Christopher Hine, PHRC
PENNBOC Conference September 22, 2023

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

www.phrc.psu.edu

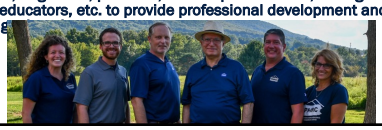
PennState College of Engineering | PENNSYLVANIA HOUSING RESEARCH CENTER

PHRC

1

Pennsylvania Housing Research Center

- 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



2

PHRC

2

Program Description

In this Residential Deck session we will look at past deck failures and briefly review the potential root cause of that failure. We will then look through the comprehensive provisions in chapter 5 of the 2018 IRC, along with some additional guidelines to see how current codes and guidelines have evolved in response to previous failures.

3

PHRC

3

Program Objectives

- Review past residential deck failures and how the failures led to occupant injury or death.
- Review provisions in chapter 5 of the 2018 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.

4

4

Why Are You Here?

5

5

Definitions

- **Definitions are not provided for Decks and Balconies in the IRC.**
  - Design is different
  - Design criteria is the same
- **Deck - A roofless, floored structure, typically with a railing, that adjoins a house. ;** www.thefreedictionary.com
- **Balcony - A platform that projects from the wall of a building and is surrounded by a railing, balustrade, or parapet. ;** www.thefreedictionary.com

6

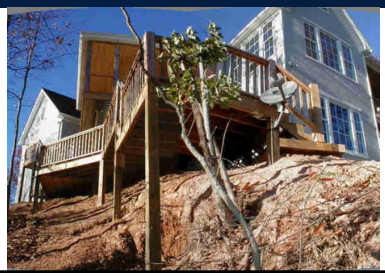
6

Normal Deck Loading

7

7

Extreme Construction Conditions



8

8

Excessive Deck Loading and ?

9

9

10

11

12


13
PHRC

13


14
PHRC

14


15
Source – www.charlotteobserver.com.com
PHRC

15

Source – www.latimes.com

16

16

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

17

17

18

18

19

Guardrail Loading

PHRC

20

Guardrail failure

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

Photo courtesy of – Darin Clements

21

PHRC

21

22

22

Post attachment

- Toe-nailed post?

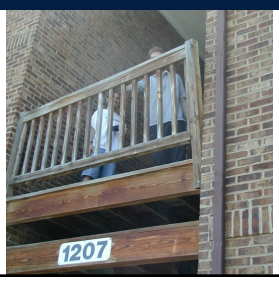
23

23

Compliant?

24

Compliant?



PHRC

25

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

26

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/

PHRC

26

Injuries

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

27

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

PHRC

27

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

28

28

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

29

29

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

30

30

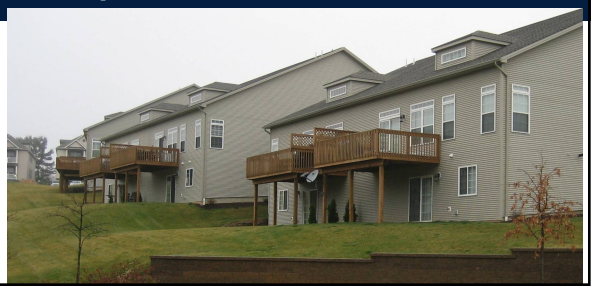
Big Take Away!

It is much more than "just a deck"!

31

31

And they are EVERYWHERE!



32

Structural Requirements

2018 International Residential Code, Chapter 3 & 5

33

33

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)

34

34

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

35

35

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[b]	10
Uninhabitable attics with limited storage[b, g]	20
Habitable attics and attics served with fixed stairs	30
Balconies (exterior) and decks[e]	40
Fire escapes	40
Guards and handrails[d]	200[h]
Guard in-fill components[f]	50[h]
Passenger vehicle garages[a]	50[a]
Rooms other than sleeping rooms	40
Sleeping rooms	30
Stairs	40[c]

- **Footnotes**
  - [d] A single concentrated load applied in any direction at any point along the top.

Image Source: International Code Council (ICC). (2021). 2018 International Residential Code. Country Club Hill, IL

36

36

Prescriptive Deck Design Through the IRC

2018 IRC Code Requirements

37

37

Permit Requirements and Exemptions - UCC: §403.62(c)(8)

- **A permit is not required for:**
  - Installation of an uncovered deck where the floor is ≤ 30" above grade
- **However:**
  - Work must still conform to IRC

38

38

Manufacturer Installation Instructions

- **If complying with the IRC or UCC requirements would violate any of the conditions of the manufacturer's installation instructions or the listing of equipment/appliances**
  - The manufacturer's installation instructions shall be followed
  - Conditions of the listing shall be followed

39

39

Responsibility

- **Who is responsible for assuring the deck is designed to the UCC?**
  - Builder (new home)
  - Remodeler
  - Design professional
  - Material suppliers
  - Building code official
- **Who is responsible for assuring the deck is constructed to the UCC?**
  - Builder (new home)
  - Remodeler
  - Design professional
  - Material suppliers
  - Building code official

PHRC

40

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.

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

PHRC

41

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

GROUND SNOW LOAD[a]	WIND DESIGN				SEISMIC DESIGN CATEGORY[f]	SUBJECT TO DAMAGE FROM			WINTER DESIGN TEMP[e]	ICE BARRIER UNDERLAYMENT REQUIRED[h]	FLOOD HAZARDS[g]	AIR FREEZING INDEX[i]	MEAN ANNUAL TEMP[j]
	Speed[d] (mph)	Topographic effects[k]	Special wind region[l]	Windborne debris zone[m]		Weathering[a]	Frost line depth[b]	Termite[c]					
—	—	—	—	—	—	—	—	—	—	—	—	—	—

MANUAL J DESIGN CRITERIA[q]

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	—
—	—	—	—	—	—	—	—

For SI: 1 pound per square foot = 0.0479 kPa, 1 mile per hour = 0.447 m/s.

a. Where weathering requires a higher strength concrete or grade of masonry than necessary to satisfy the structural requirements of this code, the frost line depth strength required for weathering shall govern. The weathering column shall be filled in with the weathering index, "negligible" or "severe" for concrete as determined from Figure R301.2(3). The grade of masonry units shall be determined from ASTM C34, C55, C73, C90, C129, C145, C216 or C62.

b. Where the frost line depth requires deeper footings than indicated in Figure R403.1(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 finish grade.

c. 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 local subterranean termite damage.

d. The jurisdiction shall fill in this part of the table with the wind speed from the basic wind speed map [Figure R301.2(5)A]. Wind exposure category shall be determined on a site-specific basis in accordance with Section R301.2.1.4.

e. The outdoor design dry-bulb temperature shall be selected from the columns of 97½-percent values for winter from Appendix D of the International Plumbing Code. Deviations from the Appendix D temperatures shall be permitted to reflect local climates or local weather experience as determined by the building official. (Also see Figure R301.2(1).)

f. The jurisdiction shall fill in this part of the table with the seismic design category determined from Section R301.2.2.1.

g. The jurisdiction shall fill in this part of the table with (a) the date of the jurisdiction's entry into the National Flood Insurance Program (date of adoption of the first code or ordinance for management of flood hazard areas), (b) the date(s) of the Flood Insurance Study and (c) the panel numbers and dates of the currently effective FIRMs and FBFMs or other flood hazard map adopted by the authority having jurisdiction, as amended.

h. In accordance with Sections R905.1.2, R905.4.3.1, R905.5.3.1, R905.6.3.1, R905.7.3.1 and R905.8.3.1, where there has been a history of local damage from the effects of ice damming, 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."

i. The jurisdiction shall fill in this part of the table with the 100-year return period air freezing index (BF-days) from Figure R403.3(2) or from the 100-year (99 percent) value on the National Climatic Data Center data table "Air Freezing Index-USA Method (Base 32°F)."

j. The jurisdiction shall fill in this part of the table with the mean annual temperature from the National Climatic Data Center data table "Air Freezing Index-USA Method (Base 32°F)."

k. In accordance with Section R301.2.1.5, 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.

l. In accordance with Figure R301.2(5)A, 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.

m. In accordance with Section R301.2.1.2 the jurisdiction shall indicate the wind-borne debris wind zone(s). Otherwise, the jurisdiction shall indicate "NO" in this part of the table.

n. The jurisdiction shall fill in these sections of the table to establish the design criteria using Table 1a or 1b from ACCA Manual J or established criteria determined by the jurisdiction.

o. The jurisdiction shall fill in this section of the table using the Ground Snow Loads in Figure R301.2(6).

42

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.

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

PHRC

43

Minimum Footing Size for Decks

TABLE R507.3.1 MINIMUM FOOTING SIZE FOR DECKS

LIVE OR GROUND SNOW LOAD[a] (psf)	TRIBUTARY AREA (sq. ft.)	LOAD BEARING VALUE OF SOIL[b] (psf)											
		1500			2000			2500			≥ 3000		
		Side of a square footing (inches)	Diameter of a round footing (inches)	Thickness (inches)	Side of a square footing (inches)	Diameter of a round footing (inches)	Thickness (inches)	Side of a square footing (inches)	Diameter of a round footing (inches)	Thickness (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	6
	40	14	16	6	12	14	6	12	14	6	12	14	6
	60	17	19	6	15	17	6	13	15	6	12	14	6
	80	20	22	7	17	19	6	15	17	6	14	16	6
	100	22	25	8	19	21	6	17	19	6	15	17	6
	120	24	27	9	21	23	7	19	21	6	17	19	6
	140	26	29	10	22	25	8	20	23	7	18	21	6
	160	28	31	11	24	27	9	21	24	8	20	22	7

For SI: 1 inch = 25.4 mm, 1 square foot = 0.0929 m², 1 pound per square foot = 0.0479 kPa.

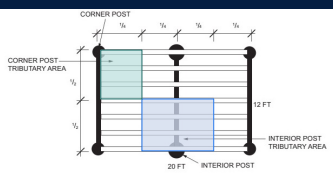
a. Interpolation permitted, extrapolation not permitted.
b. Based on highest load case: Dead + Live or Dead + Snow.
c. Assumes minimum square footing to be 12 inches x 12 inches x 6 inches for 6 x 6 post.
d. If the support is a brick or CMU pier, the footing shall have a minimum 2-inch projection on all sides.
e. Area, in square feet, of deck surface supported by post and footings.

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

PHRC

44

R507.3.1 – Minimum Footing Size for Decks – Cont.



TRIBUTARY AREA – CORNER POST
LENGTH IS ½ OF TOTAL LENGTH = 20 FT × ¼ = 5 FT
WIDTH IS ½ OF TOTAL WIDTH = 12 FT × ½ = 6 FT
AREA = 5 FT × 6 FT = 30 FT²

TRIBUTARY AREA – INTERIOR POST
LENGTH IS ½ OF TOTAL LENGTH = 20 FT × ½ = 10 FT
WIDTH IS ½ OF TOTAL WIDTH = 12 FT × ½ = 6 FT
AREA = 10 FT × 6 FT = 60 FT²

Commentary Figure R507.3.1DECK TRIBUTARY AREA

PHRC

45

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.

46

Deck Post to Deck Footing Design

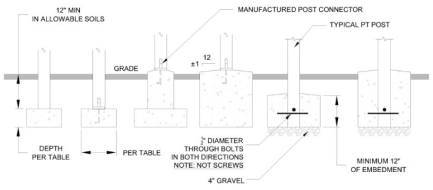


FIGURE R507.3DECK POSTS TO DECK FOOTING CONNECTION

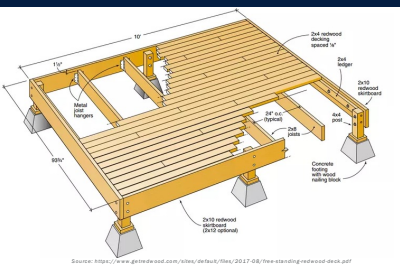
47

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.

48

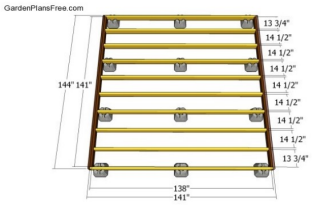
Does This Comply?



Source: https://www.getredwood.com/sites/default/files/2017-08/free-standing-redwood-deck.pdf

49

Does This Comply?



Building the deck frame

Source: https://gardenplansfree.com/furniture/deck-plans-free/

50

Does This Comply?

Source: https://www.skipintras.com/

51

Other Deck Types

Non-Ledger

Ledger Board

52

52

Free-Standing Deck Higher Than 20" Above Grade – Outside of IRC

53

53

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

54

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

54

Table R507.5 Deck Beam Span Lengths

TABLE R507.5 DECK BEAM SPAN LENGTHS[a, b, f] (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 × 6	6-11	4-0	3-7	3-3	3-0	2-10	2-8
	1 – 2 × 8	9-1	5-1	4-7	4-2	2-10	3-7	3-5
	1 – 2 × 10	7-0	6-0	5-5	4-11	4-7	4-3	4-0
	1 – 2 × 12	8-3	7-1	6-4	5-10	5-5	5-0	4-9
	2 – 2 × 6	6-11	5-11	5-4	4-10	4-6	4-3	4-0
	2 – 2 × 8	8-9	7-7	6-9	6-2	5-9	5-4	5-0
	2 – 2 × 10	10-4	9-0	8-0	7-4	6-9	6-4	6-0
	2 – 2 × 12	12-2	10-7	9-5	8-7	8-0	7-6	7-0
	3 – 2 × 6	8-2	7-0	6-8	6-1	5-8	5-3	5-0
	3 – 2 × 8	10-10	9-6	8-6	7-9	7-2	6-8	6-4
	3 – 2 × 10	13-8	11-3	10-0	9-2	8-6	7-11	7-6
	3 – 2 × 12	15-3	13-3	11-10	10-9	10-0	9-4	8-10

For SI: 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, live load = 40 psf, dead load = 10 psf, L/Δ = 360 at main span, L/Δ = 180 at cantilever with a 220-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's span divided by 4.

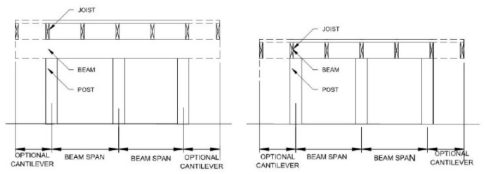
55

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

PHRC

55

Figure R507.5 Deck Beam Spans



DROPPED BEAM FLUSH BEAM

FIGURE R507.5TYPICAL DECK BEAM SPANS

56

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

PHRC

56

Deck Post to Beam Design

- **R507.5.1 Deck Beam Bearing: ... W**here multiple-span beams bear on intermediate posts, each ply must have full bearing on the post in accordance with Figures R507.5.1(1) and R507.5.1(2).
- R507.5.2 Deck Beam Connection to Supports: Deck beams shall be attached to supports in a manner capable of transferring vertical loads and resisting horizontal displacement. Deck beam connections to wood posts shall be in accordance with Figures R507.5.1(1) and R507.5.1(2). Manufactured post-to-beam connectors shall be sized for the post and beam sizes. Bolts shall have washers under the head and nut.

57

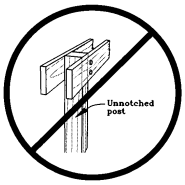
Source: International Code Council (ICC), (2017), 2018 International Residential Code, Country Club Hill, Ill.

PHRC

57

Bolted connections?

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



58

58

Deck Post to Beam Design – R507.5.1 (1)

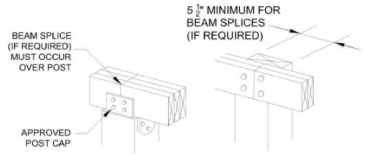


FIGURE R507.5.1(1)DECK BEAM TO DECK POST

59

59

Deck Post to Beam Design – R507.5.1 (2)

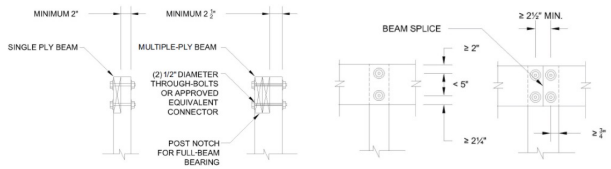
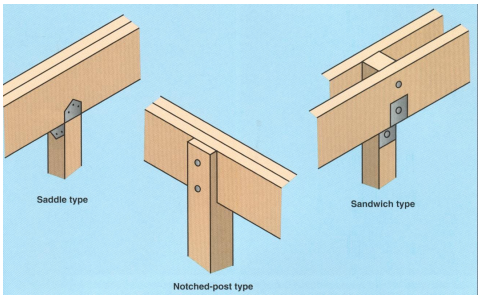


FIGURE R507.5.1(2)NOTCHED POST-TO-BEAM CONNECTION

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

60

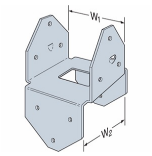
60

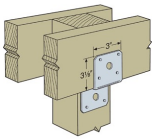


61

61

Deck Post to Beam Design - options





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

62

62

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, Ill.

63

63

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]
1¼-inch-thick wood	16 inches	12 inches
2-inch-thick wood	24 inches	16 inches
Plastic composite	In accordance with Section R507.2	In accordance with Section R507.2

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 degree = 0.01745 rad.

a. Maximum angle of 45 degrees from perpendicular for wood deck boards.

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

64

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

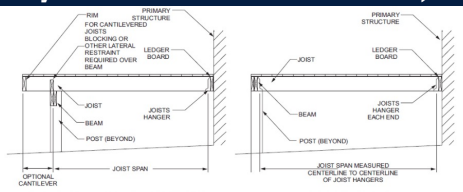


Figure R507.6
Typical Deck Joist Spans

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

65

65

Deck Joist Design (Non-Ledger)

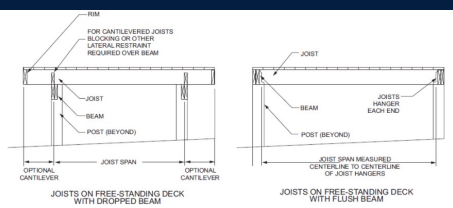


Figure R507.6
Typical Deck Joist Spans

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

66

66

Deck Joist Design

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

SPECIES[a]	SIZE	ALLOWABLE JOIST SPAN[b] SPACING OF DECK JOISTS (inches)			MAXIMUM CANTILEVER[c, f] SPACING OF DECK JOISTS WITH CANTILEVERS[d] (inches)		
		12	16	24	12	16	24
Southern pine	2 × 6	9-11	9-0	7-7	1-3	1-4	1-6
	2 × 8	13-1	11-10	9-8	2-1	2-3	2-5
	2 × 10	16-2	14-0	11-5	3-4	3-6	2-10
	2 × 12	18-0	16-6	13-6	4-6	4-2	3-4
Douglas fir-larch[e], hem-fir[e] spruce-pine-fir[e]	2 × 6	9-6	8-8	7-2	1-2	1-3	1-5
	2 × 8	12-6	11-1	9-1	1-11	2-1	2-3
	2 × 10	15-8	13-7	11-1	3-1	3-5	2-9
	2 × 12	18-0	15-9	12-10	4-6	3-11	3-3
Redwood, western cedars, ponderosa pine[e], red pine[e]	2 × 6	8-10	8-0	7-0	1-0	1-1	1-2
	2 × 8	11-8	10-7	8-8	1-8	1-10	2-0
	2 × 10	14-11	13-0	10-7	2-6	2-10	2-6
	2 × 12	17-5	15-1	12-4	3-10	3-9	3-1

For SI: inch × 25.4 mm, 1 foot × 304.8 mm, 1 pound per square foot × 0.0479 kPa, 1 pound × 0.454 kg.

a. No. 2 grade with wet service factor.
b. Ground snow load, live load = 40 psf, dead load = 10 psf, L/Δ = 360.
c. Ground snow load, live load = 40 psf, dead load = 10 psf, L/Δ = 360 at main span, L/Δ = 180 at cantilever with a 220-pound point load applied to end.
d. Includes bracing factor.
e. Northern species with no incising factor.
f. Cantilevered spans not exceeding the nominal depth of the joist are permitted.

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

67

Cantilever

68

68

Balcony

Townhouse. 15 Railroad Ave, North Reading. Photo credits to Anthony DiCesare of JR Associates.

Source: https://www.joanbissdorf.com/blog/2019/8/14/difference-between-single-family-condo-multi-family-townhouse

69

Cantilever Spans for Exterior Balconies – R502.3.3(2)

TABLE R502.3.3(2) CANTILEVER SPANS FOR FLOOR JOISTS SUPPORTING EXTERIOR BALCONY[a, b, e, f]

MEMBER SIZE	SPACING	MAXIMUM CANTILEVER SPAN (uplift force at backspan support in lbs.)[c, d] Ground Snow Load		
		≤ 30 psf	50 psf	70 psf
2 × 8	12"	42" (139)	39" (156)	34" (165)
2 × 8	16"	36" (151)	34" (171)	29" (180)
2 × 10	12"	61" (164)	57" (189)	49" (201)
2 × 10	16"	53" (180)	49" (208)	42" (220)
2 × 10	24"	43" (212)	40" (241)	34" (255)
2 × 12	16"	72" (228)	67" (260)	57" (268)
2 × 12	24"	58" (279)	54" (319)	47" (330)

For SI: 1 inch = 25.4 mm, 1 pound per square foot = 0.0479 kPa.

a. Spans are based on No. 2 Grade lumber of Douglas fir-larch, hem-fir, and spruce-pine-fir for repetitive (three or more) members. No. 1 or better shall be used for Southern pine.

b. Ratio of backspan to cantilever span shall be not less than 2:1.

c. Cantilever spans not exceeding the nominal depth of the backspan joist are permitted when full dead and live load is provided at the backspan support.

d. Uplift force is for a backspan to cantilever span ratio of 2:1. Tabulated uplift values are permitted to be reduced by multiplying by a factor equal to 2 divided by the actual backspan ratio provided (2/backspan ratio).

e. A full-depth rim joist shall be provided at the unsupported end of the cantilever joists. Solid blocking shall be provided at the supported end. Where the cantilever length is 24 inches or less and the building is assigned to Seismic Design Category A, B or C, solid blocking at the support for the cantilever shall not be required.

f. Linear interpolation shall be permitted for ground snow loads other than shown.

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

70

70

Bearing for Joists – R507.6.1

- **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
- **Joists framing from opposite sides over a bearing support shall lap a minimum of 3" and shall be nailed together with a minimum three 10d face nails.**
- **Joist framing into the side of a wood girder shall be supported by approved framing anchors or on ledger strips ≥ nominal 2x2.**

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

71

71

Joist Trimmers – R502.10

- **Framing of openings.**
  - Shall be framed with a header and trimmer joists
  - Header joist may be a single member if span does not exceed 4'-0"
  - Single trimmer joist may carry a single header joist as long as header is within 3'-0" of trimmer bearing
  - When header joist exceeds 4'-0", both header and trimmer joists are to be doubled
  - Approved joist hangers are to be used in all locations

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

72

72

Lateral Restraint at Support – R507.6.2

- Joist ends and bearing locations shall be provided with lateral restraint to prevent rotation
  - Joist hangers
  - Blocking
  - Rim Joist
- Blocking shall equal not less than 60% of the joist depth

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

73

73

Cutting, Notching and Drilling – R502.8

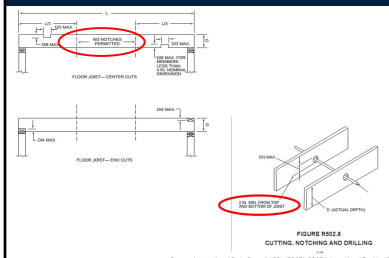


FIGURE R502.8
CUTTING, NOTCHING AND DRILLING

Floor Joist	Drilling & Notching			
	D	D/3	D/4	D/6
2x6	5 1/2	1 7/8	1 3/8	15/16
2x8	7 1/4	2 7/16	1 7/8	1 1/4
2x10	9 1/4	3 1/16	2 3/8	1 1/2
2x12	11 1/4	3 3/4	2 7/8	1 7/8

DOES NOT APPLY TO ENGINEERED PRODUCTS !

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

74

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), 2018 International Residential Code, Country Club Hill, Ill.

75

75

Deck Ledger Board Connection

- **R507.9.1 Vertical supports.** Vertical loads shall be transferred to band joists with ledgers in accordance with this section.
  - **R507.9.1.3 Ledger to band joist details.**

    Fasteners used in deck ledger connections in accordance with Table R507.9.1.3(1) shall be hot-dipped galvanized or stainless steel and shall be installed in accordance with Table R507.9.1.3(2) and Figures R507.9.1.3(1) and R507.9.1.3(2).
  - **R507.9.1.4 Alternate ledger details.**

    Alternate framing configurations supporting a ledger constructed to meet the load requirements of Section R301.5 shall be permitted.

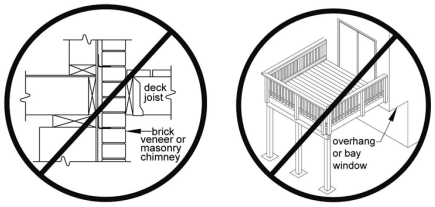
76

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

PHRC

76

Deck Attachment "Don'ts"



courtesy, American Wood Council, Leesburg, VA

77

PHRC

77

78

PHRC

78

79

Deck Ledger Board Connection

TABLE R507.9.1.3(1) DECK LEDGER CONNECTION TO BAND JOIST[a, b] (Deck live load = 40 psf, deck dead load = 10 psf, snow load ≤ 40 psf)

CONNECTION DETAILS	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'
	On-center spacing of fasteners						
½-inch diameter lag screw with ½-inch maximum sheathing[c, d]	30	23	18	15	13	11	10
½-inch diameter bolt with ½-inch maximum sheathing[c]	36	36	34	29	24	21	19
⅝-inch diameter bolt with 1-inch maximum sheathing[c]	36	36	29	24	21	18	16

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound per square foot = 0.0479 kPa.

a. Ledgers shall be flashed in accordance with Section R703.4 to prevent water from contacting the house band joist.
b. Snow load shall not be assumed to act concurrently with live load.
c. The tip of the lag screw shall fully extend beyond the inside face of the band joist.
d. Sheathing shall be wood structural panel or solid sawn lumber.
e. 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 R507.9.1.3(2) PLACEMENT OF LAG SCREWS AND BOLTS IN DECK LEDGERS AND BAND JOISTS

MINIMUM END AND EDGE DISTANCES AND SPACING BETWEEN ROWS				
	TOP EDGE	BOTTOM EDGE	ENDS	ROW SPACING
Ledger[a]	2 inches[b]	¾ inch	2 inches[b]	1⅝ inches[b]
Band Joist[a]	½ inch	2 inches	2 inches[b]	1⅝ inches[b]

For SI: 1 inch = 25.4 mm.

a. Lag screws or bolts shall be staggered from the top to the bottom along the horizontal run of the deck ledger in accordance with Figure R507.9.1.3(1).
b. Maximum 5 inches.
c. For engineered rim joists, the manufacturer's recommendations shall govern.
d. The minimum distance from bottom row of lag screws or bolts to the top edge of the ledger shall be in accordance with Figure R507.9.1.3(1).

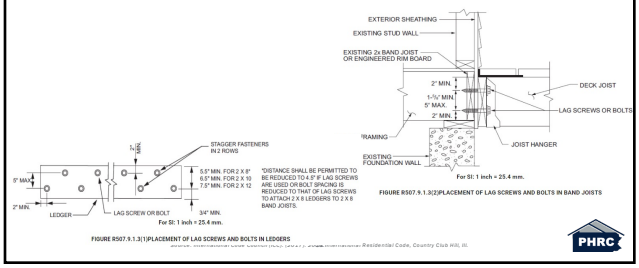
80

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

PHRC

80

Ledger Attachment Detail



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

PHRC

81

Deck Attachment Situations

House Condition	Deck Type	
	Free Standing	Ledger Board
House Floor System		
Solid Sawn Joists	Yes	Yes
TJI Floor Framing	Yes	?
Open Web Trusses	Yes	?
Brick Veneer	Yes	No
Cantilever Floor	Yes	No
Deck attached to foundation	Yes	Yes

PHRC

82

Manufactured Homes

- **The Model Installation Standards at 24 CFR Part 3285.903(c) says:**
  - ***Installation of an add-on or attached accessory building or structure.*** Each attached accessory building or structure or add-on is designed to support all of its own live and dead loads, unless the attached accessory building or structure is otherwise included in the installation instructions or designed by a registered professional engineer or registered architect in accordance with this part.
- **To meet this requirement, the manufacturer installation manuals provide this language:**
  - "Construct site-built structures to be structurally independent unless provided for in the design of the home (instructions will be provided by the home manufacturer)".

83

PHRC

83

What Happens if you Can't Confirm Positive Anchoring to the Primary Structure?

- **Free-standing Deck or Non-ledger Deck**
  - Guidance in the IRC?
  - Guidance in the DCA6-15? (non-ledger deck)
  - Engineered design?
- **Standardize your offerings**

84

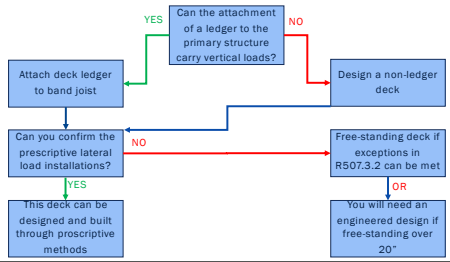
PHRC

84

85

86

Prescriptive or Engineered Design



87

What Happens if you Can't Confirm Positive Anchoring to the Primary Structure?

- **Free-standing / non-ledger Deck**
  - Guidance in the IRC R507.3.2? Less than 20"/no post/no beam/less than 200 sq.ft.
  - Non-ledger deck from IRC in R507.6?
  - Engineered design? Free-standing greater than 20"/posts/beam/greater than 200 sq.ft.
- **Standardize your offerings**

88

88

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 Hill, Ill.

89

89

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**

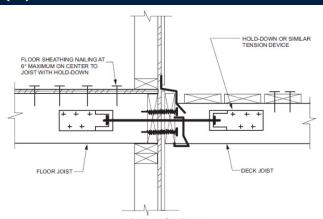
Or

- **Other method approved by the code official?**

90

90

Deck Lateral Load Connection – R507.9.2(1)



For SI: 1 inch = 25.4 mm.

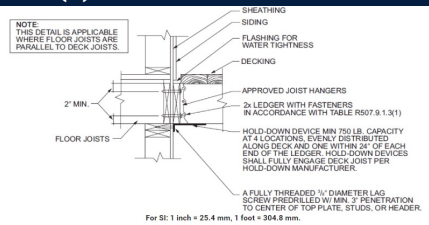
FIGURE R507.9.2(1)DECK ATTACHMENT FOR LATERAL LOADS

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

91

91

Deck Lateral Load Connection – R507.9.2(2)



For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

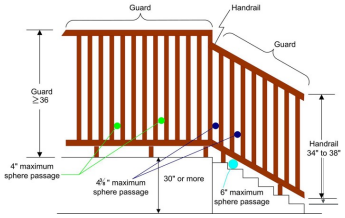
FIGURE R507.9.2(2)DECK ATTACHMENT FOR LATERAL LOADS

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

92

92

Handrails and Guards – R311.7.8 & R312.1-R312.3



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

93

93

Guards – R312

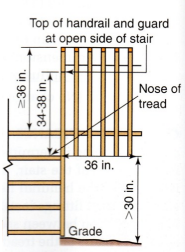
- **Vertical measurement:**
  - 30″ or greater to grade or floor below to determine requirement for a guard
  - Measurement shall be made to all points within 36″ horizontally of open side

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

94

94

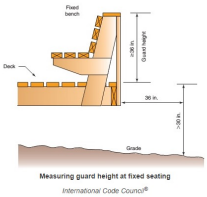
Guards



95

Guard Height - R312.1.2

- **New requirements remove the need to have an additional 36" height above fixed seating**



Measuring guard height at fixed seating

International Code Council®

96

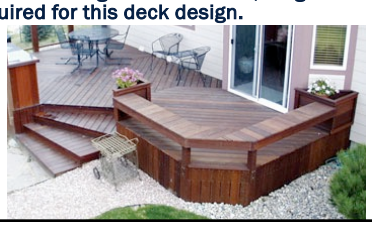
Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.
Image Source: International Code Council. (2018). 2018 Significant Changes to the IRC, ICC, Country Club Hill, Ill.

96

97

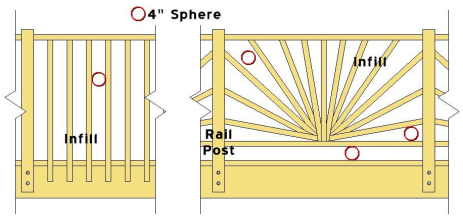
Guards

The surface of this deck is not more than 30 inches above grade. Therefore, no guards are required for this deck design.



98

Maximum Openings in Rail



99

100

100

101

101

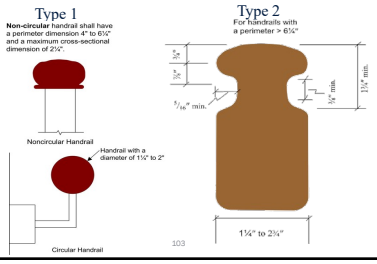
Handrails and Guards - R312.1.1

- Handrail required for 4 or more risers
- Guard required when greater than 30" from floor

102

102

Handrail Types



PHRC

103

Grip Size

PHRC

104

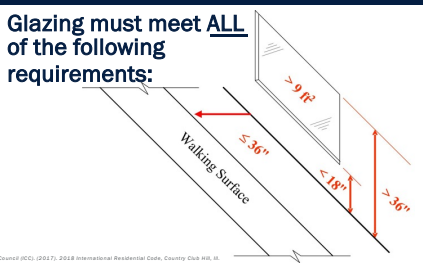
Safety Glazing Required in Hazardous Locations – R308.4

PHRC

105

Hazardous Locations – R308.4.3

Glazing must meet ALL of the following requirements:



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

PHRC

106

Hazardous Locations – R308.4.4

Glazing in Railings

Source – www.invisirail.com

PHRC

107

Hazardous Locations – R308.4.5

Glazing in enclosures for, or walls facing, hot tubs, saunas.... ...where the bottom edge of the glazing is < 60" vertically above and standing or walking surface walking surface.

- Exception: > 60" horizontally from the waters edge

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

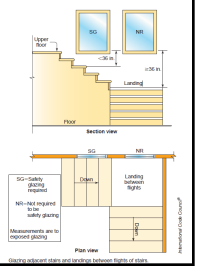
108

108

Hazardous Locations – R308.4.6

Glazing adjacent to stairways, landings or ramps within:

- < 36" horizontally from walking surface; and,
- < 36" vertically adjacent to the walking surface.

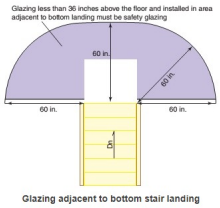


Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.
Image Source: International Code Council. (2012). 2012 Significant Changes to the IRC, ICC, Country Club Hill, Ill.
Barker, B. (2011). The Word: Safety Glazing, Part 2. Dream Home Consultants, Cary, NC.

109

Hazardous Locations – R308.4.7

Where the glazing is less than 36" above the landing and within a 60" horizontal arc les than 180 degrees from the bottom tread nosing.



Source: International Code Council (ICC). (2017). 2018 International Residential Code, Country Club Hill, Ill.
Image Source: International Code Council. (2015). 2015 Significant Changes to the IRC, ICC, Country Club Hill, Ill.

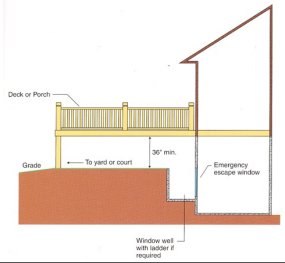
110

111

112

112

Emergency Escape – Windows Under Deck and Porches – R310.2.4



113

113

Guardrail Design (AWC DCA-6 2015 IRC Version)

https://awc.org/wp-content/uploads/2022/02/AWC-DCA62015-DeckGuide-1804.pdf

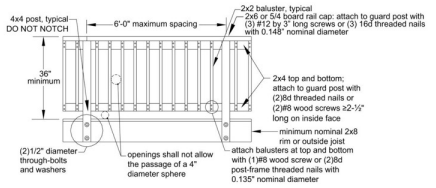
114

114

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

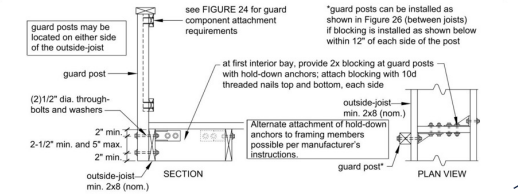
115

115

Guardrail Requirements

- Minimum 4x4 post

Figure 25. Guard Post to Outside-Joist Example.



courtesy, American Wood Council, Leesburg, VA

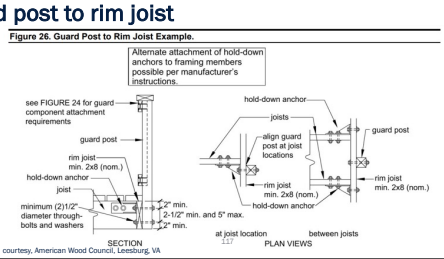
116

116

Guardrail Requirements

- Guard post to rim joist

Figure 26. Guard Post to Rim Joist Example.



courtesy, American Wood Council, Leesburg, VA

117

117

Virginia Tech Research for Guardrails

www.phrc.psu.edu

PennState College of Engineering | PENNSYLVANIA HOUSING RESEARCH CENTER

PHRC

118

VA Tech Test Program

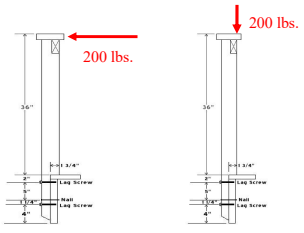
- Goal: Evaluate horizontal load capacity of common post to deck connections. Do they meet code requirements?
- Code Conforming Target Test load:
  - 200 lbs design X 2.5 safety factor = 500 lbs

119

PHRC

119

Forces Applied



120

PHRC

120

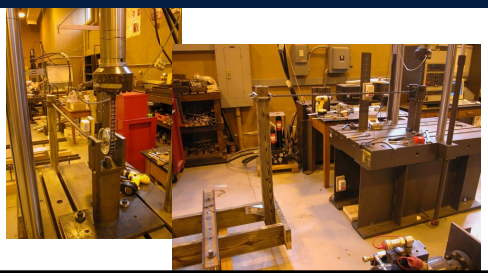
Test Parameters

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

121

121

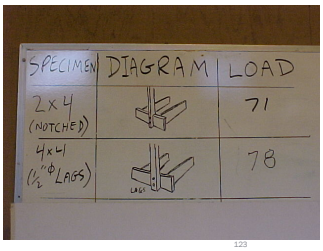
Test Set-up



122

122

Tests at VA Tech Short Course



123

123

Un-notched ½" Bolts

124

124

Results

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

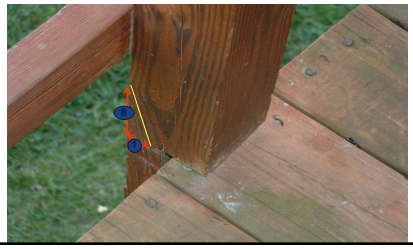
125

Notched Post, ½" Bolts

- Failed at 71 lbs

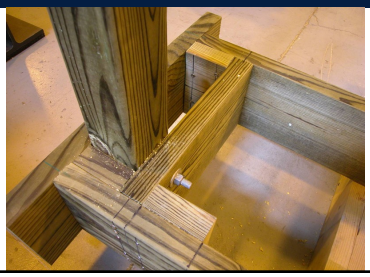
126

Notched Post, ½" Bolts



127

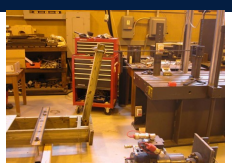
Wood Blocking



128

129

Testing Blocked Post Connection Assembly



130

Splitting Failure

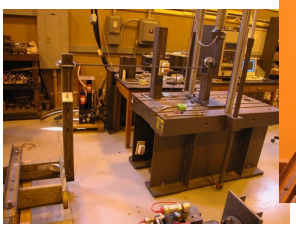
131

Shear Wall Hold-down

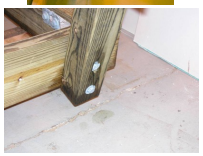
132

Passed

- Passed 200 lb force



133



134

134

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

135

Thoughts on Guards

- Never rely on nails in withdrawal.
- Guard rail post connection capacity:
  - 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.

136

136

Water Management

PennState College of Engineering | PENNSYLVANIA HOUSING RESEARCH CENTER

137

137

Water-Resistive Barrier (WRB)

- Water resistive barriers, combined with proper flashing, are intended to block liquid water from entering wall assembly.
- Objective is to channel liquid water and drain to the exterior.

138

138

Water-Resistive Barriers (WRB) – R202

- **Definition: Material behind exterior wall covering intended to resist liquid water that has penetrated behind the exterior covering from further intrusion into the exterior wall assembly.**
  - Examples:
    - #15 Felt paper (or better)
    - Grade D building paper
    - Tested & labeled house wraps
    - Some foam sheathing

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

139

139

Water-Resistive Barriers (WRB) – R703.2

- **Installation**
  - Applied over studs or sheathing on all exterior walls
  - Shall be applied horizontally with upper layer lapped over lower not less than 2" (Shingle-fashion)
  - Barrier must extend to top of walls
  - Must terminate at penetrations and appendages
  - Installed so exterior wall envelope will drain to exterior of veneer.

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

140

140

Flashing – R703.4

- **Approved corrosion-resistant flashing shall be applied shingle-fashion in a manner to prevent entry of water into the wall cavity or penetration of water to the building structural framing components. Self-adhered membranes used as flashing shall comply with AAMA 711. The flashing shall extend to the surface of the exterior wall finish. Approved corrosion-resistant flashings shall be installed at all of the following locations:**
  5. Where exterior porches, decks or stairs attach to a wall or floor assembly of wood-frame construction.

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

141

141

Flashing

- Definition: a material used to deflect bulk water or provide a capillary break.
  - Examples:
    - Flexible membrane
    - Peal & stick membrane
    - Vinyl coil stock
    - Pre-formed vinyl
    - Compatible metal

142

142

Material Properties

Material	Permeability(@90% RH)	
OSB 7/16"	2.8	
Building paper (30 lb)	3.2	
Spun bound polyolefin (SBPO)	2.99	
Extruded polystyrene	0.8	Flashing materials
Metal	0	
Butyl self-adhered flashing	< 0.5	
Mechanically attached flashing	~0	

143

143

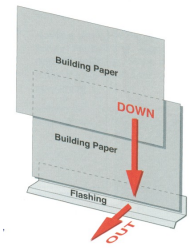
Installation of WRB

PennState College of Engineering | PENNSYLVANIA HOUSING RESEARCH CENTER

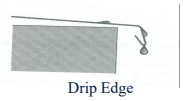
144

144

Everything is Installed in Shingle Fashion



Bulk water drains by gravity

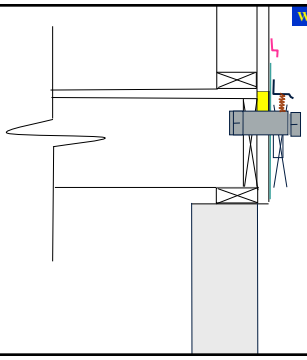


Drip Edge

145

PHRC

145



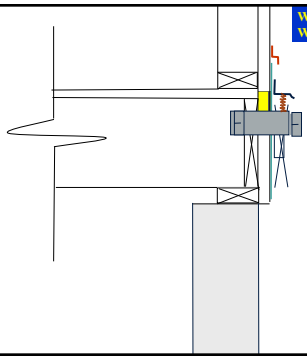
With Building Paper on Wall

1. **Remove siding**
2. **Cut building paper**
3. **Insert back flashing**
   - **Provides capillary break**
4. **Install ledger board**
5. **Install cap flashing**
   - **Extends behind building paper**

146

PHRC

146



With NO Building Paper on Wall

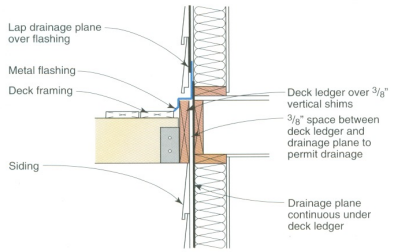
1. **Remove siding**
2. **Insert back flashing**
   - **Provides capillary break**
3. **Install ledger board**
4. **Install cap flashing**
   - **Extends behind building paper**
5. **Install strip of self adhesive flashing (counter flashing) to seal cap flashing**

147

PHRC

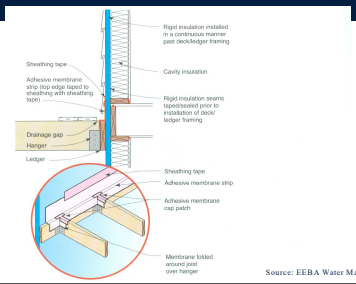
147

Oversized Ledger Board



148

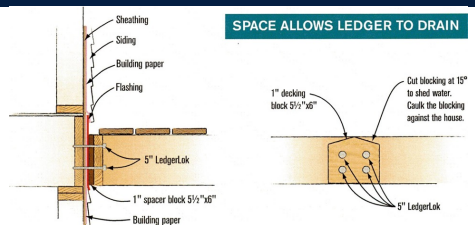
Installed Over Foam Sheathing



Source: EEBA Water Management Guide

149

Space Between Ledger and Rim Joist

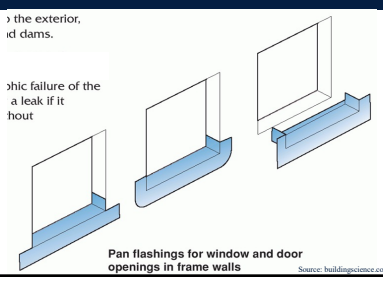


150

Source: Professional Deck Builders March/April 2007

150

Sill Flashing

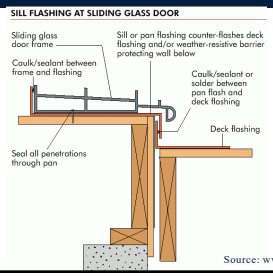


Pan flashings for window and door openings in frame walls

Source: buildingscience.com

151

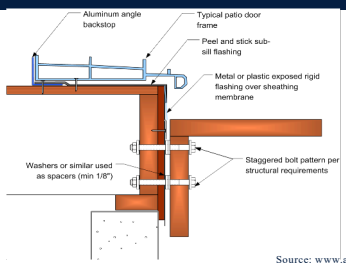
Sill Flashing



Source: www.apawood.org

152

Sill Flashing with Back-dam



Source: www.apawood.org

153

154

154

155

155

156

156

157

158

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!

PHRC

159


Questions?
www.phrc.psu.edu
160
PHRC

160


A Comprehensive Deck Design From Footings to Guards: Learning From the Past
www.phrc.psu.edu
PennState College of Engineering
PENNSYLVANIA HOUSING RESEARCH CENTER
PHRC

161