Use of Fiber Reinforced Polymer Composite Cables for Post-Tensioning Applications

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Outline

- Project Overview
- CFRP Post-Tensioned Segmental Bridge Model
- CFRP Post-Tensioned Pier Cap Model
- CFCC PT Anchorage and Creep Rupture Test
- Conclusions
Project Overview
Problem Statement
To use CFRP tendons as a viable alternative to steel strands in post-tensioned bridges in Florida, there is a need for design guidelines, construction specifications, material and device standards, and inspection and repair methodologies for CFRP post-tensioned structures.

Project Test beds
1. CFRP Post-tensioned Segmental Bridge Model
2. CFRP Post-Tensioned Pier Cap Model
3. CFCC PT Anchorage and Creep Rupture Test
CFRP Post-Tensioned Segmental Bridge
Segmental Bridge Model

Prototype: Long Key Bridge
1:3.5 Scaled model
Model Preparation
## Strand Types

<table>
<thead>
<tr>
<th>Tendon Type</th>
<th>CFCC</th>
<th>EC6</th>
<th>Low-Lax Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Diameter, in.</td>
<td>0.492</td>
<td>0.484</td>
<td>0.5</td>
</tr>
<tr>
<td>Effective Area, in²</td>
<td>0.118</td>
<td>0.1488</td>
<td>0.153</td>
</tr>
<tr>
<td>Guaranteed Strength, ksi</td>
<td>351</td>
<td>268</td>
<td>270</td>
</tr>
<tr>
<td>Guaranteed Capacity, kip</td>
<td>41.4</td>
<td>39.7</td>
<td>41.3</td>
</tr>
<tr>
<td>Elastic Modulus, msi</td>
<td>22.3</td>
<td>26.8</td>
<td>29.0</td>
</tr>
<tr>
<td>Anchorage Device Length, in.</td>
<td>13</td>
<td>4.3</td>
<td>3.6</td>
</tr>
</tbody>
</table>
Post-Tensioning

CFCC

EC6

Steel
Visual Inspection
Loading Positions

Service Load Position 1

Service Load Position 2

Service Load Position 3

Ultimate Load Position
Loading System and Instrumentation
Prestressing Relaxation Losses

Graph showing the change in Prestress Force (kips) over time (Days) with three key stress levels marked:
- 70% Stress Level of CFCC
- 63% Stress Level of EC6
- 55% Stress Level of CFCC

Axes:
- X-axis: Time (Days) from 0 to 60
Experimental Tests Results

Load – Displacement Comparisons

- 26.1 Kips Steel
- 26.1 Kips HMCC
- 25.6 Kips CFCC
- 27.1 Kips HMCC
- 27.1 Kips CFCC
- 27.2 Kips Steel
- 29.2 Kips HMCC
- 29.2 Kips CFCC
- Ultimate Load
- Service Load
Experimental Tests Results

Load – joint Opening Comparisons
Numerical Simulation

Segmental Bridge with CFCC 25.6 kips

Segmental Bridge with EC6 26.1 kips
Analytical and Experimental Results Comparison
Parametric Study
CFRP Post-Tensioned Pier Cap
Typical Cantilever piers in San Antonio Downtown “Y” Project
1:5.5 Scaled model
Model Preparation
Model Preparation
Pier Cap Reinforcement Layout

Double Shear Stirrups - 10 ga wire
@ 6 equal spaces = 23.87
@ 12 equal spaces = 8
@ 3 equal spaces = 9.20

Anchorage Zone Hoops
@ 18 equal spaces = 18

Top Bars
7 ga wire
0.63
= 16.74

Side Face Bars
(both side)

Double Shear Stirrups

Side Face Bars

Bottom Bars
7 ga wire
0.63
= 16.74

21.74

21.74

21.74

21.74

Section at Column Face

Layout for 8 strands

T1
T2
T3
T4
T5
T6
T7
T8

3
7.6

2.625
4.25
4.25
4.25
2.625

8

Layout for 6 strands

T1
T2
T3
T4
T5
T6

3
7.6

2.625
4.25
4.25
4.25
2.625

8
Post-Tensioning

CFCC

EC6

Steel
Loading System and Instrumentation

Potentiometer

Potentiometer

Potentiometer

Potentiometer
Experimental Tests Results

![Graphs showing Tip Deflection and Moment at Column Face for different materials and configurations. The graphs display data for CFCC 8 Tendons vs CFCC 6 Tendons, EC6 8 Tendons vs EC6 6 Tendons, and Steel 8 Strands vs Steel 6 Strands.](image-url)
Experimental Tests Results
Carbon Fiber Composite Cable (CFCC)
Post-Tensioning Anchorage
and Creep Rupture Test
Post-Tensioning Sleeve

A513 Steel Sleeves

- Yield Strength = 60 ksi
- Outer diameter = 1½ in.
- Wall thickness = ¼ in.
- Manually threaded to fit 1½ × 6 in. Hex nut (hardened)

Filler

- Non-Explosive Demolition Agent
- Expansive Pressure 9,960 psi
- 7-day curing time
Testing of Post-Tensioning Sleeve

- Steel Frame: four 18” tube and three plates
- 15” and 20” steel sleeves
- Manufacturer's Guaranteed Load: 41.4 kips
- Actual Failure Load: 56 kips (15 in. Sleeve), 58 kips (20 in. Sleeve)
- No Slippage Observed
Cables for Creep Rupture Test

- Four Specimens
- 15” Long Sleeve
- Applied Load: 39.3 kips
- Stress Level: 95% of the Manufacturer’s Guaranteed Load.
Test Frame and Setup
Creep Rupture Tests in Progress

Figure 1 - Load Ratio vs. Time (in hours)

- SP-1
- SP-2
- SP-3
- SP-4

Figure 2 - Load Ratio vs. Log Time (hours)

- SP-1
- SP-2
- SP-3
- SP-4
Conclusions
Both CFCC and EC6 strands offer feasible alternatives to steel for un-bonded post-tensioning applications.

The segmental bridge model showed a bilinear response with its initial stiffness generally the same for all three types of strands. The secondary stiffness after decompression and joint opening is much higher for EC6 and steel strands as compared to CFCC.

The pier cap model performed quite similarly using all three types of strands.

CFCC seems quite stable under sustained loads at 95% of guaranteed strength.

The main constructability issue for CFCC and EC6 strands is the need for factory-made end anchorage and pre-ordered cable length.
Questions?