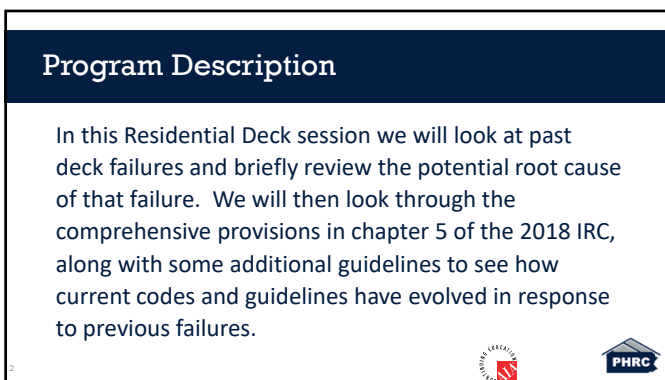
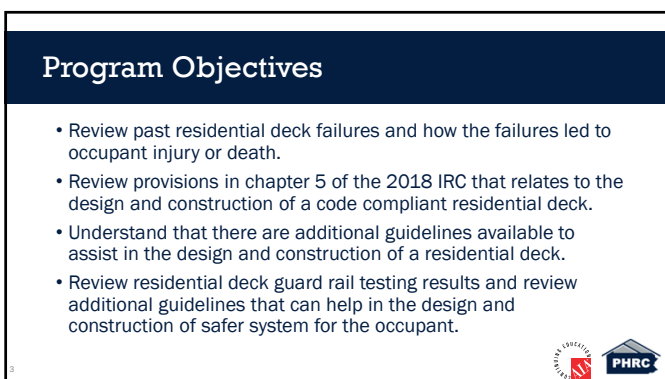


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11

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>



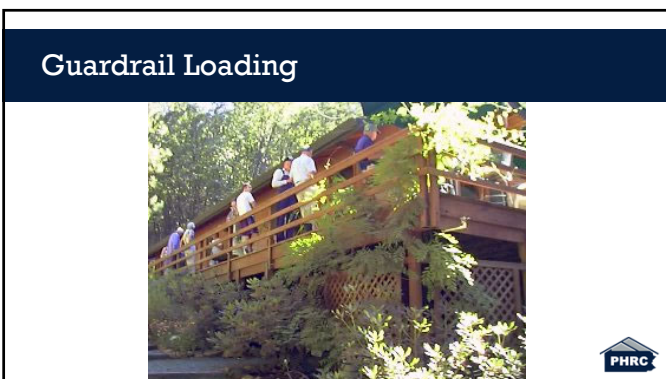
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13



14



15

Guardrail failure

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





Photo courtesy of - Darin Clements




16




17

Post attachment

- Toe-nailed post?





18



19

Slide 20 has a dark blue header with the text "They are EVERYWHERE!". Below the header, on the left, is a bulleted list:

- 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

 To the right of the text is a photograph of a modern, two-story house with a large wooden deck and railing. At the bottom left of the slide is a small number "20". At the bottom center, there is small text: "Source: JANUARY/FEBRUARY 2009, VOL. 85, NO. 1 - THE FORESTRY CHRONICLE" and "Source: <http://eyehousing.org/2019/11/shares-of-new-homes-with-decks-declines-in-2018/>". In the bottom right corner is a "PHRC" logo.

20

Slide 21 has a dark blue header with the text "Injuries". Below the header, on the left, is a bulleted list:


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

 To the right of the text is a blue medical symbol, a caduceus (a staff with two snakes and wings). At the bottom left of the slide is a small number "21". At the bottom center, there is small text: "Source - Washington State Magazine, Tina Hixling" and "<http://magazine.wsu.edu/2009/10/07/making-decks-safer/>". In the bottom right corner is a "PHRC" logo.

21

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**



22

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



23

Structural Review – House vs. Deck


- **Increased exposure (wet service – UV)**
 - Wood durability
 - Fasteners
- **Uncertain (unexpected) service load during the life of the structure**
- **Failure**
 - House failure is not catastrophic
 - Deck failure usually are




24

Big Take Away!

It is much more than “just a deck”!




25



Structural Requirements


2018 International Residential Code, Chapter 3 & 5



26

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 2012 IRC Version)




27

Decks Supported by Exterior Walls

- Wood-framed decks shall be in accordance with this Section (2018 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

28



Design Criteria

- Minimum Design Criteria

TABLE R301.5 MINIMUM UNIFORMLY DISTRIBUTED LIVE LOADS (in pounds per square foot)


USE	LIVE LOAD
Uninhabitable attics without storage ^a	10
Uninhabitable attics with limited storage ^{a, f}	20
Habitable attics and attics served with fixed stairs	30
Balconies (exterior) and decks ^a	40
Fire escapes	40
Quairs and handrails ^g	200 ^h
Guard in-fill components ^g	50 ^h
Passenger vehicle garages ^a	50 ^h
Rooms other than sleeping rooms	40
Sleeping rooms	30
Stairs	40 ^h

Footnotes

— ^a A single concentrated load applied in any direction at any point along the top.

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


29



Prescriptive Deck Design Through the IRC

2018 IRC Code Requirements

30



R507.3 Footings

- Decks shall be supported on concrete footings or other approved structural systems designed to accommodate all loads in accordance with Section R301. Deck footings shall be sized to carry the imposed loads from the deck structure to the ground as shown in Figure R507.3. The footing depth shall be in accordance with Section R403.1.4.
- Exception: Free-standing decks consisting of joists directly supported on grade over their entire length.

31

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hills, IL.

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31

TABLE R301.2(1) CLIMATIC AND GEOGRAPHIC DESIGN CRITERIA

GROUND BROWN LOAD ^a	WIND DESIGN		SEISMIC DESIGN CATEGORY ^b	SUBJECT TO DAMAGE FROM		WINTER DESIGN TEMP ^c	ICE BARRIER UNDERLAYMENT REQUIRED ^d	FLOOD HAZARD ^e	AIR FREEZING INDEX ^f	MEAN ANNUAL TEMP ^g
	Speed ^h (mph)	Topographic effects ⁱ		Special wind region ^j	Windborne debris zone ^k					
---	---	---	---	---	---	---	---	---	---	---
MINIMUM DESIGN CRITERIA ^o										
Elevation	---	Latitude	Winter heating	Summer cooling	Altitude correction factor	Indoor design temperature	Design temperature cooling	Heating temperature difference	---	
Cooling temperature difference	---	Wind velocity heating	Wind velocity cooling	Coincident wet bulb	Daily range	Winter humidity	Summer humidity	---		

^a 1 pound per square foot = 0.0479 kPa; 1 inch per foot = 0.0833 ft.

^b Where weathering requires a higher strength concrete or grade of masonry than necessary to satisfy the structural requirements of the code, the frost line depth strength required for weathering shall govern. The weathering column shall be filled in with the weathering index.

^c Where the frost line depth requires design footings from conditions not included in Figure R501.1.1, the frost line depth strength required for weathering shall govern. The jurisdiction shall fill in the frost line depth column with the minimum depth of footing below frost grade.

^d The jurisdiction shall fill in this part of the table to indicate the need for protection depending on whether there has been a history of ice water damage to the building.

^e The jurisdiction shall fill in this part of the table with the date the jurisdiction entry into the National Flood Insurance Program (date of initiation of the first claim or initiation for management of flood hazard areas), (a) the date(s) of the Flood Insurance Study and (a) the panel numbers and dates of the currently effective FIRM and FIRM(s) or other flood hazard map adopted by the authority having jurisdiction, as amended.

^f In accordance with Section R501.1.1, Section R501.1.1, Section R501.1.1, and R501.1.1, where there has been a history of ice damage from the effects of ice loading, the jurisdiction shall fill in this part of the table with "YES". Otherwise, the jurisdiction shall fill in this part of the table with "NO".

^g The jurisdiction shall fill in this part of the table with the 100-year return period or freezing index (BT days) from Figure R501.1.1, or from the 100-year (99 percent) value in the National Climatic Data Center data table for Freezing Index (USA Method) (Zone 10°F).

^h The jurisdiction shall fill in this part of the table with the mean annual temperature from the National Climatic Data Center data table for Freezing Index (USA Method) (Zone 10°F).

ⁱ In accordance with Section R501.2.1.1, where there is local historical data documenting structural damage to buildings due to topographic wind speed-up effects, the jurisdiction shall fill in this part of the table with "YES". Otherwise, the jurisdiction shall indicate "NO" in this part of the table.

^j In accordance with Figure R501.2.1.1, where there is local historical data documenting unusual wind conditions, the jurisdiction shall fill in this part of the table with "YES" and identify any specific requirements. Otherwise, the jurisdiction shall indicate "NO" in this part of the table.

^k In accordance with Section R501.2.1.2, the jurisdiction shall indicate the windborne debris zone location. Otherwise, the jurisdiction shall indicate "NO" in this part of the table.

^l The jurisdiction shall fill in this section of the table to establish the design criteria using Table R501.2.1.1 to the ICC Manual or established criteria determined by the jurisdiction.

^m The jurisdiction shall fill in this section of the table using the Ground Snow Loads in Figure R501.2.1.

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R507.3.1 Minimum Size

- The minimum size of concrete footings shall be in accordance with [Table R507.3.1](#), based on the tributary area and allowable soil-bearing pressure in accordance with [Table R401.4.1](#).

33

Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hills, IL.

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33

Minimum Footing Size for Decks												
TABLE R507.3.1 MINIMUM FOOTING SIZE FOR DECKS												
LIVE OR DEAD/NO LOAD (psf)	TERRITORY AREA (sq. ft.)	LOAD BEARING VALUE OF SOILS ^{a, b} (psf)										
		1500 ^c		2000 ^c		2500 ^c		≥ 3000 ^c				
		Side of a square footing (inches)	Diameter of a round footing (inches)	Side of a square footing (inches)	Diameter of a round footing (inches)	Side of a square footing (inches)	Diameter of a round footing (inches)	Side of a square footing (inches)	Diameter of a round footing (inches)	Side of a square footing (inches)	Diameter of a round footing (inches)	Thickness (inches)
40	20	12	14	6	12	14	6	12	14	6	12	14
	40	14	16	6	12	14	6	12	14	6	12	14
	60	17	19	6	15	17	6	13	15	6	12	14
	80	20	22	7	17	19	6	15	17	6	14	16
	100	22	25	8	19	21	6	17	19	6	16	17
	120	24	27	9	21	23	7	19	21	6	17	19
	140	26	29	10	22	25	8	20	23	7	18	21
160	28	31	31	11	24	27	9	21	24	8	20	22
For SI: 1 inch = 25.4 mm, 1 square foot = 0.0929 m ² , 1 pound per square foot = 0.0479 kPa.												
a. Interpolation permitted; extrapolation not permitted. b. Based on highest load case: Dead + Live or Dead + Snow. c. Assumes minimum square footing to be 12 inches x 12 inches x 8 inches for 8 x 6 post. d. If the support is a block or CIP pier, the footing shall have a minimum 12-inch projection on all sides. e. Area in square feet of deck surface supported by post and footings.												
34	Source: International Code Council (ICC), (2017), 2018 International Residential Code, Country Club Hill, IL											

34

R507.4.1 Deck Posts to Deck Footing												
• Where posts bear on concrete footings in accordance with Section R403 and Figure R507.3, lateral restraint shall be provided by manufactured connectors or a minimum post embedment of 12 inches in surrounding soils or concrete piers. Other footing systems shall be permitted.												
35	Source: International Code Council (ICC), (2017), 2018 International Residential Code, Country Club Hill, IL											

35

Deck Post to Deck Footing Design												
36	Source: International Code Council (ICC), (2017), 2018 International Residential Code, Country Club Hill, IL											

36

R507.3.2 Minimum Depth

- Deck footings shall extend below the frost line specified in Table R301.2(1) in accordance with Section R403.1.4.1
 - Exception:
 1. Free-standing decks that **meet all of** the following criteria:
 1. The joist bear directly on precast concrete pier blocks at grade without support by beams or posts
 2. The area of the deck does not exceed 200 square feet
 3. The walking surface is not more than 20 inches above grade
 2. Free-standing decks **need not be provided** with footings that extend below the frost line.



37

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

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Deck Beam Design

- Maximum allowable spans for wood deck beams, as shown in Figure R507.5, shall be in accordance with Table R507.5.
 - 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**



38

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

38

Table R507.5 Deck Beam Span Lengths

TABLE R507.5 DECK BEAM SPAN LENGTHS^{a, b} (feet - inches)

SPECIES ^c	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	3-10	3-7	3-5
	1-2 x 10	7-0	6-0	5-6	4-10	4-7	4-3	4-0
	1-2 x 12	8-3	7-1	6-4	5-10	5-6	5-0	4-8
	2-2 x 6	6-11	5-11	4-4	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	7-6	6-8	6-1	5-8	5-3	5-0
	3-2 x 8	10-10	9-6	8-6	7-6	7-2	6-8	6-4
	3-2 x 10	13-6	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

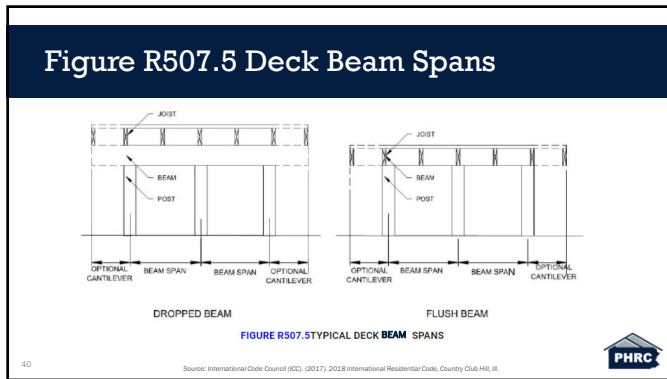
For D1: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot = 0.0479 kPa, 1 pound = 0.454 kg

^a Ground snow load for load & uplift shall not be less than 10 psf. C_u = 360 at main span, C_u = 180 at cantilever with a 200-pound point load applied at the end^b Beams supporting deck joists from one side only^c No. 2 grade wet service factor^d Beam 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 span divided by 4

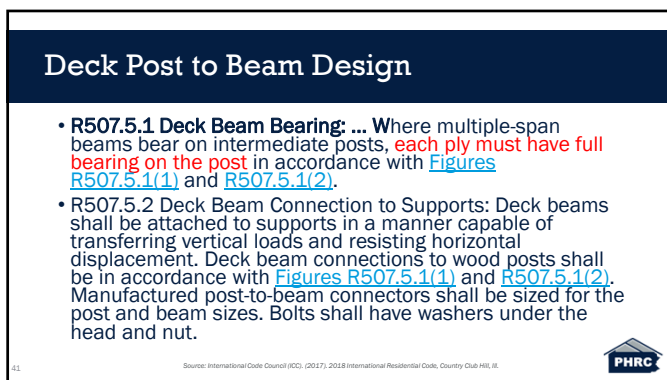
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Source: International Code Council (ICC), (2017), 2018 International Residential Code, Country Club Hill, IL

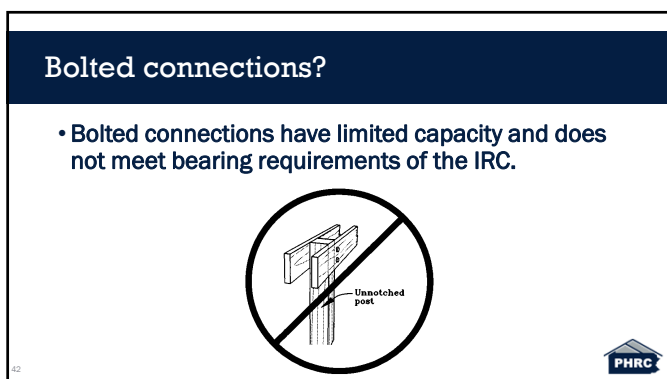
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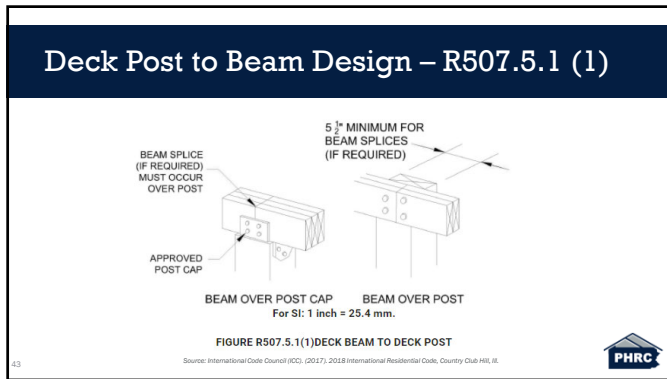
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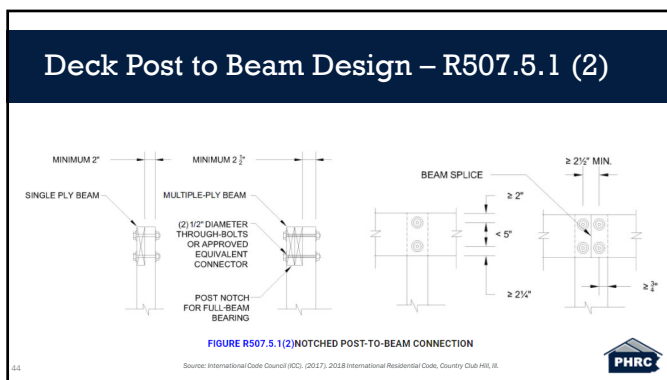
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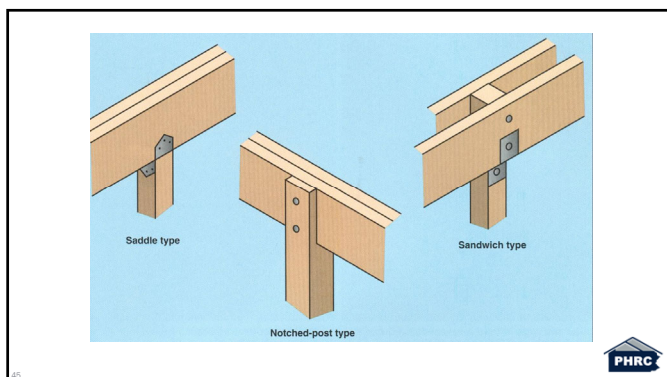
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Deck Post to Beam Design - options

Source - www.strongtie.com - Simpson Strongtie

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Deck Joist Design

- Maximum allowable spans for wood deck joists are as shown in 2018 IRC Figure R507.6 and shall be in accordance with 2018 IRC Table R507.6. **The maximum joist spacing shall be limited by the decking materials. The maximum joist cantilever shall be limited to one-fourth the joist span or the maximum cantilever length specified in Table R507.6, whichever is less.**

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

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Decking Requirements and Design

- Maximum allowable spacing for joist supporting decking shall be in accordance with 2018 IRC Table R507.7
- Wood decking shall be attached to each supporting member with minimum (2) threaded nails or screws

TABLE R507.7 MAXIMUM JOIST SPACING FOR DECKING

DECKING MATERIAL TYPE AND NOMINAL SIZE	MAXIMUM ON-CENTER JOIST SPACING	
	Decking perpendicular to joist	Decking diagonal to joist ^a
1 1/2-inch thick wood	16 inches	12 inches
2-inch thick wood	24 inches	16 inches
Plastic composite	In accordance with Section R502.2	In accordance with Section R502.2

^a For 1 1/2" x 24" max. 1" max x 304.8 mm. 1" max x 337.5 mm. Source: International Code Council (ICC), (2017), 2018 International Residential Code, Country Club Hill, IL

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Deck Joist Design (Attachment to the Primary Structure for Vertical Loads)

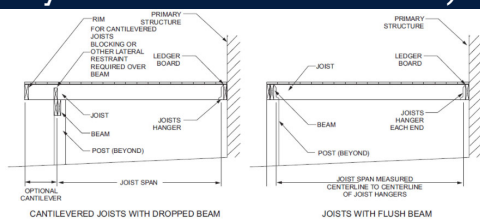


Figure R507.6
Typical Deck Joist Spans

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



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Deck Joist Design (Non-Ledger)

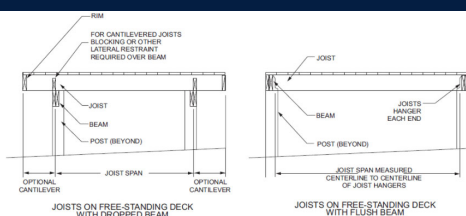


Figure R507.6
Typical Deck Joist Spans

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



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Deck Joist Design

TABLE R507.6 DECK JOIST SPANS FOR COMMON LUMBER SPECIES (B_x in in.)

SPECIES*	SIZE	ALL-OMER® DECK JOIST®				MAXIMOR® CANTILEVER ¹			
		SPACING OF DECK JOISTS (inches)				SPACING OF DECK JOISTS WITH CANTILEVER ¹ (inches)			
		12	16	24	36	12	16	24	36
Southern pine	2 x 6	8-11	9-6	2-7	1-3	1-3	1-4	1-6	1-8
	2 x 8	13-1	11-10	9-6	2-1	2-1	2-3	2-5	2-7
	2 x 10	16-2	14-0	10-6	3-4	3-4	3-6	3-10	3-12
	2 x 12	18-0	16-0	13-6	4-6	4-6	4-8	4-12	4-14
	2 x 8	8-6	8-6	7-2	3-2	3-2	3-3	3-6	3-8
Douglas fir/birch ²	2 x 6	12-6	11-1	8-1	1-1	1-1	2-1	2-3	2-5
	2 x 8	16-8	15-7	10-1	3-1	3-1	3-4	3-6	3-8
	2 x 10	18-0	16-0	12-0	4-6	4-6	5-11	5-13	5-15
Redwood, western cedar, ponderosa pine ³ , red pine ⁴	2 x 6	10-0	8-0	5-0	1-0	1-0	1-2	1-3	1-3
	2 x 8	11-6	10-7	6-0	1-6	1-10	2-0	2-5	2-6
	2 x 10	14-11	13-0	10-7	2-0	2-10	3-0	3-10	3-11

One 30.1 inch x 75.2 inch, 1 foot x 32.8 inch, 1 second eye scanner (foot x 2.7475 inch), 1 second eye 120 inch

16. No. 2 grade without service factor.
17. Ground snow load, live load = 40 psf, dead load = 10 psf, $L_{10} = 360$.
18. Ground snow load, live load = 40 psf, dead load = 10 psf, $L_{10} = 360$ at main span, $L_{10} = 180$ at cantilever with a 220-pound point load applied to end.
19. Includes freezing factor.
20. Northern species with no freezing factor.

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Deck Ledger Board Connection

- **R507.9.1 Vertical supports.** Vertical loads shall be transferred to band joists with ledgers in accordance with this section.
 - **R507.9.1.1 Ledger details.**
Deck ledgers shall be a minimum 2-inch by 8-inch (51 mm by 203 mm) nominal, pressure-preservative-treated Southern pine, incised pressure-preservative-treated hem-fir, or approved, naturally durable, No. 2 grade or better lumber. Deck ledgers shall not support concentrated loads from beams or girders. Deck ledgers shall not be supported on stone or masonry veneer.
 - **R507.9.1.2 Band joist details.**
Band joists supporting a ledger shall be a minimum 2-inch-nominal (51 mm), solid-sawn, spruce-pine-fir or better lumber or a minimum 1-inch by 9½-inch (25 mm × 241 mm) dimensional, Douglas fir or better, laminated veneer lumber. Band joists shall bear fully on the primary structure capable of supporting all required loads.

Source: International Code Council (ICC), (2017), 2021 International Residential Code, Country Club Hill, IL.

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Deck Attachment “Don’ts”

courtesy, American Wood Council, Leesburg, VA

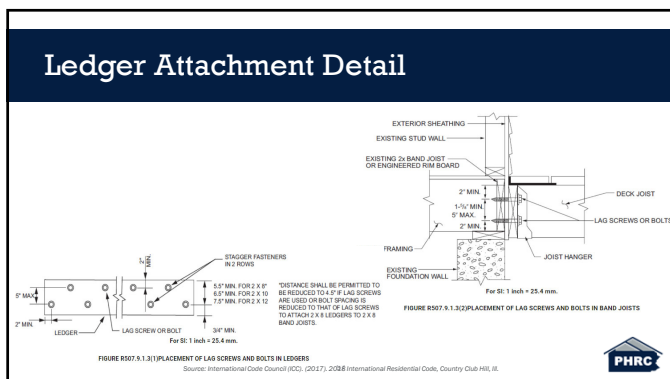
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Deck Lateral Load Connection

- R507.9.2 Lateral connection.** Lateral loads shall be transferred to the ground or to a structure capable of transmitting them to the ground. Where the lateral load connection is provided in accordance with Figure R507.9.2(1), hold-down tension devices shall be installed in **not less than two locations per deck, within 24 inches (610 mm) of each end of the deck. Each device shall have an allowable stress design capacity of not less than 1,500 pounds (6672 N).** Where the lateral load connections are provided in accordance with Figure R507.9.2(2), the hold-down tension devices shall be installed in **not less than four locations per deck, and each device shall have an allowable stress design capacity of not less than 750 pounds (3336 N).**

Source: International Code Council (ICC), (2017), 2018 International Residential Code, Country Club Hills, IL




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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?

Source: International Code Council (ICC), (2017), 2018 International Residential Code, Country Club Hills, IL



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Deck Lateral Load Connection – R507.9.2(1)

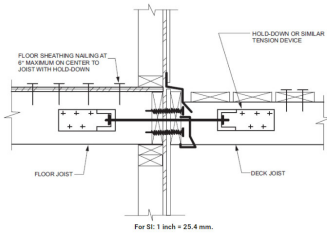

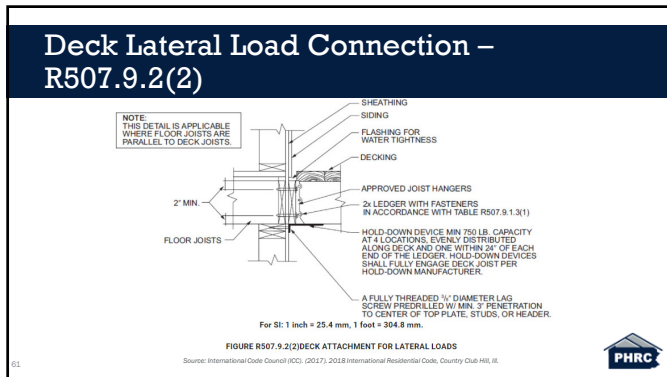


FIGURE R507.9.2(1) DECK ATTACHMENT FOR LATERAL LOADS

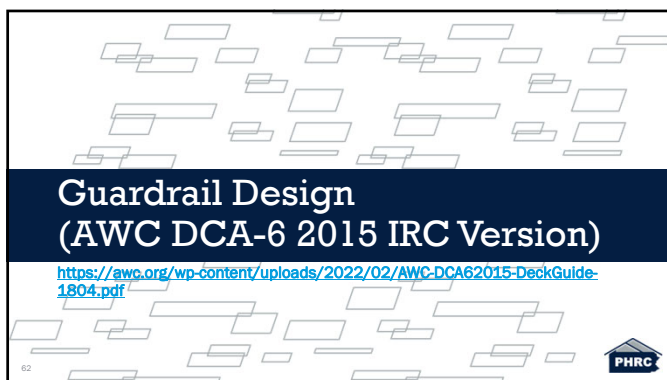
Source: International Code Council (ICC), (2017), 2018 International Residential Code, Country Club Hills, IL



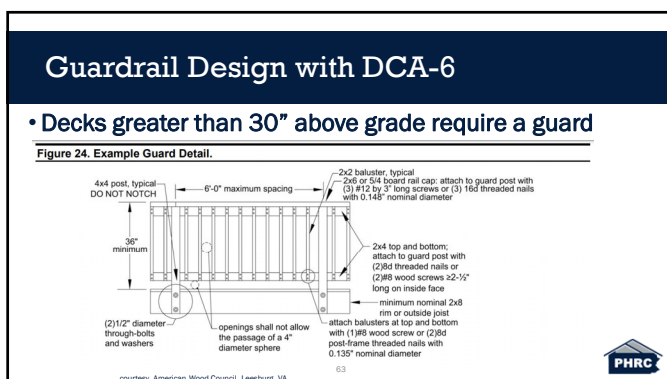
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62



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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.**

66

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Summary

- The design and construction must be compliant to the 2018 IRC
- Find the weakest link
- Is the weakest link compliant?
- Remember, it's more than just a deck!

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Questions?

www.phrc.psu.edu

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Resources

- Design for Code Acceptance 6 (DCA-6) - <https://awc.org/wp-content/uploads/2022/02/AWC-DCA62015-DeckGuide-1804.pdf>
- 2018 IRC - <https://codes.iccsafe.org/content/IRC2018P4/chapter-1-scope-and-administration>

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Evaluation & Certificate Link

This concludes The American Institute of Architects Continuing Education Systems Course

Link to certificate (only for live sessions):
<https://cvent.me/DWZKDb>

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A Comprehensive Deck Design From Footings to Guards: Learning From the Past

www.phrc.psu.edu

PennState College of Engineering

PENNSYLVANIA HOUSING RESEARCH CENTER

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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

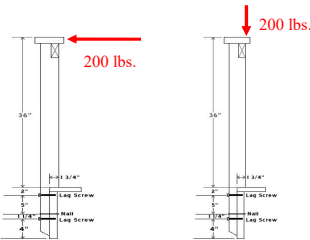
- **Goal:** Evaluate horizontal load capacity of common post to deck connections. Do they meet code requirements?
- **Code Conforming Target Test load:**
 - 200 lbs design X 2.5 safety factor = 500 lbs

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Forces Applied



74




74

Test Parameters

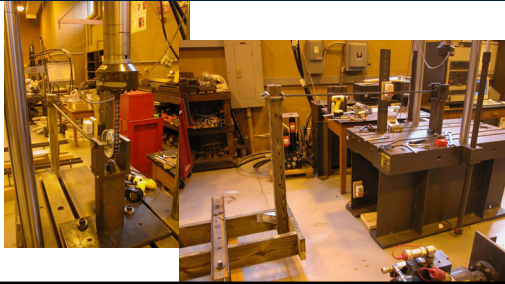
- **Horizontal load 37.5\"**
- **Test variables:**
 - Bolts, Lag screws, wood screws, wood cleats
 - Notched and un-notched posts
 - Pressure treated southern pine

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Test Set-up



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Tests at VA Tech Short Course

SPECIMEN	DIAGRAM	LOAD
2x4 (NOTCHED)		71
4x4 (1/2" LAGS)		78



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Un-notched 1/2" Bolts




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Results


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



79

Notched Post, 1/2" Bolts

- Failed at 71 lbs



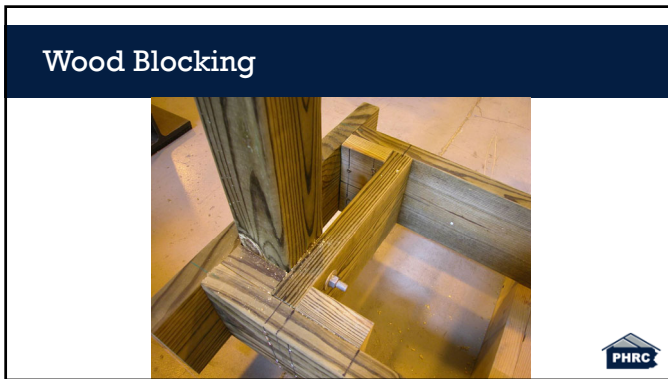
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Notched Post, 1/2" Bolts

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



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82



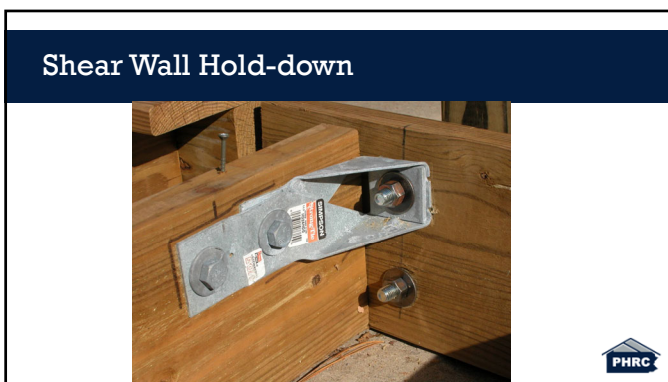
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Test Results					
Post-to-Deck Connection Assembly	Average Test Load (lbs.)	Range of Test Loads (lbs.)	Average Deflection at 200 lbs (in)	Average Test Load as % of 500 lbs.	Code Conforming Assembly?
½-inch Lag screws	178	146 to 211	NA	35%	No
½-inch 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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