Detailed information on Nordic Lam Split Analyser

References:

Scope:

This software is meant to evaluate the residual resistance of a glulam beam with a circular opening subject to uniform loads. If a point load is much higher than the uniform load, there should be a concern with the tension perpendicular to grain equations. Literature doesn't give a lot of information on how to increase the tension force for punctual loading near the hole.

In the event of a design that fails in tension perpendicular to fibre resistance, there are options to reinforce the beam using ASSY screws or 3/4" CSP with structural glue.

Beam installation:

Beams require restraint against lateral displacement and rotation at points of bearing (O86 7.5.6.3.1).

Standard:

Nordic Lam products are listed in CCMC evaluation report 13216-R.

CSA & Euro Method

Bending:
For the bending calculations, the CSA O86-14 equation was used adding a factor for the missing section.
We multiply the bending resistance for a section without holes by (h-hd)/h where h is the beam depth and hd the round hole diameter.

Shear:
Shear calculations were done using CSA O86-14 shear calculation using 7.5.7.2 (b). For the Ag value, we used a reduced section based on the remaining area.

Note: There's an option to use the results from equation (a) This method is to be confirmed by the engineering department.

Tension:
Ftp: To calculate the tension force perpendicular to wood fibres we used the bending force in Nmm instead of Nm.

The German Eurocode annex DIN 1052 was used to determine the tension perpendicular to wood fibres for beams with hd/h < 0.3.

The ANALYSIS AND DESIGN OF LAMINATED VENEER LUMBER BEAMS WITH HOLES, by Manoochehr Ardalany, University of Canterbury, September 2012 was used for its equation 7.14 for tension perpendicular to grain calculations resulting from bending forces near a round opening for beams with hd/h > = 0.3

$$F_{t,M} = \frac{3}{4}\frac{M h_d^3 (h_d + h)}{h^3 (h * h_d + h^2 + h_d^2)} \qquad (7.14)$$

Round hole geometric notes

- Holes under 2" can be ignored.
- Multiple holes can be inscribed in a larger hole to be analyzed as one.
- The maximum quantity of holes greater than 2” per beam is, 3
- The space between two holes edges must be at least twice the diameter of the largest of the two holes.
- The minimum distance from the edge of a hole and the end of a beam is one time the depth of the beam.
- The minimum distance from the edge of a hole and a notch is one and a half time the depth of the beam.
- The maximum tolerated hole vertical offset from the center of the beam is 15% of the depth up or down.

Notice to designer

- Increase for larger beam sections.
  (this adds a $(h/400mm)^{1/2}$ factor to the tension resistance.)
  The ANALYSIS AND DESIGN OF LAMINATED VENEER LUMBER BEAMS WITH HOLES, Chapter 8 section 8.5.

- US (NDS) version will be done on request in the futur.

- The KD and KH are only for beam analysis results. Repairs require normal duration factors and dry humidity conditions.

- The Vf is used to calculate tension perpendicular to grain. If equation 7.5.7.2 (a) is used, it’s still required to input a Vf.

- There is no hole to beam depth restriction other than the minimum number of lamellae. Note that beyond 30%, the truss model equation is used. (7.14)

- It’s possible to modify the software to restrict user inputs and hole to depth ratio on request.

Analysis calculations:

These are notes taken from the actual code version 6.3. Later code versions might have slight variations.

Limits

Maxh=2401
Maxb=366

Evaluate the beam residual bending resistance

hd:	Hole diameter
h:	Beam height
CMr:	is the Corrected Allowed bending

Note: there is a concern for bending if there are less than four lamellas left.
Nordic Lam can have lamellas up to 2" depth. We would try and maintain at least one top and one bottom lamella intact (4" or 101.6mm).

```
if hd <= (h-101.6):
    try:
        CMr = (h-hd)/h*Mr
        Eval = Mf/CMr
    except:
        CMr = 0
        Eval = 99999
else:
        messagebox.showinfo("Bending Calculation Error Message","Please correct the input
        value: [hd] (hd <= (h-4in))")
        print('Less than minimum top and bottom lamella left (4" (101.6mm))')
        print('repair for tension reinforcement parallel and perpendicular to grain')
        CMr = 0
        Eval = 99999
```

Evaluate the Beam residual shear resistance

Nordic-Lam Type based on CSA 086-14

h: member depth mm
b: member width mm (Input single ply dimension)
Vf: Maximum Longitudinal shear at hole location (b) N
hd: Hole depth mm
KSv: Always in dry conditions: 1.00
KT: Always untreated: 1.00
ShearA: Is the shear (a) equation used.

for single element or built-up beam in Clauses 7.5.7.2(b), 7.5.7.3, and 7.5.7.4.1,
the effect of all loads acting within a distance from a support equal to the depth of the member need not be taken into account.
As an alternative for beams less than 2.0 m^3 in volume, the factored shear resistance may be calculated using the equation in Item (b).
As long as the dimensions are restricted to 3.5" x 16" maximum cross section, the < 2.0m^3 will be met.

(An updated shear resistance with equation (a) is implemented if required.)

```
    if h <= Maxh and b <= Maxb:
        # Use equation (a) or (b) methodes
        if ShearA == 1 and Wf*Wr > 0:
            print('Shear equation values from: 7.5.7.2 (a)')
            CShearRes = Wr * (h-hd)/h
            Eval = Wf/CShearRes
            Fv = 0

        elif ShearA == 0:
        #Equation 7.5.7.2 (b) Simple shear equation
            Phi = 0.9
            fv = float(tbNL.GenDict()[NLType]['Fvx']) #This is the fv pulled from the spec file
            Fv = fv*(KD*KH*1*1)

            #Ag = b × (h - hd) = gross cross-sectional area of member,
            Ag = b*(h-hd)
            CShearRes=Phi*Fv*2/3*Ag*Ply
            Eval=Vf/CShearRes
        else:
            CShearRes=0
            Eval=99999
            Fv=0
    else:
        messagebox.showinfo("Shear Calculation Error Message","Select valid h ("+str(h)[0:5]+")
and b ("+str(b)[0:5]+"). Max h = "+str(Maxh)+" Max b = "+str(Maxb))
        CShearRes=0
        Eval=99999
        Fv=0
```

Perpendicular to grain tension calculation

h: from 9.5" to 16" (Height), mm
If h >=17.72in (450mm): The Kt,90 will need to be calculated
hd: Hole diameter, mm
Kt90: Beam depth factor for tension perpendicular to grain resistance.

For round holes only!!!

```
    if h <= Maxh and b <= Maxb:
        if hd/h < 0.3:
            try:
                Bending_tp = 0.008*Mf/((h-hd)/2+0.15*hd)
            except:
                Bending_tp = 99999999
        else:
            Bending_tp = (3*Mf*hd**3*(hd+h))/(4*h**3*(h*hd+h**2+hd**2))
            print('Alternate Bending_tp equation used\nMore conservative then DIN 1052 equation')

        Kt90 = min(1,(450/h)**0.5) # mm
        FtpRes = float(tbNL.GenDict()[NLType]['Ftp']) * Kt90 #Get the perpendicular to grain tension
resistance from the spec file.

        Shear_tp = Vf*hd*(3*h**2-hd**2)/(4*h**3)

# FtpO is the strain in the wood section with the opening. The divider is multiplied by the number
of ply instead of deviding the forces.

        FtpO = (Shear_tp + Bending_tp)/(0.5*(0.35*hd+0.5*h)*b*Ply)
        FtpNO = Shear_tp + Bending_tp #Perpendicular tension force in N
        if h <= 400:
            Ftp = FtpO
            FtpN = FtpNO
        else:

# Apply the tension amplifier. ANALYSIS AND DESIGN OF LAMINATED VENEER LUMBER
BEAMS WITH HOLES, by Manoochehr Ardalany, University of Canterbury, September 2012
section 8.5

            Ftp = ((h/400)**0.5)*FtpO
            FtpN = ((h/400)**0.5)*FtpNO
            print('Tension strain "MPa" amplified for a beam deeper than 400mm')

        Eval = Ftp/FtpRes
        print('Shear_tp = ',Shear_tp, ' N')
        print('Bending_tp = ',Bending_tp, ' N')
    else:
        messagebox.showinfo("Perpendicular Tension Calculation Error Message","Select valid h
("+str(h)[0:5]+") and b ("+str(b)[0:5]+"). Max h = "+str(Maxh)+" Max b = "+str(Maxb))
        FtpN = 0
        FtpRes = 0
        Ftp = 0
        Eval = 99999
```

APA 700 equations

Limits

Limits:
hd <= 2/3*h

User should validate that the hole placement requirements are met.

Bending

```
if hd <= 2/3*h:
    Eval, CMr = B_Eval(Mf,Mr,hd,h)
else:
    messagebox.showinfo("APA 700 Bending Calculation Error Message","Please correct the input value: [hd] (hd <= 2/3*h)")
    CMr = 0
    Eval = 99999
```

Shear:

```
    if (hd <= 2/3*h and h <= Maxh and b <= Maxb):
        # Use equation (a) or (b) methodes
        print('Shear eq (a) :', ShearA == 1)
        Chv = ((h-hd)/h)**2
        if ShearA == 1 and Wf*Wr > 0:
            print('Shear equation values from: 7.5.7.2 (a)')
            CShearRes = Wr * Chv
            Eval = Wf/CShearRes
            Fv = 0
        else:
        #Equation 7.5.7.2 (b) Simple shear equation with Hole effect factor
            Phi = 0.9
            fv = float(tbNL.GenDict()[NLType]['Fvx'])
            Fv = fv*(KD*KH*1*1)

            #Ag = b × (h - hd) = gross cross-sectional area of member,
            Ag = b*h
            CShearRes=Phi*Fv*2/3*Ag*Chv*Ply
            Eval=Vf/CShearRes
    else:
        messagebox.showinfo("APA 700 Shear Calculation Error Message","Validate parameters: h
("+str(h)[0:5]+"), b ("
                            +str(b)[0:5]+') and [hd]' +' hd/h = '+ str(round(hd/h,2)) + "." + "\n" +
                            " Max h = "+str(Maxh)+"; Max b = "+str(Maxb) + "; (hd/h <= 2/3 [0.67])")
        CShearRes=0
        Eval=99999
        Fv=0
```

Reinforcements:

Panel Reinforcement

Plywood tension check from CSA O86-14

9.5.7 Tension parallel to panel edge

The factored tensile resistance, T_r, parallel to a panel edge shall be taken as follows:

$T_r = \phi T_p b_n$

where

ϕ = 0.95 for all plywood thicknesses and numbers of plies except 3- and 4-ply layups stressed perpendicular to face grain
= 0.60 for 3- and 4-ply plywood layups stressed perpendicular to face grain
= 0.95 for OSB

$T_p = t_p(K_D K_S K_T)$

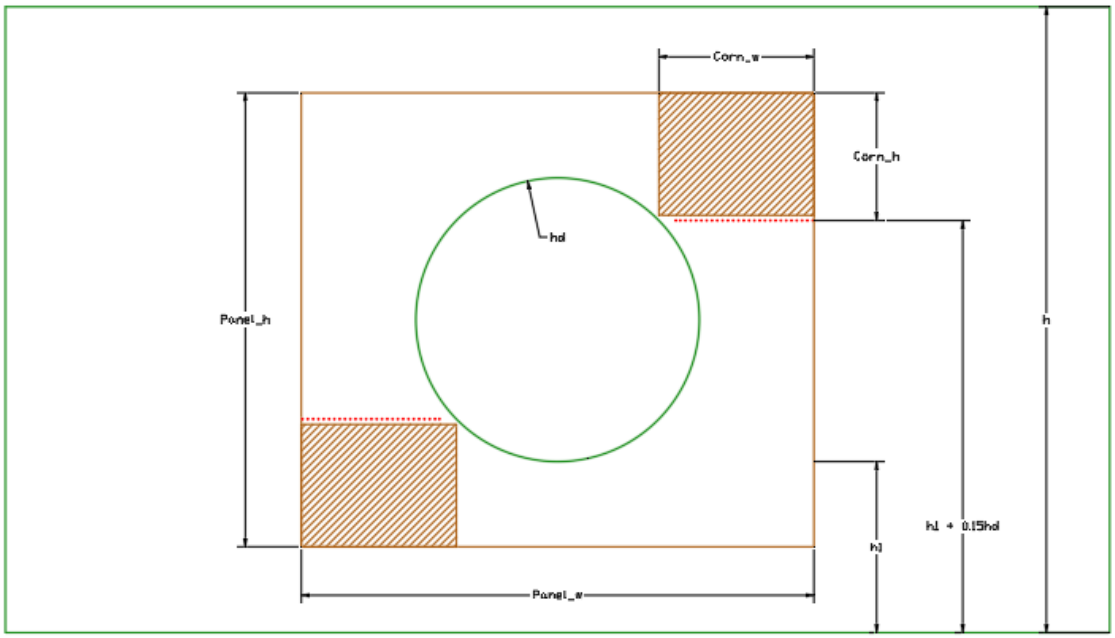
where

t_p = specified strength capacity in axial tension, N/mm (Tables 9.3A and 9.3B for plywood and Table 9.3C for OSB)

b_n = net width of panel after cutting of holes, etc., mm

The nail spacing considered is 76.2 mm
The nail row spacing considered is 38.1 mm
3/4" CSP plywood grain perpendicular to the beams span with LP… glue and 0.131 x 3.25 round head driven nail.
See spec file.

Figure 1: Glued tension shear zones for reinforcement design.



Panel reinforcement for multiple ply beams

The connection between the plies must be able to properly transfer forces from the center ply to the exterior plies. An acceptable connection between plies would be nailed and glued.

Note that the software only uses the lateral resistance of the nails in a multiply scenario to find the panel reinforcement dimension.

In single ply situation, the glue is the only fastener calculated for lateral shear resistance.

Screw Reinforcement notes

A screw length tolerance was used. It comes from the Analysis and Design of laminated Veneer lumber beams with holes. (Minimum 40 mm from screw tip to hole lower or upper edge. Minimum 50 mm from screw tip to outer edge of beam.)

There's a concern to address where screws are very long. The wood dimensional changes based on moisture will generate strains on the screw threads and can cause the wood to split and generate a hole premature splitting failure.

When the hole is offset, the tension force (Tp) is increased in the reinforcement calculations. The Tp increase equation is: $Tp = Tp * (1 + hd/h)$

There are two methods to insert screws near the hole to reinforce. It’s possible to insert screws on either side of the hole from the bottom or to insert screws on either side of the hole from different sides.

With the option same side, both screws are fastened from the bottom of the beam.

With the opposed side option, the screws are fastened from the side closest to the split area. See figure 2 and 3.

The calculations evaluate the screw edge and spacing to fit them all in one line perpendicular to the beam length.

Figure 2: Screw reinforcement from bottom side

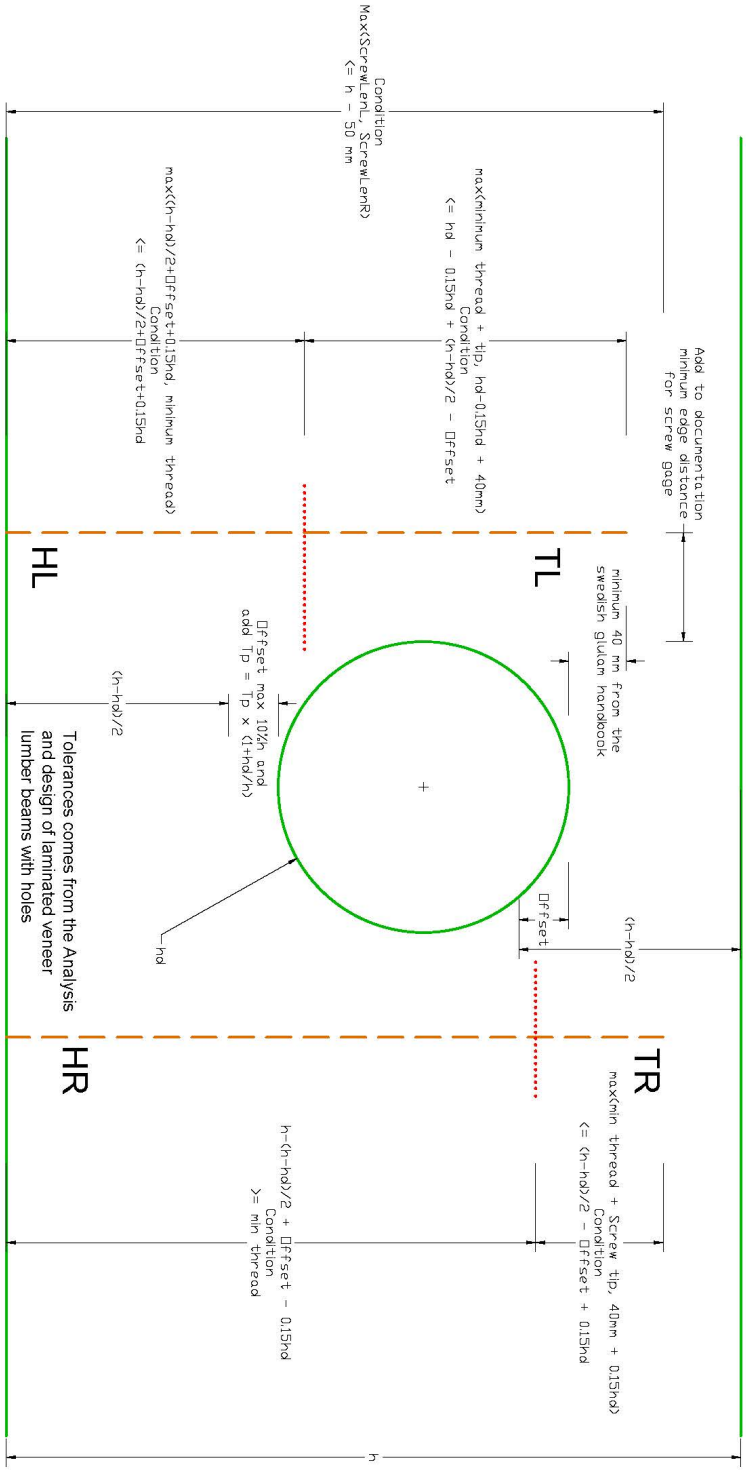
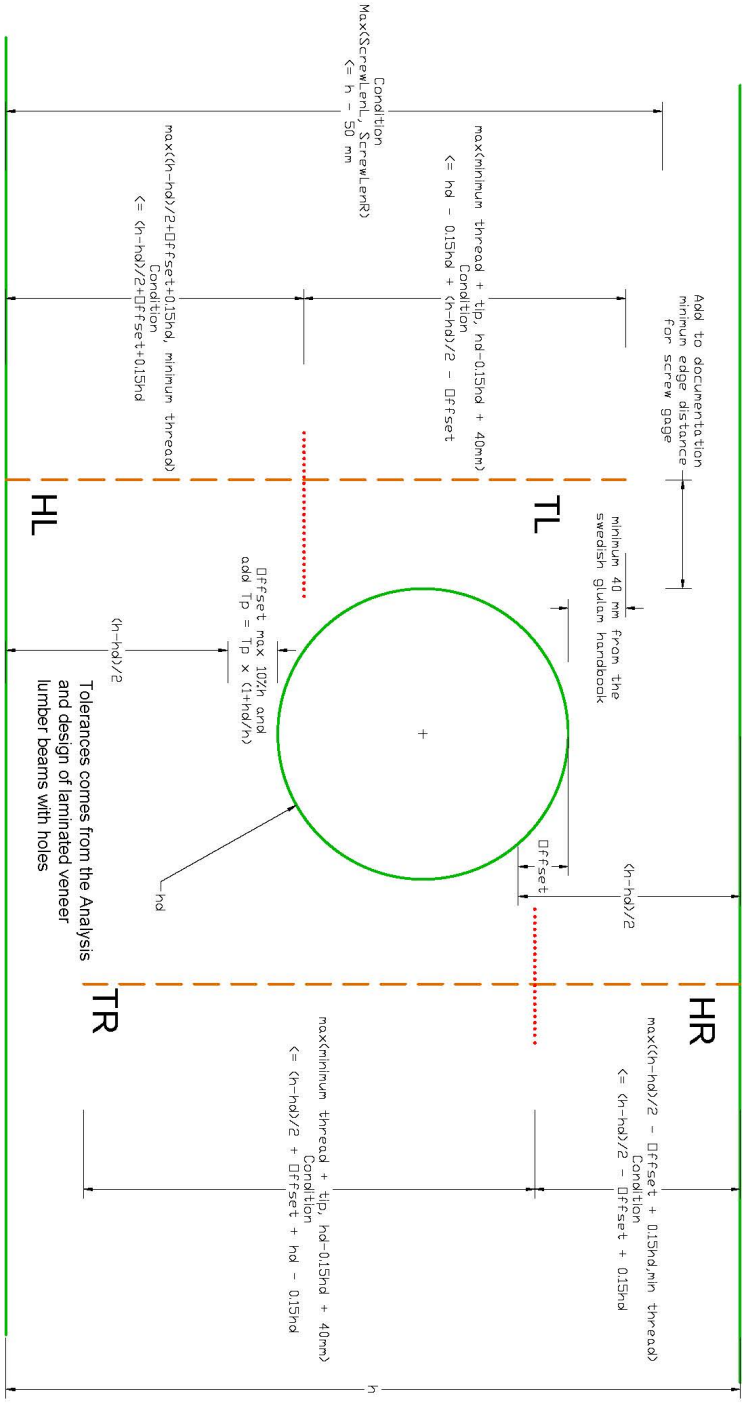


Figure 3: Screw reinforcement from opposed sides



Notes on proper glue application:

Follow structural glue application guidelines for PLPremium.

Tools Typically Required:

Utility knife, caulking gun, tool to puncture cartridge seal, spray mist water bottle.

Safety Precautions:

Wear gloves. Cured adhesive on bare skin will not come off immediately with washing and will cause skin to darken. Cured
adhesive and discolouration will come off in about 3 days.

Preparation:

Adhesive should be above be above -7°C (19°F). Surfaces must be clean and free of frost, standing water, grease, dust and
other contaminants. Pre-fit all materials and protect finished surfaces. Cut nozzle at a 45° angle to desired bead size and
puncture inner seal. Be very careful not to allow PL Premium to cure on a finished surface.

Application:

Apply adhesive to one surface of the material being bonded. Press the surfaces firmly together within 15-20 minutes. Materials
may be repositioned within 30-45 minutes after joining the surfaces. If bonding two non-porous surfaces (such as metal and
fiberglass), add water in the form of a very light or atomized spray from a spray mist water bottle to the extruded adhesive. The
repositioning time will then be reduced to less than 30 minutes. Use mechanical support for 24 hours while the adhesive cures.
Cure time is dependent upon temperature, humidity, porosity of substrate and amount of adhesive used. Low temperature and
humidity will slow cure time. When bonding EPS and XPS foam insulation, avoid cure and surface temperatures above 32°C
(90°F).

Clean-up:

Clean tools and adhesive residue immediately with mineral spirits. PL□ Premium must be removed mechanically once cured.
Solvents have little effect on cured PL Premium.

Descritpion of all terms in the reports

	Value	Units	Description
Nordic Lam Type	ES1M1	Type	This is the name of the type of glulam used based on the values in the NordicLamSpecs.xlsx file.
Ply	3	nbr	This is the number of glulam plies to consider for the inputted loads
b, Width	44.45	mm	This is a single ply thickness.
h, Depth	406.4	mm	This is the beam depth.
hd, Hole diameter	100.08	mm	This is the diameter of the round hole to be analyzed.
Method	CSA & Euro		Method used to calculate residual bending and shear resistance.
Mf, Moment force	15000	Nm	This id the bending force applied to the beam were the hole is located. Worst case Mf in the hole area. (Taken from the beam analysis by others)
Mr, Moment resistance	24000.001	Nm	This is the beams bending resistance without hole. (Taken from the beam analysis by others)
Mrr, Reduced	18089.76453	Nm	This is the bending corrected resistance.
Mf/Mrr	0.82919819	Bending	This is the bending force on bending corrected resistance for the given hole ratio.
Shear equation used	7.5.7.2 (a)		
Vf, Shear force (b)	11999.999	N	This is the beams shear force applied to the beam where the hole is located. See equation 7.5.7.2 (b) (Taken from the beam analysis by others)
Wf, Shear force (a)	26000	N	
Wr, Shear resistance (a)	50000	N	
Residual Shear Res.	37687.00787	N	This is the shear corrected resistance.
Force/Resistance	0.689892922	Shear	This is the shear force on shear corrected resistance for the given hole ratio.
KD, Load duration	1		This is the duration factor only for the beam residual resistance analysis.
KH, system factor	1		This is the system factor only for the beam residual equation (b) shear resistance analysis.

Ftp: Perp. tension	0.183084069	MPa	Tension force perpendicular to grain.
Ftpr, tension resistance	0.51	MPa	Specified strength in tension perpendicular to grain (Include reduction if applicable).
Ftp/Ftpr	0.35898837	P.Tension	
Tp, Tension force	0	N	Tension force perpendicular to grain.
Method	ASSY Screw		Method used to reinforce the beam with a hole.
Orientation	Same Side		Entering sides for the reinforcement screws.
Screw Type	ASSY Screw 6		Specific screw label
Screw Qty	3		Number of screws used on either side of the hole.
Screw Length	0	mm	Overall screw length from tip to bellow head to withstand the tension forces.
Min Thread	0	mm	The minimum amount of thread required above and below the splitting area.
Screw Resistance	56	N/mm	Screw tension resistance used per thread length.
Screw Offset	0	mm	Hole vertical offset from the center of the beam.
Tp Used	0	N	Tension force perpendicular to grain used in the screw calculations. (Will increase if hole is offset.)
Method	Glued Panel		Method used to reinforce the beam with a hole.
Panel height	406.4	mm	Height of the 3/4” CSP panel to install on the hole area.
Panel width	557.28	mm	Width of the 3/4” CSP panel to install on the hole area.
Nails	52	Qty	Minimum number of nails to install on the entire panel surface.