SECTION ### Concrete Deck Strengthening using Near Surface Mounted Fiber Reinforced Polymers

###-1 Description:

The work under this section shall consist of furnishing all labor, materials, and equipment necessary to strengthen or repair existing concrete deck through the installation of fiber reinforced polymer (FRP) as a Near Surface Mounted (NSM) system for deck surface, in accordance with the requirements of these specifications and as shown on plans. NSM system consists of FRP reinforcement bars or strips which are inserted into a saw cut groove filled with an epoxy resin for the concrete deck surface.

###-1.01 Design Requirements:

The design of the FRP composite system shall conform to ACI 440.2R and shall provide structural strengthening or repair for concrete decks as shown on the plans and per the manufacturer's requirements and these special provisions. The contractor shall submit design calculations of the FRP composite system for approval to the Engineer. The design calculations shall be signed and sealed by a registered Professional Civil Engineer in the State of Arizona and conforming to requirements set forth in the ICC ES AC125. FRP design values must be lower than the calculated mean determined from the test results of the ASTM D 7565 and/or ASTM D 3039 field test specimens.

###-1.02 Submittal Requirements:

The contractor shall submit shop drawing, design calculations and all supplemental data in accordance with the requirements of subsection 105.03 of the standard specifications to the Engineer for review. The submittal shall be complete and shall include the items listed below:

(A) Materials that are used shall include the following:

(1) Names of materials' suppliers.

(2) Technical data and safety data sheets.

(3) Commercial designation/name of the materials.

(4) Materials properties for dry fiber shall include the following:

(a) Tensile strength.

(b) Tensile modulus.

(c) Density.

(d) Effective dry fiber thickness.

(5) Material properties for resin, including primers and coatings shall include the following:

(a) Mechanical properties of resin.

(b) Mix ratio by weight and volume.

(c) Pot life and shelf life.

(d) Resin gel time, mixing, and application temperature range.

(e) Cure time

(f) Application rate.

(6) Material properties for each FRP composite system shall include the following:

(a) Number of layers.

(b) Ultimate tensile strength.

(c) Elongation at break.

(d) Tensile modulus.

(e) Effective composite thickness.

(f) Percent fiber volume fraction.

(g) Direction and orientation of the primary fiber.

(B) Contractor shall submit data sheets for all materials to be used at the job site in accordance with OSHA 29 CFR 1910.1200.

(C) Details of ends of fiber and splices including overlaps and staggered construction.

(D) Details of transition in composite thickness.

(E) The Manufacturer's Process Specification Manual for the selected system, including:

(1) Installation procedures.

(2) Surface temperature and moisture limitations.

(3) Application time limits between successive layers.

(4) Plans for curing.

(5) Methods for fabricating and field/laboratory testing.

(6) Methods to replace and repair delaminated or defective sections of FRP composites.

(7) Name of the independent testing facility to be used to test samples.

(8) Storage and handling of materials.

(F) Supplemental data shall include test data provided by the manufacturer of the FRP composite system showing the performance of the system in similar applications, with a description of the method of installation. The results of the testing shall indicate resistance to the anticipated environment, including moisture, temperature extremes and chemicals normally associated with exposed steel. Untested systems shall not be used.

(G) Measures for protecting workers and the public from hazardous materials that may be generated during construction.

(H) Measures to permit application and curing of the composites during inclement weather.

(I) Measures for preventing materials, equipment, and debris from falling from the overhead structure.

A Certificate of Compliance for the FRP composite system and the components thereof shall be furnished to the Engineer in conformance with the requirements of subsection 106.05(B) of the standard specifications.

Upon submission, the Department will review all drawings and supplemental data in 30 calendar working days. If a second submittal is required, the contractor's schedule shall allow for an additional 10 days for review.

###-1.03 Quality Assurance:

(A) General:

The contractor shall inform workers having access to the work area of the contents of the applicable material safety data sheets (MSDS) and of potential health and safety hazards and protective controls associated with materials used on the project. The contractor shall train workers in the safe handling and application of FRP materials and the exposure limit for each material that the worker will use or otherwise be exposed to during the course of the project. The contractor shall instruct personnel that have the potential to need respirators and masks in the use and maintenance of such equipment.

(B) Contractor:

The contractor shall have completed a minimum of five FRP composite strengthening projects on vertical surfaces and a minimum of one of those projects using the manufacturer's composite system. The contractor shall submit to the Engineer at the preconstruction meeting the dates of work, type, description, and amount of work performed, the type of FRP system installed for each project, and

the name and telephone number of a contact person or owner for which the work was completed.

(C) Field representative

A field representative of the contractor shall be present onsite during the installation of the FRP system. The contractor shall submit the name and qualifications for its field representative who will perform the actual work supervision, the date certification course completed, and a list of a minimum of five completed FRP composite strengthening projects of similar applications, one using the manufacturer's composite system. The contractor shall submit to the Engineer at the preconstruction meeting the dates of work, type, description, and amount of work performed, and the name and telephone number of a contact person or owner for which the work was completed.

(D) Applicators:

(1) Training:

The contractor shall submit certification that the FRP composite applicators have completed, as a minimum, a certification course provided by the FRP manufacturer, which includes hands-on application of FRP systems to concrete substrates.

(2) Experience:

Only qualified applicators meeting the requirements of section ###-1.03 (B) and those having prior experience in the specified surface preparation and coating applications shall be assigned to perform the work described herein. The contractor shall submit a syllabus of the certification course, as well as listing of past application projects completed by the applicators. The contractor shall include the dates of work, type, description, and amount of work performed, and the name and telephone number of a contact person or owner for which the work was completed.

(E) Regulatory Requirements:

The Contractor shall ensure that the composite system used does not release volatile organic compounds (VOC) into the air in excess of the most restrictive of National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (RELs), Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) or American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Values (TLVs®) for worker or occupant exposure during installation and/or over the useful life of the structure. If VOCs exceed any of the aforementioned exposure limits during installation or use, the contractor shall provide additional ventilation for the duration of the excess outgassing. The Contractor shall ensure that at no time will they exceed Short-

Term Exposure Limits (STEL), even if additional ventilation or air supply is provided.

The contractor shall provide the necessary equipment to comply with these requirements. Once cured, the contractor shall ensure the FRP composite system does not exhibit any detectable odor at a distance of one foot from the FRP surface.

The contractor shall submit certification that resins proposed for use meet Federal VOC regulations and those of the local Air Pollution Control Districts having jurisdiction over the geographical area in which the project is located.

(F) Pre-installation Meetings:

Prior to commencement of any work, the contractor shall arrange and conduct a meeting between the Engineer, contractor, and the independent special inspector to discuss the project requirements. The meeting shall consist of a review of all the requirements of the specification and overall project a review and discussion of all aspects of the project including containment, environmental control, surface preparation, strengthening system application, quality assurance, schedule requirements, and safety.

The contractor shall request clarification of any ambiguities and advise the Engineer of any potential conflicts. The contractor shall request clarification from the Engineer regarding any technical requirements that appear improper or inappropriate.

###-1.04 Delivery, Storage, and Handling:

(A) Labeling:

The contractor shall deliver the polymer resin materials in original factory-sealed containers with the manufacturer's labels intact and legible with verification of product nomenclature, manufacturer's name, product identification and batch number, date of manufacture, shelf life, and expiration date. The contractor shall not use the polymer resin materials that have exceeded the shelf life or expiration date.

(B) Storage:

The contractor shall store materials in a covered, well-ventilated area protected from exposure to any detrimental conditions including airborne contaminants, dirt, dust, sunlight, temperatures lower than 40 degrees F or greater than 100 degrees F, rainfall, sparks, or flame and shall be stored in accordance with the manufacturer's requirements. The Contractor shall store polymer resins separate from their hardeners.

###-1.05 Site Conditions:

(A) Environmental Requirements:

(1) Application Temperature:

The primers, saturating resins, and adhesives shall not be applied to cold or frozen surfaces. When the surface temperature of the concrete surface falls, below a minimum level or above a maximum level, as specified by the FRP system manufacturer, the work will cease until both the air and concrete temperature is within the range of the manufacturers' specified application temperature. Supplemental sources of heat shall not be used to raise the air or concrete surface temperature unless approved by the FRP composite system manufacturer.

(2) Wet or Damp Surfaces:

The contractor shall not apply resins and adhesives to damp or wet surfaces unless they have been formulated for such applications.

(3) Breathable Surfaces:

Concrete surfaces shall not be completely covered with FRP composite systems. The Engineer and contractor shall ensure that the FRP composite system is designed to allow air and vapor transmission in accordance with the manufacturer's recommendations.

(B) Existing Conditions:

The contractor should field verify all the existing conditions and review the as built drawings. Work Coordination

(C) Work Coordination:

The contractor shall coordinate work to minimize exposure of personnel present near the bridge, other contractor personnel, and visitors, to dust, mist, and odors from FRP system's preparation, application, and clean-up operations.

###-1.06 Warranty

The Contractor shall furnish a warranty (either by the manufacturer or FRP Installation Contractor) for the FRP composite system installation. The contractor shall ensure that the warranty covers the FRP composite system design, installation, bond to the substrate and interlaminar bond, as well as, mechanical property retention, and fabric-resin compatibility. The warranty shall run directly to the Department and shall cover a period of not less than 5 years from the date of the Department's acceptance.

###-2 Material Requirements:

###-2.01 FRP Composite System

(A) General:

The FRP composite system for the NSM System shall consist of FRP reinforcement bars/strips, epoxy resins, including primers, developed through material characterization and structural testing. The tensile modulus and strength shall be based on the cured composite. The surface of the FRP reinforcement bar/strip shall have a peel ply texture. The peel ply material shall be removed from the FRP strip prior to shipping to the jobsite.

The cured FRP reinforcement bars/strips shall conform to the requirements in Table 1:

Table 1

Properties at 72±2°F	GFRP Bars/strips	CFRP Bars/strips	Test method(1)
Ultimate tensile strength, in primary fiber direction, ksi, min	100	285	ASTM D 3039
Ultimate elongation, %, min	1.7	1.5	
Composite tensile modulus of primary fiber, ksi, min	8000	18,000	
Fiber volume, %, min	65	65	ASTM D 2584 or ASTM D 3171
Glass transition temperature, °F, min	180	180	ASTM D 3418 or ASTM D 4065
Coefficient of thermal expansion (CTE)			
CTE – Transverse direction	19 to 23 x 10^{-6} / C	74 to 104 x 10^{-6} / C	ASTM E 831
CTE – Longitudinal direction	6 to 10 x 10^{-6} / C	-9 to 0 x 10^{-6} / C	ASTM E 831

Notes:
(1) Subject to approval of the Engineer, other test methods, such as those published by Suppliers of Advanced Composite Materials Association or manufacturer's published Quality Control Procedures may be used when equivalency and suitability have been documented.

Resins for the FRP composite system shall be system compatible epoxy. Epoxy resins for all FRP composite systems shall conform to the provisions in section 1015 of the standard specifications, except that no State Specification Number will be required. Carbon and E-Glass fibers shall be properly sized to be compatible with resin used. The final resin protective coat must be formulated to resist cracking and chipping. All components of epoxy resin must be within their shelf life

and expiration date at the time of the FRP composite system installation. FRP composite system materials must be protected from dirt, moisture, chemicals, extreme temperatures, and physical damage prior to and during FRP composite system installation.

(B) NSM FRP reinforcement bars/strips:

FRP reinforcement bars/strips are fabricated using a pultrusion process or resin transfer molding process. The reinforcement bars/strips are inserted into a sawcut groove filled with compatible resin at the deck surface per the FRP composite system manufacturers recommendations.

###-2.02 Primer:

The primer shall be a low viscosity epoxy used to fill any surface microcracks of the concrete surface and enhance the bond between the FRP system and the concrete substrate.

###-2.03 Finish and Coating

The contractor shall perform a final finish and apply coatings per these special provisions and the plans.

###-2.04 Accessories:

(A) Anchors:

The contractor shall install anchors for the FRP system per the recommendation of the FRP system manufacturer and as shown on the Plans.

(B) Miscellaneous:

The contractor shall provide other materials as needed for the proper installation of the complete composite system as specified within these special provisions.

###-2.05 Mixes:

The resin components shall be mixed in accordance with the FRP composite system manufacturer's recommended procedure. The contractor shall ensure that all resin components are at a proper temperature and are mixed in the correct ratio until there is a complete mixing of components and a uniform color is achieved. The contractor shall identify and mix resin in quantities sufficiently small to ensure that all mixed resin can be used within the resin pot life. The contractor shall not use mixed resin that exceeds its pot life as defined by the FRP composite system manufacturer.

###-2.06 Fire Protection:

The FRP system shall meet requirements for Class 1 fire rating in accordance with ASTM E 84 and the flame spread index shall not be greater than 50 when tested in accordance with ASTM E 84 and meet the requirements of the ACI440-2R-17 Section 9.2.1.

###-3 Construction Requirements:

###-3.01 Preparation:

(A) Materials Testing:

The contractor and special inspector shall ensure that delivered FRP materials to the project meet the specified requirements prior to starting the project and FRP composite system installation. This may require laboratory testing. The Engineer will reject all materials that do not meet the minimum requirements, as specified in Table 1 (Section ###-2.01(A)) of these special provisions.

(B) Substrate Repair:

Before working on the concrete surfaces, the contractor shall check for unsound concrete at areas where the FRP composite system will be installed. Unsound concrete is defined as concrete that emits a dead or hollow sound when chained or tapped with a metal tool. The Engineer shall determine the soundness of concrete and the contractor shall inform the Engineer of additional unsound concrete areas discovered prior to the FRP composite system installation. The contractor shall remove and patch unsound concrete in accordance with Section ###-3.01(B)(1).

Cracks on the concrete surface to receive the FRP composite system shall be assessed and inspected by the Engineer prior to any repair work. The Engineer shall specify the crack repair work necessary based on the plans, the FRP composite system manufacturer's recommendations, and in accordance with the crack repair provisions of ACI PRC-224.1 and Section ###-3.01(B)(2).

(1) Unsound Concrete Repair:

The concrete patching material shall be a high early strength pre-mixed structural concrete patch containing cementitious materials with a minimum 28-day compressive strength (f'c) of 4,000 psi. The patch material shall be listed on the ADOT Approved Product List.

The work shall include removal and disposal of spalling concrete and cleaning corroded reinforcing. The objective of this repair is to provide adequate bonding of the FRP, provide protection to the existing reinforcement, restore the original shape of the concrete, and prevent future water penetration.

The locations on the concrete substrate that require repair shall be field identified and marked by the Engineer and confirmed by the contractor. After all the concrete repair locations are marked, the contractor shall remove only loose and spalling concrete as directed by the Engineer and in accordance with ACI 546R-14 and ICRI No. 03730.

Remove loose or delaminated concrete around reinforcement on existing concrete in accordance with ACI 546R-14 and ICRI No. 03730. After removal of concrete, undercut all exposed corroded reinforcement with a minimum 3/4-inch clearance between exposed reinforcement and surrounding concrete or 1/4-inch larger than the largest aggregate in repair patching material, whichever is greater. If non-corroded reinforcing steel is exposed during the undercut process, care shall be taken not to damage the reinforcement's bond to the surrounding concrete. If the bond between the reinforcement and the concrete is broken, undercutting of the reinforcement shall be required. Any reinforcement which is loose shall be secured in place by tying to other secure bars or by other approved methods. Where existing reinforcement is exposed, Engineer shall visually observe reinforcement before new concrete cover is installed. The contractor shall repair concrete to its original dimensions.

Existing reinforcement shall be thoroughly cleaned to remove all rust, corrosion, and scaling as needed to promote maximum bonding of the replacement material. All dirt, grease, and other deleterious materials shall be removed from the repair areas and an approved bonding agent shall be applied to repair areas prior to placement of concrete according to the manufacture's recommendations. Tools used for concrete removal shall be approved by the Engineer prior to the start of any concrete repair work. Equipment and tools shall not be used to remove spalling concrete, which in the opinion of the Engineer, can cause the removal of excess quantities of sound concrete along with spalling concrete. After patch material has properly cured concrete shall receive a penetrating crack sealer. Penetrating crack sealer shall cover all exposed concrete surfaces as specified by the engineer and plans.

Concrete patch repair work to bring concrete to original dimensions shall not take place until epoxy crack injection work is completed in accordance with the provisions in Section ###-3.01(B)(2).

(2) Crack Repair:

Crack repairs consisting of epoxy injection into the existing cracks in concrete substrate shall conform as specified herein. Crack locations will be identified and approved by the Engineer. Any cracks requiring epoxy injection in concrete surfaces not receiving FRP composite system shall be identified and approved by the Engineer.

The epoxy resin product shall conform to the physical requirements of ASTM C 881. The product shall be on the current ADOT Approved Products List and shall

conform to the requirements of Section 1015. The equipment used to meter and mix the two injection adhesive components and inject the mixed adhesive shall be portable, positive displacement type pumps with interlock to provide positive ratio control of exact proportions of the two components at the nozzle. The injection equipment shall have automatic pressure control capable of discharging the mixed adhesive at any preset pressure up to 160 +/- 5 psi. The equipment shall have the capability of maintaining the volume ratio for the injection of the adhesive prescribed by the manufacturer of the adhesive within a tolerance of +/-5 percent by volume at any discharge pressure up to 160 psi. The injection equipment shall be equipped with sensors on both the component A and B reservoirs that will automatically stop the machine when only one component is being pumped to the mixer head. Before work is begun, the equipment shall be ratio and pressure checked. These checks may be done in the field or in the contractor's office before the equipment is brought to the field. If the equipment is tested in the office, a letter documenting the test results shall be supplied to the Engineer.

(a) **Surface Preparation:**

Prior to injection of the epoxy resin adhesive, the surface adjacent to the cracks or other areas of application shall be prepared so as to expose clean, sound concrete. The surface shall be cleaned of dirt, grease, oil, efflorescence, or other foreign matter which would be detrimental to the bond of the epoxy adhesive to the concrete. Use of acid or corrosives shall not be permitted for cleaning. The determination of the exact procedure to be used shall be the responsibility of the contractor.

(b) **Ports:**

The determination of the type, location and spacing of ports shall be the responsibility of the contractor.

(c) **Surface Seal:**

Surface seal material shall be applied to the face of the crack between and around the entry ports. For through cracks, the surface seal shall be applied to both faces. The surface seal shall have sufficient strength to withstand injection pressures of 250 psi. The surface seal material shall have sufficient time to reach adequate strength before the contractor proceeds with the injection.

(d) **Injection:**

The freshly catalyzed resin shall be dispensed into the ports at sufficient pressure and for adequate duration to fill crack completely. Before moving to the next port, the resin exiting an adjacent port shall be clear and free from impurities.

The contractor shall determine the order of injection at the various ports. The operation shall be conducted in such a manner as to minimize trapped air voids in the crack and to ensure a good bond between the epoxy and the concrete.

(e) Remove Surface Seal:

Upon completion of the injection operation, the contractor shall remove the surface seal flush with the existing surface where FRP is to be installed, the surface shall be prepared in accordance with Subsection ###-3.01(C).

(C) Saw cut groove for NSM System:

The sawcut groove for the NSM FRP composite system shall be made following provisions of ACI 440.2R. The contractor shall make a saw cut groove to accommodate the FRP reinforcement using a diamond saw and chiseling, as necessary. The groove dimensions shall be in accordance with plans and specifications and shall not exceed 1.5 times the largest cross-sectional dimension of the NSM-FRP reinforcement. The contractor shall take sufficient care to not damage the existing deck reinforcement. The soundness of the concrete surface shall be checked before installing the NSM FRP reinforcement strip/bar. The inside faces of the groove shall be cleaned to ensure an adequate bond to the concrete. The resulting groove shall be free of laitance or other compounds that may interfere with the bond.

The contractor and special inspector shall test the concrete deck moisture using ASTM D 4263 prior to the installation of the FRP composite system to ensure the concrete moisture levels are within the FRP manufacturer's product tolerances and project requirements.

###-3.02 Installation of FRP:

(A) General:

The contractor shall stagger lap splices a minimum of 3 feet unless noted otherwise in the plans, shop drawings, or by the Engineer.

Overlap lengths shall be the maximum of the lengths either as recommended by the FRP composite system manufacturer or the plans but shall not be less than 18-inches. Overlapping shall be required for splices in the fiber direction of individual layers.

(B) Curing of Resins:

The contractor and special inspector shall inspect the primer and FRP composite system resin during the mixing process and after the FRP composite system has been installed to ensure proper cure according to the manufacturer's recommendation. Field modification of the FRP composite system resin chemistry is not permitted.

(C) Surface Finish:

The contractor shall apply paints and coatings prior to final FRP composite system resin cure for best results. If applying the paints and coatings after the FRP composite system resin has cured, the coating can be applied by performing an 80-grit abrasive blasting to break the gloss finish in preparation of a finish coating. Dust and residue shall be removed from all surfaces by flushing with clean water before applying the coating. The contractor shall ensure all surfaces are dry before applying the surface finish coating.

The contractor shall use coatings compatible with the FRP strengthening system in accordance with provisions of ASTM D 3359, Method A, with a minimum rating of 4A and applied in accordance with the manufacturer's recommendations. The contractor shall apply two finish layers of coating according to the coating manufacturer's instructions prior to full cure of the FRP system.

(D) Installation Procedure Modification:

Installation procedures may be modified to achieve maximum results, subject to approval by the Engineer. Procedural modifications approved by the Engineer prior to implementation are allowed.

(E) System Placement Tolerances:

The contractor shall follow the FRP composite system ply orientation and ply stacking sequence in accordance with the plans. The contractor shall ensure variations in angle from the intended direction of fiber alignment prescribed in the plans are less than 5 degrees.

###-3.03 Feature Compatibility:

(A) Weep Holes:

The contractor shall maintain all weep holes and ensure that no resin enters existing weep holes. Existing weep holes shall not be covered with the FRP composite system.

(B) Construction and Expansion Joints:

The contractor shall maintain all control and expansion joints and ensure that the FRP composite system does not bridge existing control and expansion joints.

###-3.04 Quality Control:

The contractor shall maintain quality assurance and quality control (QA/QC) programs and criteria for the project. The contractor and special inspector shall provide continuous inspection of the surface preparation and FRP composite system application to ensure full compliance with the specified requirements. The

contractor shall submit a quality assurance plan for installation and curing of all FRP composite system materials to include personnel safety issues, installer certification, application, and inspection of the FRP composite system, location, and placement of splices, curing provisions, means to ensure dry surfaces, quality assurance samples and cleanup. The plan shall indicate the testing that will be performed and identify the party or parties responsible for this testing.

The department shall hire and provide a qualified special inspector approved by the Engineer with experience and expertise in testing, evaluation, and installation of FRP composite systems. The special inspector shall not be an employee of the contractor or be financially associated with the contractor beyond the FRP composite system special inspection contract. The special inspector shall perform inspections in accordance with this specification and ICC ES AC178.

A continuous full-time inspection shall be provided by a qualified FRP special inspector approved by the Engineer to observe all aspects of the FRP composite system application as outlined in Section ###-3.08. The FRP composite system installation shall be inspected by the FRP special inspector during and immediately following the application of the FRP composite system.

The testing laboratory shall be one approved by the Engineer and the testing laboratory shall have experience and capabilities to properly test FRP materials. The testing laboratory shall submit the testing results to the Engineer for review and to verify compliance with the plans and project specifications.

###-3.05 Qualifications of Special Inspector

Prior to the start of construction, the special inspection agency shall provide written documentation to the Engineer demonstrating the competence and relevant experience or training of the FRP special inspectors who will perform the FRP special inspections and tests during FRP installation. Experience or training shall be considered relevant only where all the following documentation has been provided:

(A) Individual holding a master's or Ph.D. civil engineering degree with a structural emphasis from an ABET accredited university showing coursework and research associated with FRP.

(B) Experience pertaining to the testing, evaluation, and prior installation of FRP wet layup or NSM applications.

(C) Registered design professional in responsible charge licensed in the State of Arizona or design professional under the approved special inspection agency.

###-3.06 Field Testing:

(A) Mixed Resin Hardness:

(1) Description:

The contractor shall prepare two samples of each mixed resin, primers, binders, saturants, and adhesives, per day from two separate and non-consecutive batches of each. The resin samples should be a minimum of 1/8-inch thick and 2-inches in diameter. The mixed resin samples shall be retained for testing to evaluate curing progress.

(2) Testing:

The contractor shall evaluate the relative curing progress of the resin on the job site by measuring the hardness of the resin sample at 24-hours and 48-hours of cure in accordance with provisions of ASTM D 2240.

The contractor shall ensure the polymer resin exceeds the Shore Hardness reported by the FRP composite system manufacturer evaluated at the lowest air temperature for the curing time period. Take Measurements shall be taken at a minimum of three different points distributed over the resin specimen's surface at least 1/4-inch apart from each other.

(3) Remedial Measures:

In the event that measured hardness is less than the FRP composite system manufacturer's reported hardness, the contractor shall take remedial measures as specified by the manufacturer and the Engineer.

(B) NSM reinforcement bars/strips bond strength to concrete:

When directed by the Engineer and/or as shown on the plans, and prior to performing NSM FRP work, the contractor shall test 3 FRP strips on each side of the existing concrete barrier curb at location determined by the engineer using the (NSM) technique as described here in. An approved FRP special inspector is required to monitor the test.

The embedment groove length shall be a minimum of 18-inches. The FRP strip shall be placed transversely along the existing concrete barrier curb. The bonding of the FRP strips shall be constructed by the same crew scheduled to perform the work, using equipment, materials, mixing proportions, ambient temperatures, and procedures proposed for the work. The contractor shall perform bond strength testing to verify the in-place strip installation methods and pullout resistance. Bond strength testing shall consist of gradually loading of the FRP test strip until the maximum test load is held for the specified duration or a pullout failure occurred. The contractor shall monitor and record total movement of the test FRP strip relative to the epoxy resin during application of the test load. Test loads shall be

applied using a hydraulic jack supported by a reaction frame capable of supporting the test equipment without excessive deformation and no debonding. The hydraulic jack shall have full bearing upon the reaction frame. Test loads shall be maintained within 5-percent of the intended load throughout hold periods. Applied test loads shall be determined by using either a calibrated pressure gage or a load cell. Movements of the FRP strip shall be measured using a gage capable of measuring to 25-micrometers and recorded to the nearest 25-micrometer at the corresponding loads. The gage shall have sufficient capacity to allow the test to be completed without resetting the gage during the test. Unloading and repositioning of test equipment during testing will not be allowed.

The pressure gage shall be graduated in 75-psi increments or less and shall have an accurately reading dial at least 6-inches in diameter. Each jack and its gage shall be calibrated as a unit with the cylinder extension in the approximate position that it will have at final jacking force and shall be accompanied by a certified calibration chart. Each jack and pressure gage assembly shall be calibrated in conformance with the provisions for jacks used to stress tendons permanently anchored at greater than 25-percent of the ultimate tensile strength in Section 602-3.06. The load cell shall be calibrated by a certified laboratory and shall be provided with an indicator capable of measuring the test load in the FRP strip. The range of the load cell shall be such that the lower 10-percent of the manufacturer's rated capacity will not be used in determining the jacking force.

The contractor shall furnish complete results for each FRP strip tested including:

(1) Personnel

(2) Test loading equipment

(3) FRP reinforcement bar/strip location

(4) Groove width, depth, and length.

(5) Ambient temperature

(6) Dates and times of saw cutting and cleaning, FRP strip installation, and testing.

(7) The test load and amount of displacement when any displacement of the FRP strip relative to a fixed reference point occurs.

The contractor shall perform the bond strength test in the presence of the Engineer and an approved FRP special inspector per plans and specifications. The failure zone shall be fully contained in the concrete. A FRP strip test will be considered acceptable when all of the following conditions have been met:

(1) A pullout failure of the FRP strip occurs at a load exceeding the maximum test load of 15-kip or load as specified by the Engineer, whichever is greater.

(2) The maximum test load is held for 5 minutes.

FRP strip bond strength test that fails to meet acceptance criteria will be rejected. The Engineer or the approved FRP special inspector will determine the cause of failure for each rejected FRP strip bond strength test. Installation methods, if determined to be the cause of failure, will be rejected and the contractor shall include proposed alternative installation methods. The contractor, at the contractor's expense, shall install and test two additional FRP strips for each rejected FRP strip bond strength test at the direction of the Engineer or approved FRP special inspector until acceptance criteria are met. All materials used in the FRP strip bond strength test and existing concrete barrier curb shall become the property of the Contractor and shall be removed and disposed of in conformance with the provisions in Section 201-3.02.

###-3.07 QA/QC Inspection

(A) FRP Special Inspector Duties:

The FRP special inspector shall inspect the FRP composite system during and immediately following FRP composite system installation to ensure the FRP system installation was performed per the plans and special provisions. The FRP special inspector shall inspect the FRP composite systems, and all associated work as required by the applicable codes and as described in Section ###-3.04 of these special provisions. The FRP special inspector shall observe all aspects of onsite preparation and material application including surface preparation, resin component mixing, application of primer, application of resin, fiber sheet, curing of FRP composite system, and the application of protective coatings.

(B) Daily Inspection Records:

The FRP special inspector shall include the following information in daily inspection records:

(1) Date and time of installation.

(2) Ambient temperature, relative humidity, and general weather observations.

(3) Surface temperature of the concrete receiving the FRP composite system.

(4) Surface dryness of the concrete receiving the FRP composite system.

(5) Surface preparation methods of the concrete receiving the FRP composite system.

(6) Surface cleanliness of the concrete receiving the FRP composite system.

(7) Type of auxiliary heat source, if applicable.

(8) Fiber or pre-cured laminate batch number(s), manufacturer, and location in structure.

(9) Batch numbers, expiration dates, mix ratios, mixing times, and mixed color of all resins, including primers, putties, saturants, adhesives, and coatings mixed for the day.

(10) Observations of progress of cure of resins.

(11) Conformance with installation procedures.

(12) Pull-off test results: bond strength, failure mode, and location.

(13) FRP composite system properties and test results from witness panel tests, if required.

(14) Location and size of any delaminations or air voids.

(15) General progress of work.

The FRP special inspector shall submit daily inspection and progress reports to the Engineer and contractor.

(C) Void Detection:

After allowing at least 24-hours for initial resin cure to occur, the FRP special inspector shall perform a visual and acoustic tap test inspection of the layered FRP composite system surface. Other methods for detecting voids can be employed if approved by the engineer. The FRP special inspector shall mark voids requiring corrective action in accordance with the specified FRP composite system maintenance and repair procedures per FRP system manufacturer and per Section ###-3.09.

(D) Delaminations:

(1) Description:

The FRP special inspector shall evaluate the cured FRP composite system for delaminations or air voids between multiple plies or between the FRP composite system and concrete interface. Inspection methods that are used shall be capable of detecting delaminations of 1-square inch or greater. The special inspector shall submit all delaminations or other anomalies to the Engineer for evaluation and an appropriate remedial measure per the provisions in Section ###-3.09 shall be taken.

(2) Wet Lay-up Systems:

Small delaminations or air voids less than 1-square inch each shall be considered permissible, so long as the delaminated area is less than 5-percent of the total laminate area and there are no more than ten such delaminations or air voids per 10-square feet. The special inspector shall submit all delaminations or other anomalies to the Engineer for evaluation and an appropriate remedial measure per the provisions in Section ###-3.09 shall be taken.

The contractor shall repair large delaminations or air voids, greater than 25 square inches by selectively cutting away the affected sheet and applying a sheet patch of equivalent plies overlapping the undisturbed FRP composite system by a minimum of 4-inches on all sides. The contractor may use anchors in reticent corners where overlapping is not possible as approved by the Engineer. The number and locations of the anchors shall require approval by the Engineer.

Delaminations or air voids greater than 1 square inch and less than 25 square inches may be repaired by resin injection or ply of FRP composite system replacement, depending upon the size and number of delaminations and their locations. A minimum of 4 inch lap on all sides of the delaiminations or air voids shall be provided where a new ply of FRP composite system is used. The contractor shall notify the Engineer which repair method will be used.

(3) Pre-cured Systems:

For pre-cured FRP systems, the FRP special inspector shall evaluate each delamination or air void and any repair shall be in accordance with the Engineer's direction.

(E) Fiber Orientation:

The FRP special inspector shall evaluate fiber or pre-cured laminate orientation by visual inspection. The FRP special inspector shall evaluate fiber waviness which is defined as a localized appearance of fibers that deviate from the general straight-fiber line in the form of kinks or waves. The FRP special inspector shall report fiber or pre-cured laminate misalignment of more than 5 degrees from that specified on the Plans (approximately 1 in/ft) to the Engineer for evaluation and acceptance.

(F) Record Retention:

The FRP Special Inspector shall retain the records of the inspections and witness panels test results throughout the warranty period.

The FRP Special Inspector shall retain samples of mixed resin and maintain a record of the placement of each batch throughout the warranty period.

Upon completion of repairs, the FRP Special Inspector shall re-inspect the FRP composite system to verify that the repair was properly installed.

The FRP Special Inspector shall evaluate the FRP composite systems and accept or reject it based on conformance or nonconformance respectively with the plans and special provisions. The FRP Special Inspector shall include FRP composite system material properties, as-built fiber orientation, presence of delaminations, cure of resins, and adhesion to substrate in the evaluation.

The contractor shall submit procedures to properly maintain the installed FRP composite system, as well as written manufacturer recommended repair procedures for future possible damage to the in-place FRP composite system.

###-3.08 Repairs:

(A) Remedial Measures for Defects:

In locations where the FRP composite system adhesion does not meet the minimum adhesion requirements, the FRP composite system shall be removed from the surface and a new FRP composite system shall be applied after the properly preparing the surface in accordance with Section ###-3.

###-3.09 Work Area Clean Up:

Upon completion of the work, the contractor shall remove staging, scaffolding, and containers from the work site. The contractor shall remove any FRP composite system, resin, and other deposits on adjacent surfaces and leave the entire jobsite cleaned to equal or better condition to that prior to the start of the job. The contractor shall place cloths, cotton waste and other debris, that might constitute a fire hazard, in closed metal containers removed at the end of each day and, dispose of all resins and adhesives properly as indicated on the Safety Data Sheet. The contractor shall store and transport all resins and adhesives as indicated in the Safety Data Sheet.

The contractor shall follow the directions of the Safety Data Sheet to contain and dispose of spent abrasive blast media properly as required by local authorities and shall contain all material to be discarded at the site until properly disposed of.

###-3.10 Method of Measurement:

The quantity of the FRP composite system used for concrete deck strengthening or repairs will be measured by the linear footage of the precured FRP reinforcement bar/strip. The quantity to be paid for will be the total area receiving the FRP composite system as shown on the plans.

###-3.11 Basis of Payment:

The accepted quantities of FRP composite system used for concrete deck strengthening, measured as provided above, will be paid for at the contract unit price per linear foot, complete in place, including removal of fins, sharp edges and protrusions and filling of voids or depressions in surfaces to receive the FRP composite system, job control testing, and cleaning and painting, the deck strengthened or repaired with the FRP composite system, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

No additional compensation will be made for any additional testing, materials, enclosures, or work required because of the use of a particular type of FRP composite system, the cost being considered as included in the contract item.