

Determination of Pin-bearing Strength for the Design of Bolted Connections with Standard Pultruded Profiles

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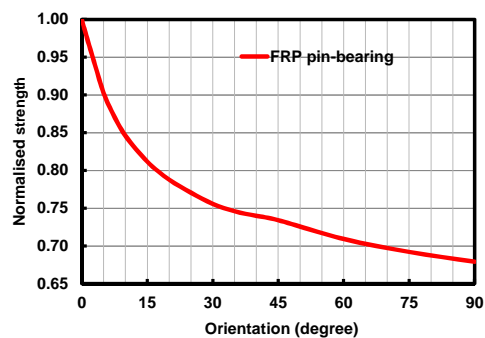
1 PhD Student & speaker
2 Reader

Bearing Strength and Bolted Connections

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Content of paper:

- WU (Warwick University) test method for determining pin-bearing strength.
- Strength variation with orientation of connection force.



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Types of Bolted Connections and Joints

Design of frame joints, such as the web-cleated type shown on top-right (classify as simple using the principles in BS EN 1993-1-8:2006), with the design of plate-to-plate connections, such as there is in each of the cleat legs and bracing members (bottom-right).

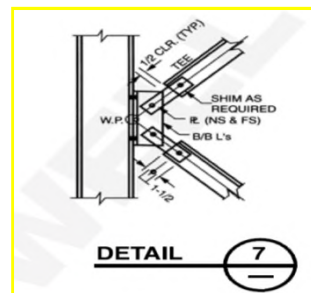
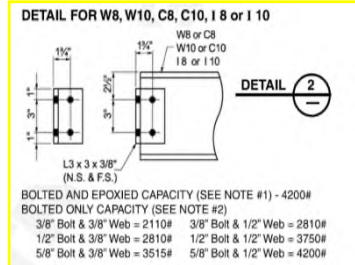
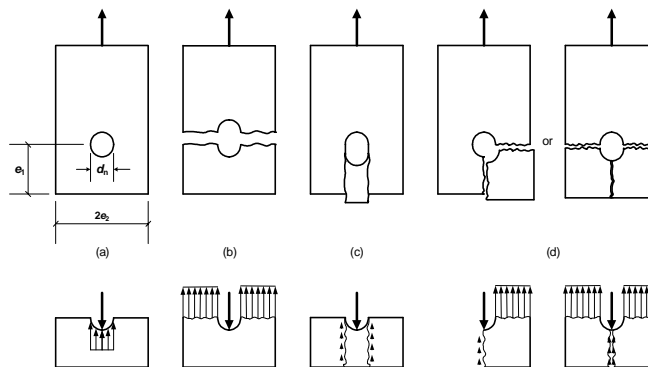


Plate-to-plate Resistances

Distinct modes of failure (single-bolted connections)



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

Strength formula – Bearing mode of failure

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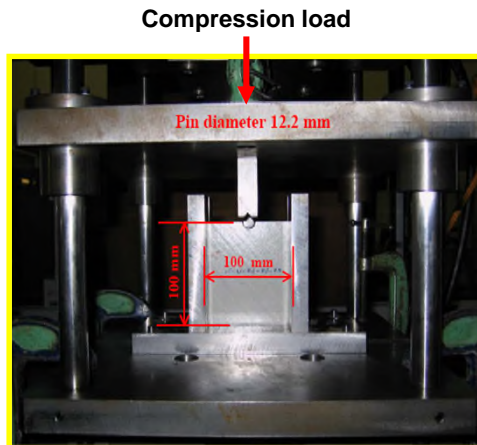
$$R_{br} = t d F_{\theta}^{br}$$

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.

$\theta = 0^{\circ}$ (or longitudinal) when direction of pultrusion is aligned with connection force.



WU pin-bearing strength test rig and 100x 100 mm specimen size

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Strength formula – Bearing mode of failure

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Specimens from web of **203 x 203 x 9.53 mm** Wide Flange section. Creative Pultrusions Inc. Pultex 1525 series with a thermoset polyester resin.

Test results for 0° , 45° and 90° material orientations, at **room temperature**.



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Pin-bearing Strength test results

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Longitudinal web material,				
Mean web thickness, t (mm)	9.16	9.14	9.12	9.14
Mean notch diameter, d_n (mm)	11.8	14.8	20.9	27.9
Mean pin diameter, d (mm)	9.7	12.2	18.8	25.4
Mean clearance, $d_n - d$ (mm)	1.9	2.6	2.1	2.5
No. of nominally identical specimens	11	11	11	11
Mean pin-bearing strength, (N/mm ²)	188	170	154	136
SD (N/mm ²)	6.2	9.1	12.7	14.8
CV (%)	3.3	5.3	8.4	10.9
Characteristic value* (N/mm²)	177	155	133	111
Mean d/t ratio	1.06	1.34	2.05	2.78

0° direction

45°

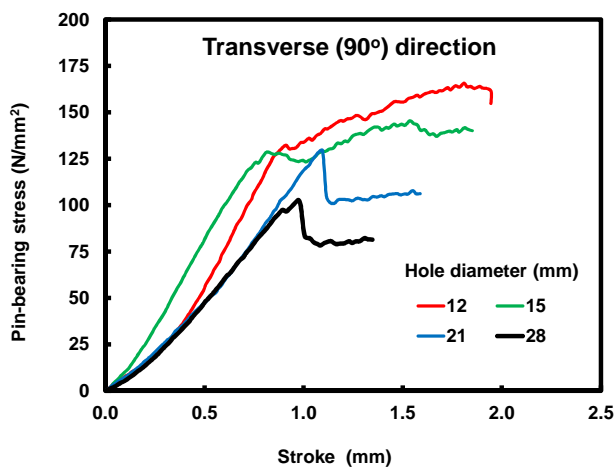
90°

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Note: * Characteristic value = Mean - 1.72SD (Batches of 10)

Pin-bearing Strength Test Results

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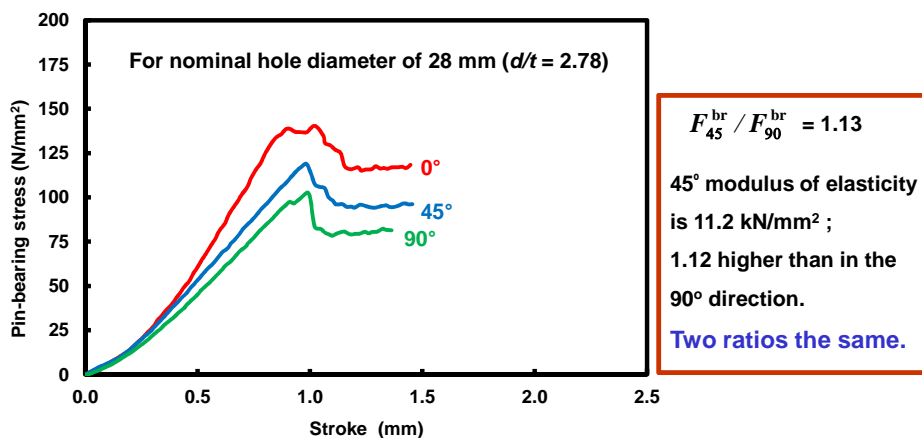


- Load-stroke curves are virtually linear for stroke to 0.8 mm.
- For hole diameters of 12 and 15 mm there is a higher load after initial failure.
- For hole diameter 21 and 28 mm the bearing failure is brittle.

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Pin-bearing Strength Test Results

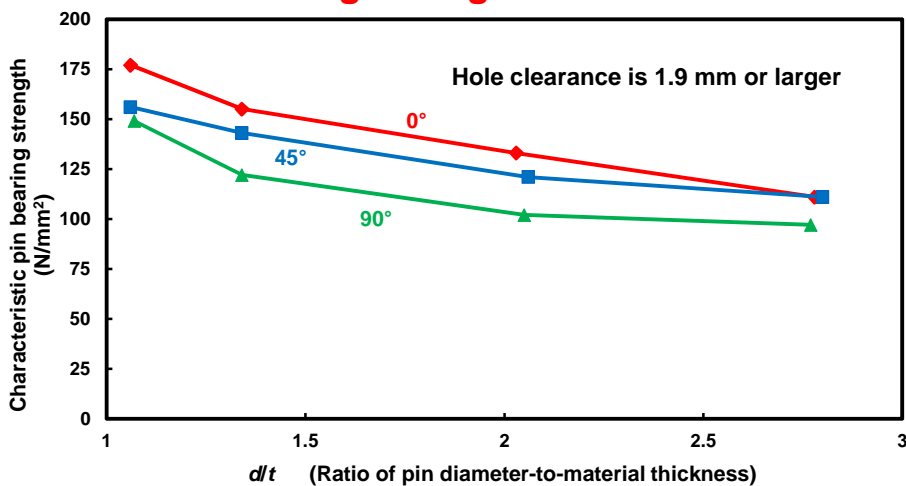
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Pin-bearing Strength Test Results

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Reduces between 50 and 60% on increasing pin diameter from 9.7 to 25.4 mm.

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Concluding Remarks

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- Warwick University pin-bearing strength test method has the potential to be developed into a standard test method.
- Minimum characteristic strength values are **111 N/mm² (0°) (CV @ 11%)**, **111 N/mm² (45°) (CV @ 4%)**, and **97 N/mm² (90°) (CV @ 6.6%)**.
- Characteristic strengths are very different (and unsafe) from **206 N/mm² for 0°**, and **124 N/mm² for 90°** given in Creative Pultrusions' design manual.
- Pin-bearing strength reduces with increase in the ratio of the pin diameter-to-material thickness and standard test methods do not account for this.
- Further series of tests are required to establish design strengths for conditions found in practice over the life of pultruded structures.

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