The effect of surface preparation on FRP-concrete bond strength

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Research significance

- Design approach of CNR DT200 for delamination

\[ f_{fd} = \frac{1}{\gamma_{f,d} \cdot \sqrt{\gamma_c}} \cdot \sqrt{2 \cdot E_f \cdot \Gamma_{Fk}} \cdot t_f \]

\[ \Gamma_{Fk} = 0.03 \cdot k_b \cdot \sqrt{f_{ck} \cdot f_{ctm}} \]

- Lack of information regarding effects of different surface preparations on interface law.

Safety coefficients (certified methods)

FRP geometrical & mechanical properties

Concrete strengths

\[ k_p = \sqrt{\frac{2 - \frac{b}{b_t}}{\frac{b}{400}} \cdot \frac{b}{1 + b_t}} \geq 1 \]
Experimental tests

Set-up 1

Mazzotti et al., FRAMCOS 5, Vail (CO) 2004

Set-up 2

Mazzotti et al., ICF XI, Turin 2005

Set-up 3

Mazzotti et al., FRPRCS 7, Kansas City (MO) 2005
Concrete

- $f_{cm} = 52.7 \text{ MPa}$
- $f_{ctm} = 3.81 \text{ MPa}$
- $E_c = 30700 \text{ MPa}$

FRP plate
- $E_n = 165000 \text{ MPa}$

FRP sheet
- $E_n = 230000 \text{ MPa}$

Experimental Set-up (3)

- 13 strain gauges
- Load cell
- Reaction element
- LVDT
- 100 mm
- 150 mm
- 200 mm
- Clamping area

CFRP plate / sheet
- $80 \times 1.2 / 0.13 \text{ mm}$

Adhesive
- $80 \times 1.5 \text{ mm}$

80 mm width
Experimental Set-up (3) – Stable delamination

Clamping system

DELAMINATION PHASE

$\Delta t \approx 500$ seconds
Experimental Set-up (3) – Force

Test under displacement control

APPLIED FORCE

ELONGATION

$F_{\text{max}}$

Force transmissible by an anchorage of infinite length can be easily determined

COMPLETE DELAMINATION – ELONGATION OF THE PLATE ONLY
Experimental Set-up (3) – Strain

VERY STABLE DELAMINATION PHENOMENON

Distance x from loaded end

Strain

Model
SP 2
SP 1

A
B
C
SURFACE PREPARATION

Grinding with marble dust - 1

Grinding with steel dust - 2

Sand blasting - 3

Surface partially uneven

Surface strongly uneven and partially damaged

Surface very smooth
SURFACE AFTER DELAMINATION

- Sheet + Sand blasting
- Plate + Sand blasting
- Plate + Primer + S.b.
- Sheet + Grinding 1
- Plate + Grinding 1
- Plate + Grinding 2
## Experimental results – Max. transmissible FORCE

### F_{\text{max}} = b_p \sqrt{2E_p h_p G_f}

<table>
<thead>
<tr>
<th></th>
<th>Sheet - sand blast.</th>
<th>Sheet - grinded 1</th>
<th>Plate - sand blast.</th>
<th>Plate - grinded 1</th>
<th>Plate - grinded 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>F_{\text{max}} (kN)</td>
<td>P5A</td>
<td>P5B</td>
<td>P8A</td>
<td>P8B</td>
<td>P9A</td>
</tr>
<tr>
<td></td>
<td>16.50</td>
<td>17.40</td>
<td>14.40</td>
<td>14.60</td>
<td>37.60</td>
</tr>
<tr>
<td>F_{\text{max}} (kN) - Mean</td>
<td>16.95</td>
<td>14.50</td>
<td>38.35</td>
<td>34.00</td>
<td>39.50</td>
</tr>
<tr>
<td>E_p (MPa)</td>
<td>283653</td>
<td>291024</td>
<td>197630</td>
<td>195700</td>
<td>195460</td>
</tr>
<tr>
<td>G_f (MPa mm)</td>
<td><strong>0.61</strong></td>
<td><strong>0.43</strong></td>
<td><strong>0.49</strong></td>
<td><strong>0.39</strong></td>
<td><strong>0.52</strong></td>
</tr>
</tbody>
</table>

\[ E_n = 230000 \text{ MPa} \quad \text{and} \quad E_n = 165000 \text{ MPa} \]
Experimental results – Shear stress-slip curves

\[ \tau_{i+1/2} = \frac{E_p A_p (\varepsilon_{i+1} - \varepsilon_i)}{b_p (x_{i+1} - x_i)} \] 

\[ s(x) = s(x_i) + \int_{x_i}^{x} \varepsilon(x) \, dx = s(x_i) + \frac{(\varepsilon_{i+1} - \varepsilon_i)}{2} \frac{x^2}{(x_{i+1} - x_i)} + \varepsilon_i x \] 

\[ \tau = \frac{s}{S} \left( n - 1 \right) + \left( \frac{s}{\bar{s}} \right)^n \]  

Interface law

Sand blasting effects
- decrease stiffness;
- reduce peak stress;
- increase max. slip;
- increase \( G_f \) (+50%)
### Experimental results – Shear stress-slip curves

<table>
<thead>
<tr>
<th></th>
<th>( \bar{\tau} ) (MPa)</th>
<th>( \bar{s} ) (mm)</th>
<th>( n )</th>
<th>( k_p ) (MPa/mm)</th>
<th>( G_f ) (MPa mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet (P5) – sand blasted</td>
<td>5.72</td>
<td>0.069</td>
<td>4.2535</td>
<td>108.4</td>
<td>0.61</td>
</tr>
<tr>
<td>Sheet (P8) – grinded 1</td>
<td>6.22</td>
<td>0.038</td>
<td>3.6862</td>
<td>224.6</td>
<td>0.43</td>
</tr>
<tr>
<td>Plate (P9) – sand blasted</td>
<td>8.00</td>
<td>0.030</td>
<td>3.7063</td>
<td>365.2</td>
<td>0.49</td>
</tr>
<tr>
<td>Plate (P1) – grinded 1</td>
<td>6.43</td>
<td>0.044</td>
<td>4.437</td>
<td>188.7</td>
<td>0.39</td>
</tr>
<tr>
<td>Plate (P6) – grinded 2</td>
<td>5.41</td>
<td>0.062</td>
<td>4.640</td>
<td>110.7</td>
<td>0.52</td>
</tr>
</tbody>
</table>

#### Sand blasting
- Plate has higher strength;
- Plate has higher stiffness;
- Plate has lower \( G_f \) (+25%).

- Sheet has lower strength
- Sheet has lower stiffness
- Sheet has higher \( G_f \) (+50%)