MICHIGAN
DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION
FOR
COLUMN WRAPPING WITH FIBER REINFORCED POLYMER (FRP) SHEETS

C&T:SCK 1 of 7 C&T:APPR:TES:EMB:01-14-10

a. Description. This work consists of furnishing and installing Fiber Reinforced Polymer (FRP) sheets to repair concrete bridge columns by wrapping as shown on the plans. The FRP sheet and adhesive composite system must consist of two layers of carbon fiber sheets attached to the concrete substrate using an adhesive, which is then top coated with a gray color protective coating. All work must be in accordance with the Standard Specifications for Construction, except as modified herein.

b. Materials. Materials must meet the following requirements:

The carbon fibers used in the FRP sheet must have a tensile chord modulus greater than 33,000,000 psi and a tensile strain at failure greater than 0.8 percent when tested according to ASTM D 4018 at 75.0 ±3.0 degrees F. The FRP sheet and adhesive composite system must have an ultimate tensile strength greater than 2,400 pounds per inch of sheet width and a tensile strain at failure greater than 1.3 percent when tested according to ASTM D 3039 at 75.0 ±3.0 degrees F. The stiffness of the FRP sheet and adhesive composite system, defined as either (1) the composite tensile modulus multiplied by the total composite area, or (2) the carbon fiber tensile modulus multiplied by the equivalent fiber area, must be greater than 198,000 pounds per inch of sheet width. The FRP sheet and adhesive composite system must meet the California Department of Transportation's Pre-qualification Requirements for Alternative Column Casings for Seismic Retrofit regarding durability testing.

Contact: Jim Gutierrez, Ph.D., P.E. Senior Bridge Engineer, at (916) 227-8256
California, Department of Transportation Engineering Services,
Office of Earthquake Engineering
1801 30th Street Sacramento, CA 95816

The structural adhesive used to attach the carbon composite wrap to the concrete substrate must be a highly-filled epoxy material having the minimum properties listed in Table 1:

Table 1 Structural Adhesive Minimum Properties

PROPERTIES	MINIMUM VALUES	ASTM TEST METHOD
Tensile strength	9,600 psi	D 638
Elongation at break	4.4%	D 638
Modulus of elasticity 7 days	390,000 psi	D 638
Flexural strength	6,700 psi	D 790
Shear strength 14 days	3,500 psi	D 732
Deflection temperature	47 C	D 648
Water absorption	0.03%	

The protective top coat must be concrete gray in color and must be in accordance with the FRP sheet manufacturer's recommendations.

Using more than one FRP sheet and adhesive composite system in a project is not permitted.

Submit the following for review and/or approval:

1. List of all materials and manufacturers, with material safety data sheets and storage and handling requirements.

2. FRP sheet and adhesive composite system product data, submitted by the FRP system supplier, indicating physical properties, chemical properties, technical specifications, installation instructions, and maintenance instructions for the system.

3. Independent test results that verify that the tensile properties and durability requirements stated above are met.

4. Manufacturer recommended repair procedures to be used for correcting defects that might be found during inspection or QC/QA testing.

5. Details of the FRP sheet and adhesive composite system including the method of application, epoxy impregnation, and curing.

6. Drawings that detail the geometry, placement and orientation of the carbon fibers to mee the coverage and lap length shown on the drawings.

7. Details of any construction device or access device that may be attached to the structure during construction.

8. List of Quality Control (QC) personnel to be employed, their work history and training.

c. Construction. Apply two layers of FRP to the columns shown on the plans. Each individual layer of FRP must meet the material requirements.

Quality Control is the responsibility of the Contractor. Because of the nature of this work, continuous quality control monitoring must be performed. Employ one or more Quality Control (QC) Inspectors in order to provide continuous monitoring of the work of this special provision. The QC Inspector(s) must have full stop-work authority based on quality and technical merits. The QC Inspector(s) must have authority to discuss the quality of the work with the Engineer and to make available all documents and records related to the work on demand, at any time, with or without the presence of other Contractor personnel. The QC Inspector(s) must have had adequate training in this work to be able to make decisions regarding quality and technical merits. QC Inspector(s) having specialized expertise may be employed to perform these functions for distinct phases of the work under this special provision. Submit the name(s), training and previous work history of all the QC Inspector(s), and the phase of work that they will be involved with, to the Engineer for review and approval prior to their employment. QC Inspector(s) may not be substituted without prior written approval by the Engineer.

The FRP sheet and adhesive composite system supplier must provide an on-site representative

specifically trained in the installation of FRP sheets on concrete substrate. The FRP sheet and adhesive composite system supplier on-site representative may also serve as the QC Inspector for the FRP system, provided that they perform continuous monitoring and inspection during construction of that phase of the work.

Follow the installation directions given by the FRP sheet and adhesive composite system suppliers' on-site representative and as documented in the submittals. Schedule installation such that the ambient air temperature remains within the allowable limits for the material used during the entire application and curing process. Specific aspects of installation must be as follows:

Remove unsound or loose concrete and patching of columns, and prepare the surface to be patched, prior to installation of the FRP sheet and adhesive composite system as detailed in the plans and proposal. Supply patching mixtures in accordance with Table 703-1. Form, finish, and cure the patches in accordance with subsection 712.03.O and as recommended by the FRP sheet and adhesive composite system supplier prior to application of the FRP sheet system.

Grind uneven surfaces, protrusions, and sharp edges on the concrete smooth, and round, or bevel all corners by grinding as recommended by the suppliers on-site representative. Remove dust from surface grinding by using an oil-free air blower or other suitable means. Clean the concrete surface as recommended by the suppliers' on-site representative. The suppliers' on-site representative must inspect and certify that the surface preparation has been performed in accordance with their recommendations.

Apply the FRP sheet and adhesive composite system to the concrete substrate according to the suppliers on-site representative's recommendations. However, do not apply the FRP sheet and adhesive composite system when the ambient temperatures are lower than 40 degrees F, when the concrete surface is wet, when the dew point is within 5 degrees F of the concrete surface temperature, or when the relative humidity is greater than 80 percent.

After allowing at least 24 hours for initial resin cure to occur, the suppliers' on-site representative must perform a visual and acoustic tap test inspection of the applied FRP sheet in the presence of the Engineer. Repair delaminations larger than 0.25 square inches. Voids between 0.25 to 2.5 square inches must be repaired by resin injection or cut around the FRP sheet and replace as for larger voids. For larger voids, cut around the perimeter of the damaged area and peel off the surface. Smooth the surface, apply additional FRP sheet and adhesive composite system with at least a 4 inch overlap onto the surface, and cure in place.

Provide a complete cure of the FRP sheet and adhesive composite system before applying the protective top coat. Protect the work during the curing process from large temperature variations and monitor the temperature of the curing surface. Maintain the temperature of the entire curing surface within the range recommended by the manufacturer and monitor the surface temperature at the beginning and ending of each shift.

Apply the protective top coat according to the manufacturer's recommendations.

d. Workmanship Warranty. The Contractor shall unconditionally warrant to the MDOT the FRP sheet and adhesive composite system applied to the bridge to be free of defects, as hereinafter defined and determined by visual and audible inspection for a period of 2 years from the date of final inspection by the Engineer. On projects that extend over more than 1 year in

contract duration, the warranty period will be for 2 years from the project acceptance date. The warranty called for must be on a warranty form furnished by MDOT, a copy of which is included in this special provision. This warranty must be submitted to the MDOT Financial Services Division prior to the award of the contract.

The FRP sheet and adhesive composite system will be considered defective if any of the following conditions are discovered within the 2 year warranty period:

1. The occurrence of visible or audible delamination of the FRP sheet from the concrete substrate.

2. FRP sheet applied over dirt, debris, or blasting debris not removed during concrete cleaning.

3. Incomplete FRP system thicknesses less than the minimums specified in the FRP system specifications.

4. Damage to the FRP system caused by the Contractor while removing scaffolding or performing other work.

Warranty Evaluation. During the month before the end of the 2 year warranty period, or earlier, the Engineer will inspect the bridge thoroughly for the FRP sheet and adhesive composite system defects listed. This inspection will be done by MDOT personnel using equipment provided by the Contractor. The inspection equipment must be MIOSHA approved, vehicle-mounted, and provide access to all areas of the structure. Traffic control and signing is the Contractor's responsibility. The Contractor may accompany the Engineer during this inspection. The Engineer will determine if there are defective areas present as defined above.

Acceptance by the Engineer of any portion of the work during the original contract FRP application will not relieve the Contractor of the requirements of this warranty.

Corrective Work. All defective areas identified by the Engineer must be repaired by the Contractor in a manner approved by the Engineer. The FRP sheet and adhesive composite system supplier must provide field supervision for the repair work on the FRP sheets. The directions of the on-site representative must be followed. All repair procedures and Progress Schedule must be submitted in writing to the Engineer for review and approval prior to any work. All FRP system repair work will be done the same season as the inspection, unless the seasonal limitations stated in the specifications prevents the completion that season. In this case the corrective work will be completed the following season. The Engineer must be given at least 2 weeks notification before the Contractor begins the corrective work and must be allowed full inspection of all operations and provided safe access to the areas being repaired.

Supply verification to the MDOT Financial Services Division that the required liability insurance is in effect during the period the corrective work is being done.

When completing any identified corrective work the Contractor must maintain traffic as described in the original contract documents.

Special Supplemental Performance and Lien Bonds. Furnish, in addition to the regular performance and lien bonds for the contract, a supplemental performance bond to MDOT. The bond must be in the sum of 100 percent of the original total contract amount for "Column Wrap

with FRP Sheet." The bond is to secure the performance by the Contractor of correction work on any FRP system defects that he is directed by MDOT to perform and must be in force for the period covering the 2 year warranty and the time required to perform any corrective work covered by the warranty. Use the form provided by the MDOT, a copy of which is included in this special provision, and executed in accordance with the requirements of this special provision. If corrective work is required, the Contractor must provide a supplemental lien bond (form provided by MDOT) that is in effect for the duration of the corrective work. The supplemental performance and lien bonds must be in all respects satisfactory and acceptable to MDOT, executed by a surety company authorized to do business in the State of Michigan.

Upon completion of the work and final inspection of the project, the supplemental performance bond must become effective and must continue in full force and effect until such time as MDOT will, in accordance with the FRP Quality Warranty, advise the Contractor that there are either no FRP sheet and adhesive composite system defects, or, if the Contractor has been notified that there are defects, said defects have been repaired by the Contractor to the satisfaction of the MDOT as specified under the FRP Quality Warranty. The Engineer will withhold in reserve an amount equal to 100 percent of the total contract amount for "Column Wrap with FRP Sheet" until the Supplemental Performance Bond has been received.

Permit. If corrective work is required, the Contractor must apply to the Region Utility-Permits Engineer for a permit to work within MDOT right-of-way (Form 2205). The permit fee and an individual permit performance bond will not be required. The permit insurance requirements however, will apply.

e. Measurement and Payment. The completed work, as described, will be measured and paid for at the contract unit price using the following contract item (pay item):

Contract Item (Pay Item)	**Pay Unit**
Column Wrap with FRP Sheet	Square Foot

Column Wrap with FRP Sheet includes only the area of concrete column surfaces covered by the sheet and includes all costs to furnish and install all layers of the sheet, including materials and labor. The cost of shaping, smoothing, grinding, cleaning, and preparing the concrete surface for application of the FRP sheet and adhesive composite system is included in the payment. Individual layers of the FRP sheet and adhesive composite system will not be paid for separately.

Concrete removal, patching, forming, and placement will be paid for separately.

All costs associated with performance of the warranty work, including the required maintaining traffic, the required supplemental performance and lien bonds, and the required permit insurance will not be paid for separately but will be considered to be included in the Contractor's overhead and administrative costs.

MICHIGAN DEPARTMENT OF TRANSPORTATION
INITIAL ACCEPTANCE FOR FRP SYSTEM QUALITY WARRANTY

CONTRACT ID: _____

CONTRACT SECTION: _____ JOB NUMBER: _____

SURETY NAME: _____

SURETY ADDRESS: _____

CONTRACTOR NAME: _____

CONTRACTOR ADDRESS: _____

IDENTIFY EACH JOB NUMBER, LOCATION AND WORK SEPARATELY

JOB NUMBER	ROUTE NUMBER	STRUCTURE NUMBER	STRUCTURE DESCRIPTION	DATE ACCEPTED	PROJECT ENGINEER

INITIAL ACCEPTANCE OF WARRANTY WORK APPROVAL

CONTRACTOR'S SIGNATURE: _____

ENGINEER'S SIGNATURE: _____

ACCEPTANCE DATE: _____

cc: Surety Company, Financial Services - Payments

MICHIGAN DEPARTMENT OF TRANSPORTATION
FRP SYSTEM QUALITY WARRANTY BOND

Bond Number _____

KNOWN ALL MEN BY THESE PRESENTS:

That we,_____ (hereinafter called the "Principal"), and _____, a corporation duly organized under the laws of the State of _____ and duly licensed to transact business in the State of Michigan (hereinafter called "Surety"), are held and firmly bound unto the Michigan Department of Transportation (hereinafter called the "Obligee""), in the sum of _____ Dollars ($), for the payment of which sum well and truly to be made, we, the said Principal and the said Surety, bind ourselves, our heirs, executors, administrators, successors and assigns , jointly and severally, firmly by these presents.

WHEREAS, the said Principal has heretofore entered into a contract with the Michigan Department of Transportation dated _____ under Contract ID _____and;

WHEREAS, the said Principal is required to guarantee the work of applying FRP sheet System installed under said contract, against specific pavement defects which may develop during the period of two (2) years beginning the date of the Acceptance Date of Construction by the Obligee.

In no event shall losses paid under this bond aggregate more than the amount of the bond.

NOW, THEREFORE, THE CONDITION OF THIS OBLIGATION IS SUCH, that if said Principal shall faithfully carry out and perform the said guarantee, and shall, on due notice, repair and make good at its own expense any and all specific pavement defects in the said work which may develop during the period specified above or shall pay over, make good and reimburse to the said Obligee all loss and damage which said Obligee may sustain by reason of failure or default of said Principal so to do, then this obligation shall be null and void; otherwise shall remain in full force and effect.

PROVIDED HOWEVER, that in the event of any default on the part of said Principal, a written statement of the particular facts showing such default and the date thereof shall be delivered to the Surety by registered mail, within thirty (30) days after the Obligee or his representative shall learn of such default and that no claim, suit or action by reason of any default of the Principal shall be brought hereunder after the expiration of thirty (30) days from the end of the warranty period as herein set forth.

Signed this _____ day of _____, _____.

Contractor _____

By _____

Surety _____

By _____

Attorney-In-Fact