Fatigue Durability of RC Beams Strengthened with CFRP Sheets and Plates & Conditioned in Environmental Chamber

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Research Objectives

- Evaluation of the pre-cracked RC beams under fatigue tests:
  - with/without CFRP strengthening
  - with/without delaminations

- Investigation of aggressive environmental (conditioning) effect on strengthened RC beams
## Test Program

<table>
<thead>
<tr>
<th></th>
<th>No Strengthening</th>
<th>CFRP Strengthening (open air)</th>
<th>CFRP Strengthening (in chamber) 4 cycles</th>
<th>CFRP Strengthening (in chamber) 8 cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1</td>
<td>1+1(^{(2)})+1(^{(3)})</td>
<td>1+1(^{(1)})</td>
<td>1+1(^{(1)})</td>
</tr>
<tr>
<td>Sustained Load Applied(^{(4)})</td>
<td></td>
<td>1+1(^{(1)})</td>
<td>1+1(^{(1)})</td>
<td>1+1(^{(1)})</td>
</tr>
</tbody>
</table>

- Control samples are kept in Lab. conditions
- \(^{(1)}\) These samples have delaminations
- \(^{(2)}\) This sample has anchor spikes
- \(^{(3)}\) This sample is strengthened by CFRP plate
- \(^{(4)}\) Sustained load is applied as 40% of the moment capacity
Test Beams

0.021 = \rho_{\text{max}} > \rho = 0.0073 > \rho_{\text{min}} = 0.0033

L = 6.5'
Pre-cracking RC Beams
Delamination Formation
Anchor Spike Placement
Environmental Cycle

- **Temp (°F), RH (%)**
  - High Temperature Cycles
  - 50 Freeze Thaw Cycles
  - Relative Humidity Cycles

- **Cycles**
  - 40 cycles
  - 20 cycles

**Time**
Time

\[ \sigma_{max} \quad \sigma_{min} \]

- Minimum: 33\% of the ultimate moment carrying capacity
- Maximum: 63\% of the ultimate moment carrying capacity
- Loading rate of 2 Hz.
Test Results

Load versus Mid-span deflection of un-strengthened control sample under cyclic loading for first and 1-million cycles (normalized data)

\[ y = 35,875x \]
\[ R^2 = 1 \]

\[ y = 44,116x \]
\[ R^2 = 1 \]
Load versus Mid-span deflection of CFRP sheet strengthened sample under cyclic loading for first and 2-million cycles (4 env. cycles) (normalized data)
Test Results

Load versus Mid-span deflection of CFRP sheet strengthened sample under cyclic loading for first and 2-million cycles (8 env. cycles)(normalized data)

\[ y = 62,392x \quad R^2 = 1 \]

\[ y = 52,399x \quad R^2 = 1 \]
Conclusions

• Fatigue resistance of RC beams improved significantly by strengthening with CFRP sheets, all beams survived after 2 million cycles so far.
• Environmental conditioning and sustained load significantly effected the flexural stiffness of the beams, the decrease was as high as 22%.
Thank You!

Questions?