Resin injected bolted connections: A step towards achieving slip-resistant joints in FRP bridge engineering

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Jawed Qureshi (Presenting author)
& J Toby Mottram
School of Engineering
Email: J.Qureshi@warwick.ac.uk

Outline

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Introduction

- Fatigue and slip resistance are critical to bridges.
- In steel bridges, the conventional way to achieve slip resistance is to use rivets, fitted bolts or HSFG bolts.
- In FRP bridges:
  - Hot riveting is unsuitable due to lack of labour and equipment.
  - Fitted bolts are expensive and not a practical solution.
  - FRP can lose tightening over lifetime due to creep relaxation and HSFG bolts cannot be relied upon.
- Injection bolts offer slip, fatigue and shock resistant connections.
- They can be used as an alternative to fitted bolts, rivets or preloaded HSFG bolts.

1. Quality control tests
   - Injection assembly with perspex to check passage of resin.
   - Static load test to check curing of resin – slip not more than 0.15 mm.

2. Static creep test
   - Test for determination of design bearing resistance of the resin – creep should be less than 0.3 mm during lifetime.

3. Fatigue test
   - Bearing resistance from creep test is used to establish bearing stress ranges.
   - If total slip between the inner and outer plates is more than 0.3 mm, the fatigue life is at its end.
Double lap shear bolted connection specimens as per Annex G of BS EN 1090-2* (dimensions in mm).

Details of four test specimens.

<table>
<thead>
<tr>
<th>Standard bolts</th>
<th>Test</th>
<th>Bolt</th>
<th>Bolt hole</th>
<th>Resin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>M16</td>
<td>18 mm</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Test 2</td>
<td>M16</td>
<td>16 mm</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resin Injected bolts</th>
<th>Test</th>
<th>Bolt</th>
<th>Bolt hole</th>
<th>Resin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 3</td>
<td>M16</td>
<td>18 mm</td>
<td>RenGel SW404</td>
<td>—</td>
</tr>
<tr>
<td>Test 4</td>
<td>M16</td>
<td>18 mm</td>
<td>Sikadur-30</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: Both inner and outer plates are of pultruded FRP material.

Note: Bolts tightened to a bolt torque of 88 N.m, using tension formula given in Smith et al*.

Note: There is a standard procedure to produce hexagon injection bolts in ECCS 79* and BS EN 1090-2:2008.

Injection bolts – Preparation of bolts and washers

Bottom washer

Top washer

Standard
EN 1090
6 under cuts
12 under cuts

Top washer

Empty perspex tube

Perspex tube with resin

Bolt hole

Bottom washer

Nut
Injection bolts – Trial injection procedure

Sikadur-30  RenGel SW404  Empty perspex

Injection bolts – Assembling and resin injection

Unassembled specimen

Bolt centreline location jig
Injection bolts – Assembling and resin injection

Test specimen

Test specimen in location jig

Injection bolts – Assembling and resin injection

Resin injection process
Injection bolts – Assembling and resin injection

Test specimen in location jig after resin injection

Injection bolts – Assembling and resin injection

Resin injected test specimen ready to be tested
Test results – Test 1: No resin and clearance hole

Note: Static slip resistance is the load corresponding to a slip of 0.15 mm in load-slip curve (indicated by dashed line)

Specimen with M16 bolts, 18 mm holes and no resin

Test results – Test 2: No resin and no clearance

Specimen with M16 bolts, 16 mm holes and no resin
Test results – Test 3: RenGel SW404+HY2404 resin

Specimen with M16 bolts, 18 mm holes and RenGel SW404+HY2404 resin

Test results – Test 4: Sikadur-30 resin

Specimen with M16 bolts, 18 mm holes and Sikadur-30 resin
Concluding remarks

- Resins RenGel SW404+HY2404 and Sikadur-30 were used.
- The resin injected bolts showed slip resistance.
- The new top washer ensured smooth filling of resin.
- Design bearing resistance of resin will be determined from static creep tests.
- This property will be used to establish bearing stress range in a fatigue test.
- Injection bolts look promising to provide slip and fatigue resistant connections in FRP bridges.

Thanks for your attention
Any questions?

Email: J.Qureshi@warwick.ac.uk