



WIN6U01346



## DPWH Standard Specification for ITEM 416A – CARBON FIBER PLATE

### 416A.1 Description

This item covers Carbon Fiber Plate (CFP) for reinforced concrete repair and strengthening systems. CFP and resins such as epoxies and other adhesive materials, act as a composite material to enhance the structural capacity and extend the life of concrete structures. The role of the resin is to serve as adhesive bond to the concrete surface and facilitate the transfer of stresses to and from the carbon fiber plate.

### 416A.2 Material Requirements

The CFP shall conform to the Specifications shown in Table 416A.1.

Table 416A.1 - Specifications of CFP to Concrete Girder

Property	Test Method	Unit	Specifications			
Carbon Fiber Type	-	-	High Strength			High Modulus
Thickness	-	mm	1.0 (±0.1)	1.5 (±0.1)	2.0 (±0.1)	2.0 (±0.1)
Width	-	mm	50 (+2/-0)	50 (+2/-0)	50 (+2/-0)	50 (+2/-0)
Density	ASTM D3039	g/cm <sup>3</sup>	1.6 (Min)	1.6 (Min)	1.6 (Min)	1.6 (Min)
Tensile Strength	ASTM D3039	N/mm <sup>2</sup>	2400 (Min)	2400 (Min)	2400 (Min)	1500 (Min)
Modulus of Young's Elasticity	ASTM D3039	kN/mm <sup>2</sup>	167 (Min)	167 (Min)	167 (Min)	285 (Min)
Carbon Fiber Weight / Unit Length	-	g/m <sup>2</sup>	60	90	120	120
Carbon Fiber Weight / Unit Area	-	g/m <sup>2</sup>	1200	1800	2400	2400
Pull-Off Bond Strength to Concrete: • Dry • Wet	ASTM D7234	N/mm <sup>2</sup> N/mm <sup>2</sup>	1.5(Min)CF 1.5(Min)CF	1.5(Min)CF 1.5(Min)CF	1.5(Min)CF 1.5(Min)CF	1.5(Min)CF 1.5(Min)CF

*Tensile strength of carbon fiber plate shall be approved by the Engineer.*

*\*CF – Concrete Failure*

The epoxy adhesive for bonding CFP shall conform to the Specifications shown in Table 416A.2.



Table 416A.2 - Specifications of Epoxy Adhesive for Bonding CFP

Property	Test Method	Unit	Specifications
Specific Gravity	ASTM D792	-	1.7±0.20
Flexural Strength	ASTM D790M	N/mm <sup>2</sup>	45 (Min)
Compressive Strength	ASTM D695M	N/mm <sup>2</sup>	70 (Min)
Modulus of Elasticity	ASTM D695M	N/mm <sup>2</sup>	4000 (Min)
Tensile Strength	ASTM D638M	N/mm <sup>2</sup>	25 (Min)
Tensile Shear Bond	ASTM D1002	N/mm <sup>2</sup>	15 (Min)
Bond Strength to: <ul style="list-style-type: none"> <li>Concrete Fiber Plate and Concrete</li> <li>Concrete Fiber Plate and Steel</li> </ul>	ASTM D7234	N/mm <sup>2</sup> N/mm <sup>2</sup>	1.5 (Min)CF 3.5 (Min)

*The epoxy adhesive shall be approved by the Engineer through mill certificate of the supplier.*

*\*CF – Concrete Failure*

### 416A.3 Construction Requirements

#### 416A.3.1 Application Criteria

The system for concrete girder shall generally consist of CFP bonded to the concrete with epoxy. The center position or section of girder which is one-half in span is applied with CFP for protection against flexural cracks caused by live load. A non-destructive test can be used to determine the compressive strength of the existing concrete and the deficient strength to be covered by the application of the CFP.

#### 416A.3.2 Surface Preparation

All concrete surfaces shall be clean, sound and free from surface moisture. Crack sealing or water proofing shall be provided prior to concrete surface restoration. If water leaks through on concrete surface to be covered with CFP, surface preparation and application of the CFP shall be in accordance with the approved manufacturer's application specifications. Both the Contractor and the manufacturer's technical representative must verify the suitability of any changes to the application methods proposed by the Engineer. Cracks larger than 0.3 mm shall be injected with epoxy using a system/method approved by the Engineer.

#### 416A.3.3 Crack Sealing

Crack sealing shall conform to the applicable requirements of Item 740 – Structural Concrete Injection and Crack Repair.

#### 416A.3.4 Waterproofing

Waterproofing shall conform to the applicable requirements of Item 407 – Concrete Structures, No. 6 of Subsection 407.2 Waterproofing and Damp proofing.



#### **416A.3.5 Material Handling**

The carbon fiber plate and components shall be delivered in original, unopened (except carbon fabric or strips) containers clearly marked with the manufacturer's name, product identification, and batch numbers. Storage and handling of the various products shall be in conformity with the manufacturer's recommendations and instructions.

#### **416A.3.6 Prime Coat**

Contact surface shall be dry before coating with primer. The primer should be formulated and compatible with the carbon fiber material and not to be applied during rains, storms or when the air is misty or when conditions are unsatisfactory as observed by the Engineer.

Application rate shall be such as to ensure complete saturation of the contact surface. Primer should be cured between 2-3 hours before proceeding to the next step.

#### **416A.3.7 Putty Application**

For the adjustment and correction of surface irregularity and unevenness, epoxy putty should be applied, after the primer is tack-free. Any concave, pores, or gap on the concrete surface must be smoothened with epoxy putty. After the putty becomes tack-free, it is required to roughen the surface with sandpaper, then cleaned.

#### **416A.3.8 Application of Epoxy Resin for Undercoat**

The Contractor shall submit for the Engineer's approval, his proposed method of application of epoxy resin undercoat. In accordance with approved manufacturer's specifications for the CFP System. The contact surface condition shall be tack-free and application shall not be done during rain or storms or when the air is misty, or when in the opinion of the Engineer, conditions are unsatisfactory to carry on with the work. The following specified quantity of the adhesive is only for reference. Actual quantity should be determined in consideration with ambient temperature and manufacturer's recommendation in the work site, subject to Engineer's approval.

1. The mixing and application of the adhesive (resin and hardener) should be in accordance with the manufacturer's instructions approved by the Engineer.
2. Apply the adhesive on the surface at the rate of 0.2 – 0.3 kg/m<sup>2</sup>.

#### **416A.3.9 Carbon Fiber Plate Application**

CFP shall be cut in 4 m to 6 m length and applied considering the following measures.

1. CFP may be used on surfaces where some abrasion is required as per manufacturer's recommendations, provided that the plates are manufactured according to the required roughness;
2. Apply the epoxy adhesive on the surface of the CFP at the rate of 0.2 – 0.3 kg/Lm of the plate.



3. The adhesive layer shall be applied to the plates in a curved profile measuring 3 mm in the center and 1 mm on the edges, in order to reduce formation of voids; and,
4. During installation of CFP, uniform pressure using roller should be applied, moving from the longitudinal centerline then outwards. This is intended to expel excess adhesive and produce even edges.

#### **416A.3.10 Over Coating Resin Application**

No over coating is required for CFP since no second layer is usually required.

#### **416A.3.11 Quality Control and Inspection**

The Contractor shall conduct a quality control program that includes, but not limited to the following:

1. Inspection of all materials to ensure conformity with contract requirements, and that all materials are new and undamaged.
2. Inspection of all surface preparation is carried out prior to CFP application.
3. Inspection of work in progress to ensure work is being done in accordance with this specification and approved manufacturer's instructions
4. Inspection of all work completed including sounding of all repairs to check for any debonding and correction of any defective work.

#### **416A.3.12 Testing**

After allowing at least 24 hours for the epoxy adhesive to cure, the Contractor shall perform a visual and acoustic tap test inspection of the layered surface. All voids and delamination shall be repaired in accordance with the manufacturer's recommendations. The Contractor shall conduct adhesion testing of the fully cured CFP installation using direct pull-off tests, at locations determined by the Engineer. Failure at the bond line at tensile stress below 1.379 MPa will be the cause for rejection of the repair. A minimum of two (2) pull-off tests per system (span) shall be performed.

#### **416A.4 Method of Measurement**

CFP installed in accordance with the plans and specifications shall be measured in linear meters (l.m). The quantity to be paid for shall be the linear meters of CFP used and accepted by the Engineer. No measurement shall be made for epoxy injection of cracks.



#### 416A.5 Basis of Payment

The quantity measured as prescribed above shall be paid for at the Contract Unit Price. This unit price shall cover full compensation for all materials, labor, equipment, supervision, and related services necessary for reinforcing of the concrete as detailed in the plans and specifications. If an alternative carbon fiber system is used, the price shall also include all engineering, design and technical services, as well as contractor submittals required as per Specifications.

Payment will be made under:

Pay Item Number	Description	Unit of Measurement
416A	Carbon Fiber Plate	Linear Meter

#### References:

- 1) *Carbon Plate System, Fortec Stabilization*
- 2) *V-Wrap Carbon Plate, Structural Technologies, LLC*
- 3) *SikaCarboDur Plates PDS, Sika Limited*
- 4) *Sika CarboDur Structural Strengthening Systems, Sika Services AG*
- 5) *SikaCarbodur Heavy Duty CFRP System, Sika Philippines, Inc.*
- 6) *Toray "Torayca" Carbon Fiber Laminate*
- 7) *Alphatec CFP System*
- 8) *Shear and Flexural Strengthening of R/C Beams with Carbon Fiber Sheet, Arizona USA*
- 9) *American Society for Testing and Materials (ASTM)*
- 10) *American Association of State Highway and Transport Officials (AASHTO)*
- 11) *Bridge Repair Manual 2<sup>nd</sup> Edition (Improvement of Quality Management for Highway and Bridge Construction and Maintenance, Phase II), Department of Public Works and Highways (DPWH) and Japan International Cooperation Agency (JICA)*