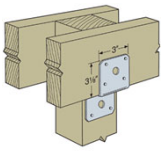
Deck Post to Beam Design - options





Source – www.strongtie.com – Simpson Strong-tie

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Guardrail Design (AWC DCA-6 2015 IRC Version)

https://www.awc.org/pdf/codes-standards/publications/dca/AWC-DCA62015-DeckGuide-1804.pdf

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Guards

- Quick overview of Virginia Tech research
- Look at the design guidelines in AWC DCA-6

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VA Tech Test Program

- Goal: Evaluate horizontal load capacity of common post to deck connections. Do they meet code requirements?
- Code Conforming Target Test load:
  - 200 lbs design X 2.5 safety factor = 500 lbs

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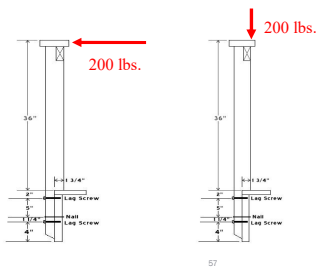
Forces Applied



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Test Parameters

- Horizontal load 37.5" above joist
- Test variables:
  - Bolts, Lag screws, wood screws, wood cleats
  - Notched and un-notched posts
  - Pressure treated southern pine

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Test Set-up

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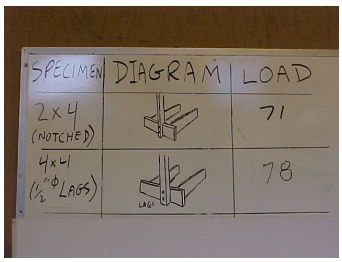
Tests at VA Tech Short Course



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Un-notched ½" Bolts

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Results

- Failed, on average, at 47% of required test load.
  - Note 3" SS screws in band joists.

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Notched Post, ½" Bolts

- Failed at 71 lbs

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Notched Post, ½ " Bolts

- No. 2 visually graded 4x4, allowable slop of grain is 1:8

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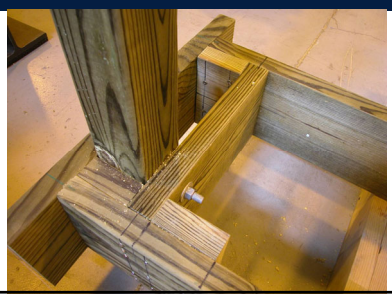
Wood Blocking



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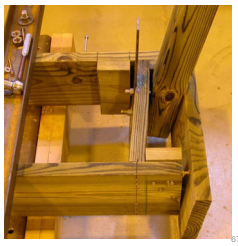
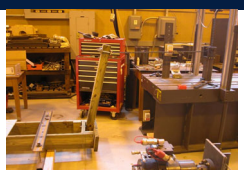
Testing Blocked Post Connection Assembly





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Splitting Failure

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Shear Wall Hold-down

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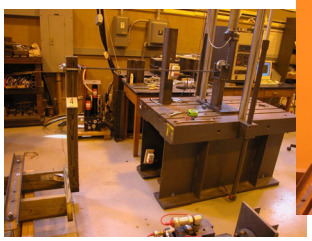
Passed

- Passed 200 lb force



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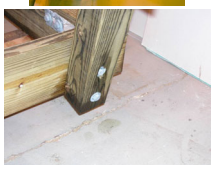

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Test Results

Post-to-Deck Connection Assembly	Average Test Load (lbs.)	Range of Test Loads (lbs.)	Average Deflection at 200 lbs (in)	Average Test Load as % of 500 lbs.	Code Conforming Assembly?
½-inch Lag screws	178	146 to 211	NA	35%	No
½-inch Bolts	237	217 to 248	4.4	47%	No
HD2A Anchor (4x4 post inside band)	645	593 to 687*	2.0	**129%**	**Yes**
HD2A Anchor (4x4 post outside band)	686*	653* to 713*	1.9	**137%**	**Yes**

* Test was stopped

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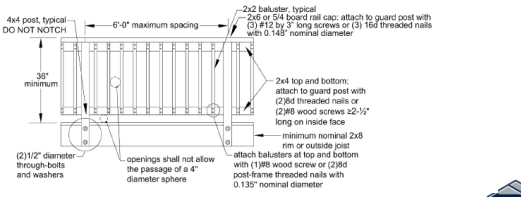
Guardrail Design with DCA-6

- Decks greater than 30” above grade require a guard

Figure 24. Example Guard Detail.



courtesy, American Wood Council, Leesburg, VA

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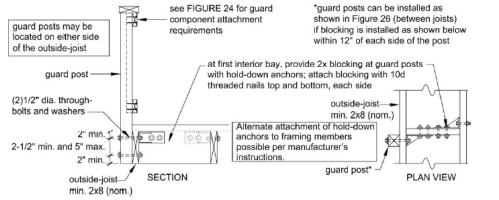
Guardrail Requirements

- Minimum 4x4 post

Figure 25. Guard Post to Outside-Joist Example.



courtesy, American Wood Council, Leesburg, VA

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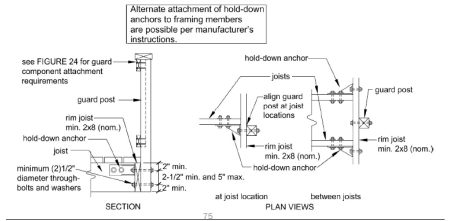
Guardrail Requirements

- Guard post to rim joist

Figure 26. Guard Post to Rim Joist Example.



courtesy, American Wood Council, Leesburg, VA

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Thoughts on Guards

- Never rely on nails in withdrawal.
- Guard rail post connection capacity:
  - can not be determined by analyses (too many varies, large number of connections, requires 3 dimensional analyses)
  - relies on full assembly (weakest link)
  - is difficult to field verify (hip check is probably ~ 30lbs)
- Notched posts should not be allowed.
- Proprietary systems are all tested at required load + factor-of-safety.

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