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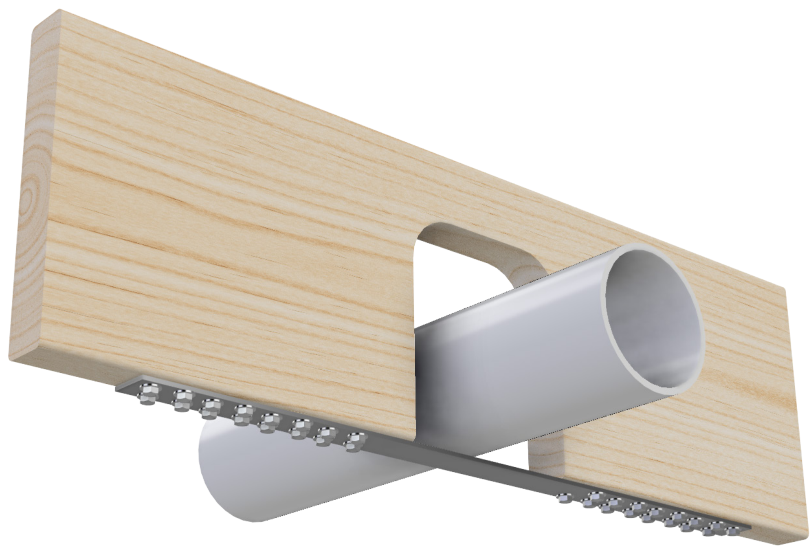
DP24/DP30 Installation Instructions

Kits includes:

DP 24/36 Repair Strap(s)
32) Fasteners
1) Pilot drill bit
1) Nut socket driver
1) Instructions



Details:

The DP24/36 Joist Repair Strap, when installed accordering to the provided instructions is designed to restore the full strength of any size dimensional lumber joist assuming the following:

- Maximum floor dead load is 12psf and maximum live load is 40psd (PSF = Pounds per square foot).

- A least 2 inches of solid material remains over the notch.

- The notch width is less than 6” for the DP24, or 12” for the DP30

- The joist spacing is 16” on center or less (if greater that 16” o.c. the joist strap is still beneficial and may restore full strength to the joist depending on the length of the joist span (Please contact us for further information).

- The joist span is in accordance with good engineering practices and/or tables provided in the buiding code.

Installation Instructions

1. Center strap over the notch and secure temporarily with tape or other method.

2. Drill a 3/16” pilot hole at each fastener location on the strap and install a screw at each end to secure strap in place.

3. Drill additional pilot screws and install remaining fastners, using a fastener in each hole.

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DESIGN CALCULATIONS – DP24 and DP30 JOIST REPAIR KIT

June 17, 2019
Revision #2

Projection Name:	Joist Repair Kit Design Calculations
Owner:	Nolan Engineering, PLLC
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Product Description
This product is designed to restore the full strength of notched or drilled floor joists assuming the joist wood species is Douglas-Fir #2 (DF) or a weaker wood species such as Spruce Pine Fir (SPF) #2; the recovery of full strength to the floor joist also assumes that the original joist span was per the 2015 International Residential Code. Also, a certain amount of material must remain above or below the notch as specified in Table 2; other assumptions are listed below.

Certain notching and drilling of floor joists are acceptable per most building codes such as the 2015 IRC. However, notching or drilling in excess of what is permitted by the code could result in weakening the joist beyond its ability to safely support the floor loads. When the joist repair strap is installed at the bottom of a notched floor joists, the strap transmits the tension load that is generated back into the remaining wood at either side of the notch. The strap is also able to restore the full strength of a drilled or otherwise similarly damage floor joist.

It should be noted that multiple steel straps on the same floor joists may be used if the straps do not overlap. Also, the straps may be used on as many adjacent floor joists as required.

Abbreviations

DF, Douglas Fir
SPF, Spruce Pine Fir
PSF, Pounds per Square Foot
PLF, Pounds per Linear Foot
PSI, Pounds per Square Inch
IRC, International Residential Code
#, Pounds

Assumptions

- Any structural benefits resulting from the attached floor sheathing is ignored, this is a conservative assumption as the attached floor sheathing will likely strengthen the floor system.

- Maximum floor joists spacing is per 2015 International Residential Code span charts.
- The floor dead load is assumed to be 10 PSF and live load to be 40 PSF.
- Typical floor joists are Spruce-Pine-Fir (SPF)#2 or Douglas-Fir (DF) #2 the analysis is bounded for by the use of DF which has higher design values
- The maximum width of the notch is limited to six inches.
- The calculations provided to demonstrate the notch repair are also applicable to repairing a hole in a joist since a hole is less structurally damaging than a notch of the same size since some wood material (although perhaps minimal) surrounds the hole adding strength which is not the case for a notch.

DESIGN CODE REFERENCES

Reference (a): National Design Specification (NDS) for Wood Construction - 2018

Reference (b): American Institute of Steel Construction (AISC) – Thirteenth Edition
Reference (c): 2015 International Residential Code (IRC).

Analysis

Per Table 4A of Reference (a) the reference design value of Douglas Fir-Larch No. 2 is 900 psi and the shear value is 180 psi. For a typical joist the adjustment factors are load duration factor, size factor and repetitive use factor. The size factors are listed in Table 1 below and are dependent on the depth of the joists.

Table 1 - Size Adjustment Factor

Member Size	Size Factor
2 x 6	1.3
2 x 8	1.2
2 x 10	1.1
2 x 12	1.0

The load duration factor used for the floor joist is 0.9 for dead and 1.0 for live load. The repetitive use factor is 1.15.

A load duration factor of 1.0 (live load) is used since this results in the highest stress, the maximum permitted bending stress in a rafter would be:

Fb = 900 x 1.0 x 1.15 x 1.3 = 1,346 psi (for a 2x6) and

Fb =900 x 1.0 x 1.15 x 1.0 = 1,035 psi (for a 2x12)

The bending stress is equal to Fb = Mc/I where M is the bending moment, c is half the depth of the member and I is the area moment of the member. Solving for the bending moment M:

M = Fb x I / c

The cross-section area moments are computed below:

I(2x6) = (1/12) x 1.5 x 5.53 = 20.8 in4 (for a 2x6)

I(2x12) = (1/12) x 1.5 x 11.253 = 178.0 in4 (for a 2x12)

The half depth of a 2 x 6 and 2 x 12 are computed below:

c(2x6) = 5.5 / 2 = 2.75 in

c(2x12) = 11.25 / 2 = 5.63 in

The bending moments are computed below:

M = 1,346 x 20.8 / 2.75 = 10,181 in # (for 2 x 6)

M = 1,035 x 178 / 5.63 = 32,723 in # (for 2 x 12)

The tension in the strap at the bottom of the notched member where the strap is installed is computed below and is equal to the bending moment divided by the depth of the member.

T = M / d

T = 10,181 in # / 5.5 in = 1,851# (for 2 x 6)

T = 32,723 in # / 11.25 in = 2,909# (for 2 x 12)

Tension in strap
Strap material is A36 with a minimum tensile strength of 36,000 psi. The strap is 1/8-inch-thick and 1.25 inches wide. The diameter of the holes are 0.25 inches. The minimum cross-sectional area is at a hole location and is calculated below.

A = 0.125 x (1.25 – 0.25) = 0.125 in2

The maximum safe tensile force in the steel strap assuming 66% of the yield strength is calculated below:

T = 0.66 x 36,000 psi x 0.125 in2 = 2,970 #

Shear in Wood
This section calculates the required depth of wood remaining above the notched for the member to have acceptable remaining shear strength. The shear strength of concern in the wood member is transverse shear stress. The formula used to calculate the transverse shear stress is provided below (Eq. x.x)

$$\sigma_V = \left(\frac{3}{2}\right)\frac{V}{A}$$ Equation (x.x)

Where V, is the end reaction in the member and “A” is the cross-sectional arear of the material remaining above the notch. Since floor joists are 1.5 inches wide, equation (x.x) can be rewritten as:

$$\sigma_V = \left(\frac{3}{2}\right)\frac{V}{1.5\ x\ d_r}$$ Equation (x.x)

Where “d_r” is the depth of the material remaining above the notch. The end reaction “V,“ is equal to half of the product of the distributed load on the floor joists, the length span of the floor joist and teh spacing as shown below.

Solving Equation x.x for the minimum depth of material remaining “d_r”, yields:

$$d_r = \left(\frac{3}{2}\right)\frac{V}{1.5\ x\ \sigma_V}$$ Equation (x.x)

V = 1.33 x Q x Span / 2

Where “Q” is the distributed load on the floor joists. The reaction at the end of the beam will be maximum when the floor joists is at its maximum span. Table 1 below lists the maximum span of Douglas Fir #2 and Spruce Pine Fir #2 Per Table R502.3.1(2) of Reference (a). The end reaction is also provided in Table 1 using equation (x.x). Per Reference (b) (NDS), the allowable transverse (parallel to grain) shear stress for D.F. # 2 is 180 psi and for SPF #2 135 psi. Equation x.x is solved for the dr for the different sized floor joists and wood species using the end reaction force and allowed sheared stress. A sample calculation for a 2x6, SPF #2 is provided below.

Maximum span of 2x6 SPF #2 per Reference (a): 9.3’

V = 1.33 x 50 PSF x 9.3’ / 2 = 309#

Table 2 – maximum floor joists spans and minimum required material remaining

Joist Size	D.F. #2 Mas Span FT	SPF #2 Mas Span FT	D.F. #2 End Reaction	SPF #2 End Reaction	D.F. #2 Min Notch Remaining in	SPF #2 Min. notch remaining in
2x6	9.8	9.3	327	310	1.8	2.3
2x8	12.8	12.3	427	410	2.4	3.0
2x10	15.6	15.4	520	513	2.9	3.8
2x12	18.1	17.8	603	593	3.4	4.4

STRENGTH OF MATERIAL REMAINING ABOVE NOTCH

The material remaining above the notch experiences axial compression from the bending moment developed in the joist and the bending moment in from the floor load. The minimum material left above the notch per Table 2 is 1.8 inches. The maximum length of the notch is 6 inches. The material remaining over the notch experiences both bending from the floor loads and axial compression from the moment developed in the joist. Therefore, the combined bending and axial loading equations of section 3.9 of reference (a) must be satisfied.

The bending moment in the material remaining above the notch is calculated below, using a dead weight of 10 PSF and a live load of 40 PSF.

M = (QxL2) / 8

Where Q, is the distributed load adjusted for joist spacing of 16” = (10PSF + 40PSF) x 1.33’ = 66.67 PLF. “L,” is the length of the notch (0.5’).

M = (66.67 x 0.52) / 8 = 2.1 ft #

SPF has a lower minimum modulus of elasticity compared to DF and this value is therefore used in the calculations.

The bending stress in the material remaining above the notch is calculated below.

fb1 = MC / I

Where: “M” is the bending moment calculated above, “C” is half the depth of the material remaining above the notch (1.8 / 2 = 0.9”) and “I” is the section modulus of the material remaining above the notch as calculated below.

I = (1/12) x b x d13 = (1/12) x 1.5 x 1.83 = 0.73 in^4

fb1 = 2.1 ft # x 0.9” / 0.73 in4 x (12”/ft) = 31 psi

Emin = 510,000 psi (SPF 2)

The minimum dimensions of the material remaining above the notch are provided below.

d1 = 1.8” (wide face dimension

d2 = 1.5” (narrow face dimension)

The section 3.9 equations from reference (a) that must be satisfied are provided below.

$$\left[\frac{f_c}{F'_c}\right]^2 + \frac{f_{b1}}{F'_{b1}\left[1 - \left(\frac{f_c}{F_{cE1}}\right)\right]} + \frac{f_{b2}}{F'_{b2}\left[1 - \left(\frac{f_c}{F_{cE2}}\right) - \left(\frac{f_{b1}}{F_{bE}}\right)^2\right]} \leq 1.0$$

And:

$$\frac{f_c}{F_{cE2}} + \left(\frac{f_{b1}}{F_{bE}}\right)^2 < 1.0$$

Where:

fb1 = actual edgewise bending stress (bending load applied to narrow face of member), psi = 31 psi as calculated above.

fb2 = actual flatwise bending stress (bending load applied to wide face of member), psi = 0 since no load applied in this direction.

Equation 3.9-3 is re-written below with fb2 set equal to zero since there is no flatwise bending stress.

$$\left[\frac{f_c}{F'_c}\right]^2 + \frac{f_{b1}}{F'_{b1}\left[1 - \left(\frac{f_c}{F_{cE1}}\right)\right]} \leq 1.0$$

$$f_c < F_{cE1} = \frac{0.822\ E'_{min}}{(l_{e1}/d_1)^2}$$

E’min = 1.0 x Emin = 510,000psi since no relevant adjustment factors apply.

fc, is the actually compression stress in the member. The maximum compressive stress in the material remaining above the notch is 2,909# divided by the cross-sectional area of the material remaining above the notch as calculated below.

f_c = 2,909# / (1.5” x 1.8”) = 1,077 psi

$$f_c < F_{cE1} = \frac{0.822\ (510{,}000psi)}{(6"/1.8")^2} = 37{,}730psi$$

1,077 psi < 37,730 psi

$$f_c < F_{cE2} = \frac{0.822\ (510{,}000psi)}{(6"/1.5")^2} = 26{,}201psi$$

1,077 psi < 26,201 psi

$\mathrm{F_{bE}} = \frac{1.20\ \mathrm{E'_{min}}}{\mathrm{R_B^2}}$ Equation 3.3-5 or reference (a)

$$R_B = \sqrt{\frac{l_e d}{b^2}} = \sqrt{\frac{6"(1.8")}{1.5"^2}} = 2.2$$

$\mathrm{F_{bE}} = \frac{1.20\ (510{,}000\mathrm{psi})}{2.2^2}$=126,446 psi

$$\left[\frac{1077psi}{1150psi}\right]^2 + \frac{31psi}{875psi(1-(\frac{1077psi}{37730psi})} = 0.97 < 1.0$$

$$\frac{1077psi}{26201psi} + \left(\frac{31psi}{126{,}446psi}\right)^2 = 0.04 < 1.0$$

The reference design value bending stress, Fb for SPF is 875 psi per table 4 of reference (a).

There are no adjustment factors that apply, therefore, Fb’ = Fb = 875 psi.

The reference design value compressive stress parallel to the grain, Fc for SPF is 1150 psi per table 4 of reference (a).

There are no adjustment factors that apply, therefore, Fc’ = Fc = 1150 psi.

The reference (a) combined bending and axial load eqautions are calculated below.

$$\left[\frac{1077psi}{1150psi}\right]^2 + \frac{31psi}{875psi(1-(\frac{1077psi}{37730psi})} = 0.97 < 1.0$$

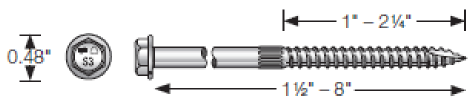
$$\frac{1077psi}{26201psi} + \left(\frac{31psi}{126{,}446psi}\right)^2 = 0.04 < 1.0$$

Both equations are less than unity, therefore, the material remaining above the notch is acceptable for bending and the axial load.

Strength of Fastener with Steel Side Plate

Group Fasteners

The fasteners used are Simpson Strong-Tie SDS25212 which are ¼" diameter screws that are 2.5 inches in length. Per Figure 1 below, the shear strength for the 10 gauge or greater steel side plate is 420# for Douglas-Fir and 300# for Spruce-Pine-Fir. The steel strap is equivalent to 11 gauge. There are 10 screws used in each end of the strap, therefore the strength provided by the screws is 10 x 420# = 4,200# for DF and 10 x 300# = 3000# for SPF which is greater than the 2,970# required.



Some straps may be manufactured with 16 - ¼" diameter x 1.5" long screws per side. These screws are acceptable for 180# in SPF and 250# for DF. These screws can therefore withstand a tension load of 2880# for SPF joists and 4000# for DF joists. Note that the tension maximum force in a SPF joists at its maximum capacity is less than 2880#.

Table 3 – Simpson Strong-Tie (See Page 329 of Simpson Technical Information)

Size (in.)	Thread Length (in.)	Coating Material	Model No	DF/SP Allowable Shear (lb)			SPF/HF Allowable Loads (lb)		
				Steel Side Pplate Thickness, mil (ga)			Steel Side Plate Shear, mil (ga)		
				54 (16)	68 and 97 (14 and 12)	123 (10 or greater)	54 (16)	68 and 97 (14 and 12)	123 (10 or greater)
1/4" x 1 1/2"	1	Double-barrier coating	SDS25112	2501	250	250	180	180	180

CONCLUSION

The joist repair strap has been designed to restore the strength of any size floor joists of either SPF #2 or DF #2 with spans up to the maximum allowed per the span tables provided in the 2015 International Residential Code. The following items were demonstrated to be structurally acceptable by analysis or using tables.

- Ability of the strap to withstand the tension force.
- Ability of the screws to withstand the tension force.
- The acceptability in the material remaining above the notch to support both the floor load and the compression developed from the bending moment in the joist simultaneously.
- The ability of the material remaining above the notch to support the shear load developed in the joist.

I certify that when properly installed, the joist repair strap will restore the full intended strength of floor joists within the assumptions and limitations provided herein.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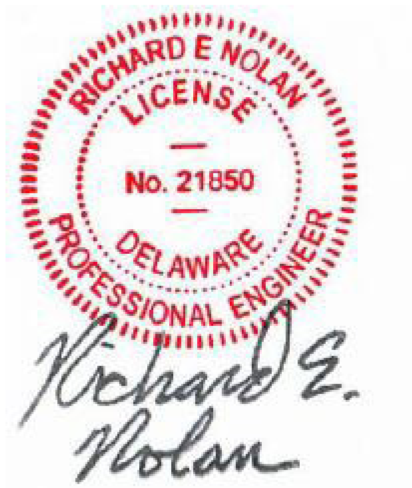
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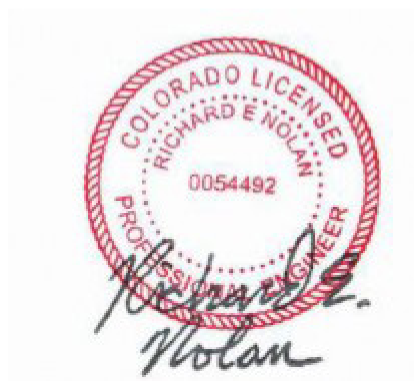
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