Effect of Orientation on Pin-bearing Strength for Bolted Connections in Pultruded Joints

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Bearing Strength and Bolted Connections

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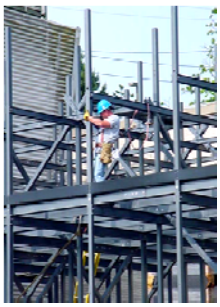
Content:

- Test method for determining pin-bearing strength.
- Strength variation with orientation of connection force.
- Suitability of Hankinson formula for design strength calculations.



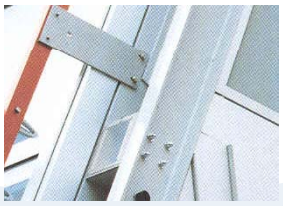


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Plate-to-plate Resistances

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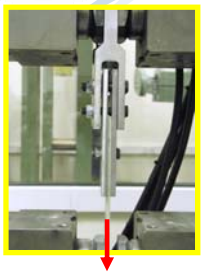
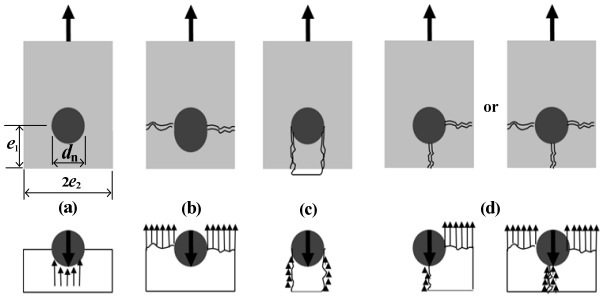
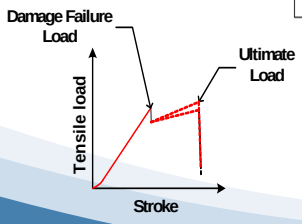
Distinct modes of failure (single-bolted connections)







(a) bearing, (b) net-tension, (c) shear-out, (d) cleavage

Failure mode can be made to change by varying the geometric ratios e_1/d (or e_1/d_n) and w/d (or w/d_n), with $w = 2e_2$. d is bolt diameter, < d_n.

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Mix modes for off-axis and block shear with multi-rows.

Strength Formula – Bearing Mode of Failure

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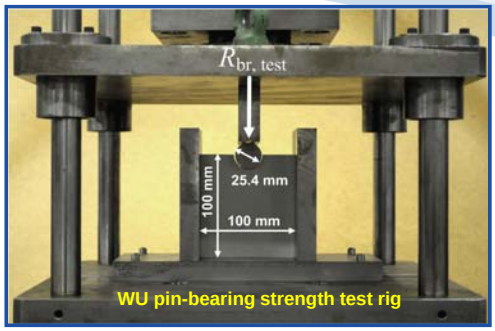
$$R_{br} = t\,d\,F_{\theta}^{br}$$

t is thickness of FRP

d is diameter of bolt

F_{θ}^{br} is pin-bearing strength for the orientation of material to the resultant connection force. Can Hankinson formula give F_{θ}^{br} from F_0^{br} and F_{90}^{br} ?



WU pin-bearing strength test rig

Specimens cut from the web of a 203 × 203 × 9.53 mm WF of the Pultex 1525 series with a thermoset polyester resin, from Creative Pultrusions Inc.

Test results for 0°, 5°, 10°, 20°, 45° and 90° material orientations, at room temperature.

Bearing failure - 0° specimen

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Pin-bearing Strength Test Results

Warwick University (WU) batch strengths at 0°, 5°, 10°, 20°, 45° and 90° and for four different pin (bolt) diameters

Pin diameter *d* (mm)	9.7	12.2	18.8	25.4	
Mean *d/t* ratio	1.06	1.34	2.05	2.78	
Characteristic strength F_θ^{br} (N/mm²)					
0° *	177	155	133	120	Average
Normalised strength	1.000	1.000	1.000	1.000	1.000
5° *	0.938	0.981	1.015	0.975	0.975
10° *	0.893	0.962	0.925	0.992	0.940
20° *	0.871	0.916	0.903	0.950	0.900
45° **	0.881	0.923	0.910	0.925	0.928
90° **	0.842	0.788	0.677	0.808	0.818

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* Characteristic value = Mean – 1.72SD (batches of 10)

** Characteristic value = Mean – 1.77SD (batches of 6)

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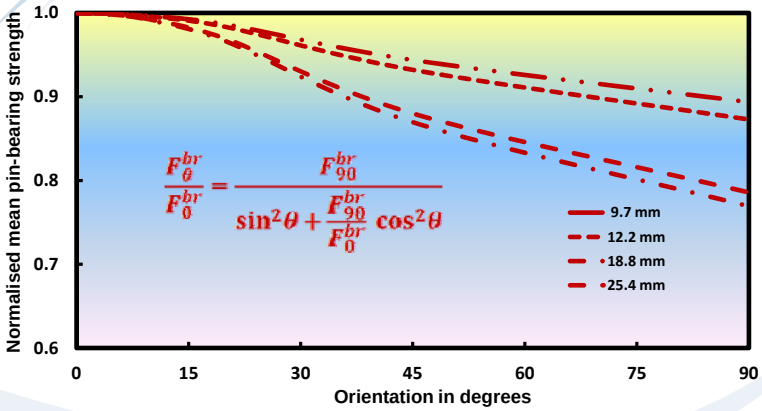
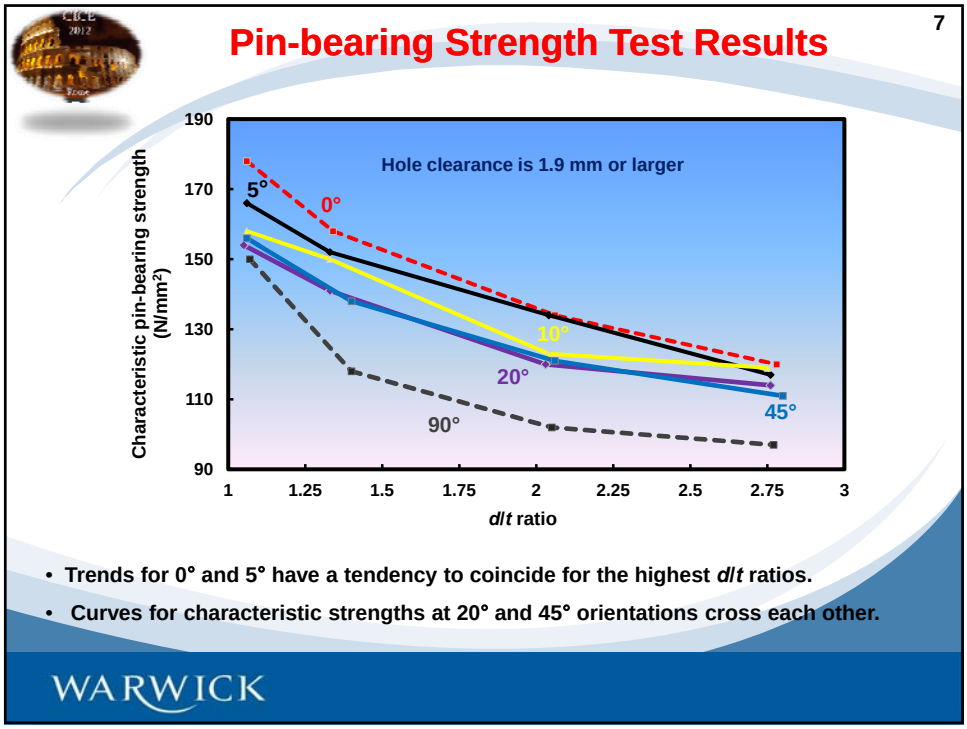
Types of Bolted Connections and Joints

Hankinson formula with 0° and 90° characteristic values from the Warwick University (WU) test results reported in Slide 5



Hankinson formula is used (AF&PA/ASCE 16-95) to predict the off-axis dowel (or pin-bearing) strength of timber.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Pin-bearing Strength Test Results
Hole clearance is 1.9 mm or larger
Characteristic pin-bearing strength (N/mm²)
190
170
150
130
110
90
1
1.25
1.5
1.75
2
2.25
2.5
2.75
3
d/t ratio
5°
0°
10°
20°
45°
90°
• Trends for 0° and 5° have a tendency to coincide for the highest d/t ratios.
• Curves for characteristic strengths at 20° and 45° orientations cross each other.
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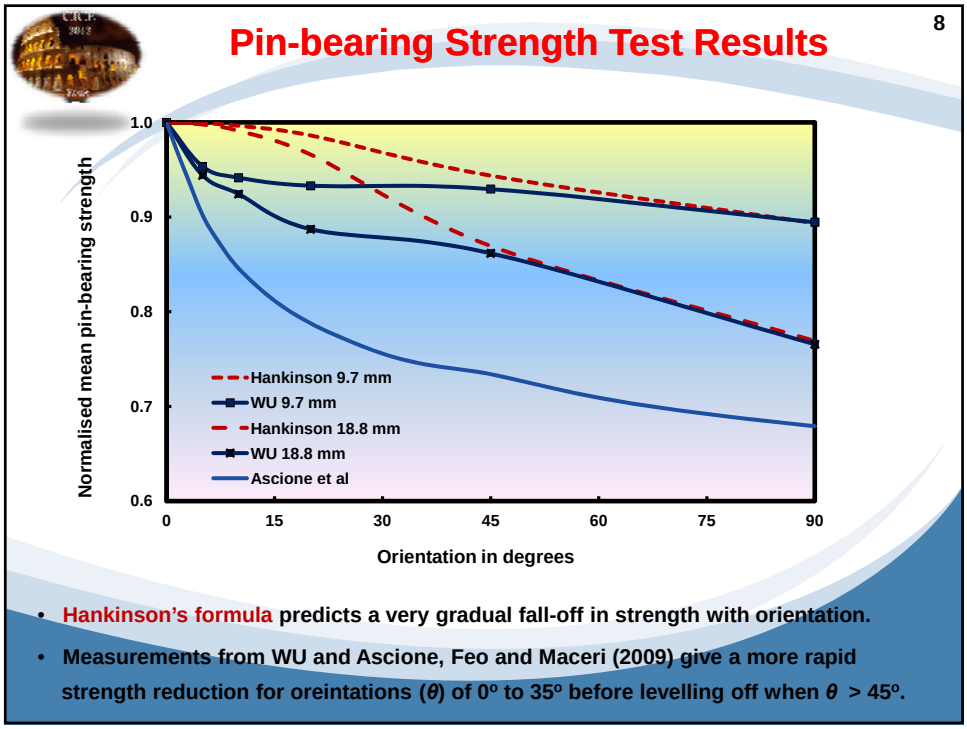
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Pin-bearing Strength Test Results
Normalised mean pin-bearing strength
1.0
0.9
0.8
0.7
0.6
0
15
30
45
60
75
90
Orientation in degrees
Hankinson 9.7 mm
WU 9.7 mm
Hankinson 18.8 mm
WU 18.8 mm
Ascione et al
• Hankinson's formula predicts a very gradual fall-off in strength with orientation.
• Measurements from WU and Ascione, Feo and Maceri (2009) give a more rapid strength reduction for oreintations (θ) of 0° to 35° before levelling off when θ > 45°.

Concluding Remarks

- Reduction in pin-bearing strength is minimal for the two material orientations of 0ºand 5º and, at the higher *d*/*t* ratios, there is a tendency for their two means to coincide.
- Results do not contradict the current proposed design guidance in the American pre-standard to use the 0º characteristic strength for orientations between 0 and 5º and the 90º value for all other orientations.
- Variation of pin-bearing strength of (standard) pultruded FRP cannot be predicted using the (simple) Hankinson formula.
- To establish a 'good' curve fit with orientation requires a polynomial expression of order six, and this is not suitable for a strength formula in a design standard.

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Thank you for your attention.

Any questions?

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