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REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
OFFICE OF THE SECRETARY
MANILA

01 AUG 2016

DEPARTMENT ORDER)
NO. **160**)
Series of 2016)

SUBJECT: DPWH Standard Specification for
Item 416 – Carbon Fiber Sheet

It has been the thrust of the Department to formulate effective standard specifications in the implementation of various government infrastructure projects. Whenever necessary and as the need arises, existing standard specifications are superseded for updating purposes, to incorporate more significant/relevant provisions and remove those deemed outdated or no longer necessary.

In this regard, the Department hereby prescribes the **DPWH Standard Specification for Carbon Fiber Sheet, Item 416**, for the guidance and compliance of all concerned. Henceforth, this specification shall form part of the revised 2012 edition of the DPWH Standard Specifications for Highways, Bridges and Airports, Volume II.

This Order shall supersede Department Order No. 33, Series of 2010 (*DPWH Standard Specification for Carbon Fiber, Item 416*) and shall take effect immediately.


RAFAEL C. YABUT
Acting Secretary

14.1.2 FET/JFS

Department of Public Works and Highways
Office of the Secretary



WIN6U01353

**DPWH Standard Specification for
ITEM 416 - CARBON FIBER SHEET**

416.1 Description

This Item covers Carbon Fiber Sheet (CFS) for use to reinforced concrete structures as shown on the Plans or as directed by the Engineer.

416.2 Material Requirements

416.2.1 Description of Raw Materials

The raw material used to make carbon fiber is made from 90% polyacrylonitrile. The remaining 10% are made from rayon or petroleum pitch. All of these materials are organic polymers, characterized by long strings of molecules bound together by carbon atoms. The density of carbon fiber's also considerably lower than the density of steel, making it ideal for applications requiring low weight.

416.2.2 Carbon Fiber Sheet Properties

The Carbon Fiber Sheet (CFS) shall conform to the specifications shown in the Table 416.1.

Table 416.1 - Specifications of Carbon Fiber Sheet

Property	Test Method	Unit	Specifications				
Type	-	-	Uni-directional, high strength cloth				
Carbon Fiber Weight	-	g/m ²	200	300	400	450	600
Sheet thickness	-	mm	0.111	0.167	0.222	0.25	0.333
Density	ASTM D3039	g/cm ³	1.8	1.8	1.8	1.8	1.8
Tensile Strength	ASTM D3039	N/mm ²	3400 (Min)	3400 (Min)	3400 (Min)	3400 (Min)	3400 (Min)
Young's Modulus of Elasticity	ASTM D3039	kN/mm ²	230 (Min)	230 (Min)	230 (Min)	230 (Min)	230 (Min)
Pull-off Bond Strength to Concrete	ASTM D7234						
• Dry		N/mm ²	1.5(Min) CF	1.5(Min) CF	1.5(Min) CF	1.5(Min) CF	1.5(Min) CF
• Wet		N/mm ²	1.5(Min) CF	1.5(Min) CF	1.5(Min) CF	1.5(Min) CF	1.5(Min) CF

Tensile strength and Pull-off Bond Strength of the carbon fiber sheet shall be approved by the Engineer.

**CF- Concrete Failure*

The epoxy adhesive for bonding CFS shall conform to the specification shown in the Table 416.2.

Table 416.2 - Specifications of Epoxy Adhesive for bonding CFS

Property	Test Method	Unit	Specifications		
			Primer	Epoxy Putty	Penetrating Epoxy Resin/Impregnation
Viscosity	ASTM D2393	mPa.s	≤1000	Paste - like	5000 (Min)
Tensile Strength	ASTM D638M	N/mm ²	≥15	≥20	≥30
Flexural Strength	ASTM D790M	N/mm ²	≥20	≥40	≥40
Compressive Strength	ASTM D695M	N/mm ²	≥20	≥50	≥50
Tensile Shear Bond to Steel	ASTM D1002	N/mm ²	≥10	≥10	≥10
Pull-off Bond Strength	ASTM D7234				
<ul style="list-style-type: none"> • Dry • Wet 		N/mm ² N/mm ²	≥1.5 CF ≥1.5 CF	≥1.5 CF ≥1.5 CF	≥1.5 CF ≥1.5 CF

The material shall be approved by the Engineer through mill certificate of the supplier.

*CF- Concrete Failure

416.3 Construction Requirements

416.3.1 Material Handling

The carbon fiber 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.

416.3.2 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 cracks on concrete surface to be covered with CFS, surface preparation and application of CFS 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 0.3mm shall be injected with epoxy using a system/method approved by the Engineer.

For the preparation of concrete, disc grinder or abrasive sandblasting is used to clean the Concrete and to ensure that concrete surface is even and smooth.

416.3.3 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 in the opinion of 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.

416.3.4 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 smoothed with epoxy putty. After the putty becomes tack-free, it is required to roughen the surface with sandpaper, then cleaned.

416.3.5 Application of Epoxy Resin for Undercoat (Penetrating/Impregnation Epoxy Resin)

Prior to undercoating epoxy resin adhesive, ambient temperature at the work site shall be checked to confirm the curing conditions before applying the resin. The Contractor shall check and confirm that the primer and putty have become tack-free and there is no clay and dust on the concrete surface prior to the Engineer's inspection. If there is a time interval of longer than 3 days after the primer and putty application, the primer and putty coated surface should be roughened with sandpaper, and the surface cleaned before the adhesive application.

The contact surface condition shall be tack-free and application shall not be done during rains or storms or when the air is misty, or when in the opinion of the Engineer, conditions are unsatisfactory to carry out the work. The following specified quantity of the resin is only reference. The actual quantity should be determined in consideration with ambient temperature and manufacturer's recommendation in the work site, subject to the Engineer's approval.

The mixing and application of the adhesive resin (resin and hardener) should be in accordance with the manufacturer's instruction approved by the Engineer.

Application rate of the penetrating epoxy resin shall be in accordance with Table 416.3.

Table 416.3 - Application Rate of the Penetrating Epoxy Resin

Carbon Fiber Sheet Area Weight (g/m ²)	Standard Usage Weight of Penetrating/Impregnation of Epoxy Resin			Unit
	Undercoating	Over-coating	Total	
200	0.3 ~ 0.4	0.4 ~ 0.2	0.5 ~ 0.7	kg/m ²
300	0.4 ~ 0.5	0.4 ~ 0.3	0.7 ~ 0.9	kg/m ²
400	0.5 ~ 0.6	0.5 ~ 0.4	0.9 ~ 1.1	kg/m ²
450	0.55 ~ 0.65	0.5 ~ 0.4	1.0 ~ 1.15	kg/m ²
650	0.6 ~ 0.65	0.5 ~ 0.65	1.1 ~ 1.3	kg/m ²

416.3.6 Carbon Fiber Application (First Layer)

The standard length of carbon sheet will be cut from 4 to 6 m. If standard cut length is exceeded, wrinkles will appear and installation becomes more difficult. The CFS shall be applied in accordance with the following procedures.

- a) Install the CFS in the longitudinal direction after the epoxy resin application.
- b) Press the CFS using a roller starting from the center towards the edge to squeeze out entrapped air before the epoxy resin sets.
- c) When lapping of two CFS is required, a lap length of not less than 20 cm shall be provided.

The specified normal curing time is only for reference purposes. The actual curing periods should be determined considering the ambient temperature and manufacturer's recommendation in the work site, subject to the Engineer's approval.

416.3.7 Over Coating Resin Application

Verification and confirmation of resin mixing and application procedure shall be executed similar to that of the under-coating resin. The actual quantity should be determined considering the ambient temperature and manufacturer's recommendation in the work site, subject to the Engineer's approval.

416.3.8 Quality Control and Inspection

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

- a) Inspection of all materials to ensure conformity with contract requirements, and that all materials are new and undamaged.
- b) Inspection of all surface preparation is carried out prior to CFS application.
- c) Inspection of work in progress to ensure work is being done in accordance with the DPWH Standard Specifications and approved manufacturer's instructions.
- d) Inspection of all work completed including sounding of all repairs to check for any debonding and correction of any defective work.

416.3.9 Sampling and Testing

After allowing at least 24 hours for the initial resin saturate to cure, the Contractor shall perform a visual and acoustic tap test inspection of the layered surface. All voids, bubbles and delaminations shall be repaired in accordance with the manufacturer's recommendation. The Contractor shall conduct adhesion testing of the fully cured CFS installation using direct pull-off tests, at locations determined by the Engineer. Failure at the bond line at tensile stress below 1.373 N/mm² will be cause for rejection of the repair. A minimum of two pull-

off tests per system (span) shall be performed. The test shall be completed prior to the application of the protective top coat on the CFS.

The product subjected to sampling shall meet ACI Guidelines and ASTM D 3039.

416.4 Method of Measurement

CFS installed in accordance with the Plans and Specifications will be measured in square meters. The quantity to be paid for shall be the square meters of CFS used and accepted by the Engineer. No measurement will be made for epoxy injection of cracks.

416.5 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
416	Carbon Fiber Sheet	Square Meter

References:

- 1) *Toray "Torayca" Carbon Fiber Laminate*
- 2) *Alphatec CFP System*
- 3) *Sika_CarboDur_Structural Strengthening Systems, Sika Services AG*
- 4) *Shear and Flexural Strengthening of R/C Beams with Carbon Fiber Sheet, Arizona USA*
- 5) *American Society for Testing and Materials (ASTM)*
- 6) *American Association of State Highway and Transport Officials (AASHTO)*
- 7) *Bridge Repair Manual 2nd 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)*