Section 12.1
Volume II
FIBER REINFORCED POLYMER COMPOSITES

12.1.1 PURPOSE

This procedure provides guidance for the development and implementation of the Quality Control Plan (QCP) for the manufacture, storage, and transportation of Fiber Reinforced Polymer (FRP) composites for Florida Department of Transportation (FDOT) projects. FRP composites, hereinafter referred to as composites, include glass, carbon, and basalt reinforced polymeric materials.

12.1.2 AUTHORITY

Code of Federal Regulations (CFR), Federal-Aid Policy Guide (FAPG), Subchapter G – Engineering and Traffic Operations, Part 637 – Construction Inspection and Approval, Subpart B – Quality Assurance Procedures for Construction

Sections 20.23(3)(a) and 334.048(3), Florida Statutes.

12.1.3 REFERENCES

Design Standards, Topic No. 625-010-003, Florida Department of Transportation

Florida Department of Transportation Standard Specifications for Road and Bridge Construction

American Society for Testing and Materials (ASTM) Standard Test Methods and Specifications, Philadelphia, Pennsylvania

American Association of State Highway and Transportation Officials (AASHTO), Part I Specifications, and Part II Tests, Washington, D.C.

Field Sampling and Testing Manual, Florida Department of Transportation

US Department of Transportation Federal Aviation Administration, Advisory Circular AC No. 21-26A

12.1.4 SCOPE

This procedure is used by composite producers to perform the required inspections and testing of composites during and after manufacturing. These requirements and activities pertain to the inspections, measurements, and necessary tests to substantiate that materials and composites are in conformity with the contract documents. The QCP provides the guidelines utilized by producers to consistently manufacture quality composite products in conformance with the ***FDOT Specifications*** and other ***Contract Documents.***

12.1.5 GENERAL INFORMATION

Producers are responsible for the production, inspection, documentation, storage, and shipment of the composites. The composites delivered to the project shall meet the requirements of the ***FDOT Specifications*** and other ***Contract Documents***.

12.1.6 PLANT QUALIFICATION PROCESS

12.1.6.1 General

Prepare the proposed Quality Control Plan (QCP) in accordance with ***Materials Manual Section 5.6***.

The QCP shall include procedures that ensure the quality of all incoming raw materials, the control of in-process manufacturing, and testing performed to evaluate the end product for conformity to contract requirements. In addition, the QCP shall include test standards to be used for nondestructive and destructive evaluations, visual inspection techniques during the manufacturing process, and product final acceptance. These standards define the acceptance or rejection criteria of manufacturing induced defects.

12.1.6.2 Review of Plant's Proposed Quality Control Plan

Submit the proposed QCP to the State Materials Office (SMO). Upon the producer's submittal of their QCP, the SMO will review the proposed QCP and make the necessary arrangements for the initial manufacturing facility qualification review in accordance with ***Section 12.1.6.3***.

In the QCP, include the work experience, qualifications, and responsibilities of the production and quality control personnel. Identify

the on-site Production Manager, General Manager, Quality Control Inspectors/Technicians, and Quality Control Manager. Identify the responsibilities for monitoring key quality attributes and quality control data. Include the applicable information required in ***FDOT Specifications Section 105***. Include a copy of any available repair methods frequently utilized to repair minor deficiencies.

12.1.6.3 Review of Product Qualification Testing

Submit to the SMO, a test report of the physical and mechanical property requirements in Table 1 and Table 2 as applicable for the types and sizes of FRP reinforcing produced. Qualification testing shall be conducted by an independent laboratory approved by the Department for performing the FRP test methods.

Three production LOTs shall be randomly sampled at the production facility by a designee of the SMO. The minimum number of specimens per production LOT and the coefficient of variation (COV) for the test results of each production LOT shall be as indicated in Table 1 and Table 2. Outliers shall be subject to further investigation per ASTM E178. If the COV exceeds the requirements listed in Table 1 and Table 2 the number of test specimens per production LOT may be doubled, a maximum of two times, to meet the COV requirement. Otherwise, the results shall be rejected. A production LOT is defined as a LOT of FRP reinforcing produced from start to finish with the same constituent materials used in the same proportions without changing any production parameter, such as cure temperature or line speed.

Table 1
Physical and Mechanical Property Requirements for Straight FRP Reinforcing Bars

Property	Test Method	Requirement	Specimens per LOT	COV
Fiber Mass Fraction	ASTM D2584 or ASTM D3171	≥70%	5[n]	≤15%
Short-Term Moisture Absorption	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%	5[m]	N/A
Long-Term Moisture Absorption	ASTM D570, Procedure 7.4; immersion to full saturation at 122°F	≤1.0%	5[m]	N/A
Glass Transition Temperature (Tg)	ASTM D7028 (DMA) or ASTM E1356 (DSC; T_m)/ASTM	≥230°F	3[m]	≤15%

Table 1 Physical and Mechanical Property Requirements for Straight FRP Reinforcing Bars				
	D3418 (DSC; T_{mg})	≥212°F		
Total Enthalpy of Polymerization (Resin)	ASTM E2160	Identify the resin system used for each bar size and report the average value of three replicates for each system	--	≤15%
Degree of Cure	ASTM E2160	≥95% of Total polymerization enthalpy	3[n]	≤15%
Measured Cross-Sectional Area	ASTM D7205	Within the range listed in Table 932-6	10[n]	≤15%
Guaranteed Tensile Load[a]		≥ Value listed in Table 932-6		
Tensile Modulus		≥6,500 ksi for BFRP and GFRP (Type 0) ≥8,500 ksi for BFRP and GFRP (Type III) ≥18,000 ksi for CFRP (Type I) Bars ≥ 22,400 ksi for CFRP (Type II) Strands		
Alkali Resistance with Load	ASTM D7705; Procedure B, set sustained load to 30% of value in Table 932-6; 3 months test duration, followed by tensile strength per ASTM D7205	≥ 70% Tensile strength retention for BFRP & GFRP ≥ 95% Tensile strength retention for CFRP	5[m]	≤15%
Transverse Shear Strength	ASTM D7617	>22 ksi	5[n]	≤15%
Horizontal Shear Strength[p]	ASTM D4475	>5.5 ksi	5[n]	≤15%
Bond Strength to Concrete, Block Pull-Out	ACI 440.3R, Method B.3 or ASTM D7913	>1.4 ksi for Type III Bars >1.1 ksi for Type 0 & II Bars >0.9 ksi for Strands	5[m]	≤15%

a – Guaranteed tensile load shall be equal to the average test result from all three LOTs minus three standard deviations.
n – Tests shall be conducted for all bar sizes produced.
m – Tests shall be conducted for the smallest, median, and largest bar size produced.
p – Only required for Type III and BFRP bars.

12.1.6.3.1 Additional Requirements for Bent FRP Bars For all bars produced by bending straight solid FRP bars before the resin is fully cured, the minimum inside bend radius shall be at least three times the nominal diameters for bar sizes 2 through 8; and four times the nominal diameters for sizes 9 through 11.

The straight portion of a bent FRP reinforcing bar shall be extracted with sufficient length for tensile testing according to Table 2. When the bent shape does not allow for the tensile testing of one of its straight portions, test specimens produced at the same time during the same production LOT shall be used.

Table 2
Physical and Mechanical Property Requirements for Bent FRP Reinforcing Bars

Property	Test Method	Requirement	Specimens per LOT	COV
Fiber Mass Fraction – Bent Portion[b]	ASTM D2584 or ASTM D3171	≥70%	5[m]	≤15%
Short-Term Moisture Absorption – Bent Portion[b]	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%	5[m]	N/A
Long-Term Moisture Absorption – Bent Portion[b]	ASTM D570, Procedure 7.4; immersion to full saturation at 122°F	≤1.0%	5[m]	N/A
Glass Transition Temperature – Bent Portion[b]	ASTM E1356 (DSC; T_m) /ASTM D3418 (DSC; T_{mg})	≥212°F	3[m]	≤15%
Degree of Cure – Bent Portion[b]	ASTM E2160	≥95% of Total polymerization enthalpy	3[m]	≤15%
Measured Cross-Sectional Area – Straight Portion	ASTM D7205	Within the range listed in Table 932-6	5[m]	≤15%
Guaranteed Tensile Load[a] – Straight Portion		≥ Value listed in Table 932-6		
Tensile Modulus – Straight Portion		≥6,500 ksi for BFRP and GFRP (Type 0 & III)		

Table 2 Physical and Mechanical Property Requirements for Bent FRP Reinforcing Bars				
Property	Test Method	Requirement	Specimens per LOT	COV
		≥18,000 ksi for CFRP (Type I) Bar ≥ 22,400 ksi for CFRP (Type II) Strand		
Alkali Resistance without Load – Straight Portion	ASTM D7705; 3 months test duration, followed by tensile strength per ASTM D7205	≥ 80% Tensile strength retention	5[m]	≤15%
Strength of 90° Bends	ACI 440.3, Method B.5 or ASTM D7914	> 60% Guaranteed tensile load listed in Table 932-6	5[m]	≤15%
Transverse Shear Strength – Straight Portion	ASTM D7617	>22 ksi	5[m]	≤15%
Horizontal Shear Strength[p]	ASTM D4475	>5.5 ksi	5[m]	≤15%
a – Guaranteed tensile load shall be equal to the average test result from all three LOTs minus three standard deviations. b – Bent portion specimens shall be extracted from a central location within a 90° bend. m – Tests shall be conducted for the smallest, median, and largest bent bar size produced. p – Only required for Type III and BFRP bars.				

12.1.6.3.2 Requirements for CFRP Strands

Producers shall submit to the SMO, a test report of the physical and mechanical property requirements in Table 3. Qualification testing shall be conducted by an independent laboratory approved by the Department for performing the FRP test methods. Three production LOTS shall be randomly sampled at the production facility by a designee of the SMO. The minimum number of specimens per production LOT and the COV for the test results of each production LOT shall be as indicated in Table 3. Outliers shall be subject to further investigation in accordance with ASTM E178. If the COV exceeds the requirements listed in Table 3, the number of test specimens per production LOT may be doubled a maximum of two times, to meet the COV requirement. Otherwise, the results shall be rejected. A production LOT is defined as a LOT of CFRP strand produced from start to finish with the same constituent materials used in the same proportions without changing any production parameter, such as cure temperature or line speed.

Table 3
Physical and Mechanical Property Requirements for CFRP Prestressing Strands

Property	Test Method	Requirement	Specimens per LOT	COV
Fiber Mass Fraction	ASTM D2584 or ASTM D3171	≥70%	10	≤ 15%
Short-Term Moisture Absorption	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0. 25%	10	N/A
Long-Term Moisture Absorption	ASTM D570, Procedure 7.4; immersion to full saturation at 122°F	≤1.0%	10	N/A
Glass Transition Temperature (T_g)	ASTM D7028 (DMA) or ASTM E1356 (DSC; T_m)/ASTM D3418 (DSC; T_{mg})	≥230°F ≥212°F	3	≤ 15%
Total Enthalpy of Polymerization (Resin)	ASTM E2160	Identify the resin system used for each bar size and report the average value of three replicates for each system	-	≤ 15%
Degree of Cure	ASTM E2160	≥95% of Total polymerization enthalpy	3	≤ 15%
Measured Cross Sectional Area	ASTM D7205	Within -5% to +10% of nominal values listed in Table 933-1	10	≤ 15%
Ultimate Tensile Strength (UTS)		≥ Value listed in Table 933-1		≤ 15%
Tensile Modulus		≥18,000 ksi for Bar; ≥ 22,400 ksi for 7-strand & 5mm Ø.		≤ 15%
Alkali Resistance with Load	ASTM D7705, 3 months test duration at 140 ± 5°F. Apply sustained tensile stress to induce 3000 micro-strain, followed by tensile test per ASTM D7205	Tensile strength retention ≥70% of UTS	5	≤ 15%
Creep Rupture Strength	ASTM D7337, 3 months test duration at laboratory	Equivalent sustained load ≥75% UTS	3	≤ 15%

Table 3 Physical and Mechanical Property Requirements for CFRP Prestressing Strands				
Property	Test Method	Requirement	Specimens per LOT	COV
	conditions. Apply sustained tensile load equivalent to 75% UTS, followed by tensile test per ASTM D7205	AND Tensile strength retention ≥90% UTS		

12.1.6.4 Manufacturing Facility Qualification Review

The Department will perform an initial qualification review of producers that intend to manufacture composites for the Department. An initial review is required for producers that submit their QCP and also for producers that have not provided products for the Department in excess of one year. In addition, routine manufacturing facility qualification reviews will be performed at least annually for all active producers.

12.1.6.5 Maintenance of Producer's Qualification

Upon the Department's satisfactory review of the proposed QCP, in compliance with ***Materials Manual Section 5.6***, and satisfactory manufacturing facility qualification reviews, the SMO will accept the proposed QCP and include the producer the Department's ***Production Facility Listing***. Any changes to a QCP must be submitted to the SMO and accepted prior to manufacturing product for the Department.

Producers that are on the Department's ***Production Facility Listing*** will be inspected in accordance with ***FDOT Specifications Section 105*** and the ***Materials Manual***.

12.1.7 FUNCTIONS AND RESPONSIBILITIES OF COMPOSITE PRODUCER

12.1.7.1 General

Producers are responsible for the quality of their finished composites. Facilities and qualified personnel must be provided to perform specified inspections and tests and maintain an acceptable QCP in compliance with the requirements specified herein and in applicable ***FDOT Specifications***.

12.1.7.2 Quality Control Manager

The Quality Control Manager shall ensure that the quality of the products at each manufacturing facility meets the quality requirements of the contract documents. The Quality Control Manager may serve in more than one manufacturing facility. The responsibilities of the Quality Control Manager include, but are not limited to, the following:

A. Maintain the quality control approval label and apply it to acceptable composites, or designate a qualified Quality Control Technician, who is working under the direct supervision of the Quality Control Manager to apply the plant approval label.

B. Be present, or designate a Quality Control Technician/Inspector working under the direct supervision of the Quality Control Manager to be present during the production of all composites that will be shipped to Department projects.

C. Perform and/or supervise the QC testing and inspection.

D. Ensure that the producer has a sufficient number of Quality Control Technician(s)/Inspector(s) to maintain adequate inspection and testing during the production of composites for Department projects. In lieu of permanent staff, testing at the plant may be performed by an engineering consulting firm or laboratory meeting the requirements of FDOT ***Specifications Section 105***.

E. Ensure that the testing equipment is maintained and calibrated in accordance with the applicable test methods and ***Specifications***.

F. Ensure that all inspections are performed by a qualified technician. Each composite product shall be inspected before shipment to the project site. Implement effective controls including Non-Destructive Inspection (NDI) techniques that result in a product meeting the ***Contract Documents***. These control processes shall be included in the QCP and approved by the Department. The following shall be addressed:

    1. A QCP including approved NDI procedures to be used.

    2. Periodic qualification of personnel conducting inspections. This includes regularly scheduled vision examinations and inspection of a standard with a known defect.

3. Establish realistic acceptance standards for use by process and final inspection personnel.

4. Calibration of equipment used in the inspection. Include any standard with known defects that is used for comparison. The calibration procedure shall provide for periodic requalification of any such equipment at specific time intervals.

5. An internal audit program that validates the effectiveness of the NDI.

G. Ensure that all materials used in the manufacture of the composites are from sources that meet the ***FDOT Specification*** requirements.

H. Maintain a daily production log that, at a minimum, includes fiber lot numbers, resin lot numbers, composite lot numbers, sizes and number of composites produced.

I. Ensure that all composites are properly stored and marked with the producer's name and other information that is required in the applicable ASTM or AASHTO Standards.

J. Maintain the files of material certifications, test data, and inspection results.

K. Arrange meetings with the Verification Inspector as needed.

L. Provide certifications attesting to applicable specification compliance and include a detailed listing of the composite type, size, and quantities.

M. Ensure that the composite joints/connections comply with any requirements of ***FDOT Specifications.*** In addition, perform any required testing on a periodic basis to ensure continuing compliance. Any testing required by the Department must be conducted in the presence of a representative of the Department.

12.1.8 QUALITY CONTROL OF RAW MATERIALS

12.1.8.1 General

The producer shall have an incoming material acceptance plan that ensures raw materials purchased to produce composite products are in

conformance with the ***FDOT Specifications***. Laboratory test reports that document actual test results for each batch of material received must be provided for review and approval. A material supplier's test report alone is not adequate documentation to substantiate that materials satisfy all ***FDOT Specification*** requirements. Samples of these materials shall be taken on a batch-to-batch basis and tested to verify the accuracy of suppliers' laboratory reports. Sample testing may be performed by the producer at their production facility or by an independent laboratory identified in the producer's QCP. Testing frequency shall be based on historical test results and may be decreased over time if results indicate that a source supplies consistent materials.

12.1.8.2 Fiber Reinforcements

The producer shall establish procedures in coordination with its material suppliers to control the quality of raw materials sources. For example, fibrous materials such as roving, tow, and fabric shall be tested for physical properties including tensile and modulus of elasticity. In addition, a means shall be developed to control the quality of fiber surface treatments, sizing, etc. Department Verification Inspectors may take samples, at each facility, from randomly selected LOTs at any time. A LOT is the entire volume of fibers represented by the raw material supplier's test report or the fiber producer's lot number.

Each LOT of basalt fibers must meet the requirements of Table 3 when tested using X-ray fluorescence (XRF). In addition, the fibers must be coated (sized) with a chemical intended for, and compatible with, both the fibers and the polymer matrix system.

Table 3
Chemical Constituent Requirements
for Basalt Fibers

Constituent/Parameter	Content by Weight %
SiO_2	50-60
Al_2O_3	7-20
$Fe_2O_3 + FeO$	7-15
CaO	6-12

Table 3 Chemical Constituent Requirements for Basalt Fibers	
Constituent/Parameter	Content by Weight %
MgO	3-9
Na_2O	< 5
TiO_2	0.1-2
K_2O	< 5
MnO	< 0.25
SO_3	< 0.2
Acidity Modulus (M_a), calculated using weight percentages of oxides by: $(SiO_2 + Al_2O_3)/(CaO + MgO)$	> 1.8
Viscosity Modulus (M_v), calculated using molar ratios of oxides by: $(SiO_2 + Al_2O_3)/$ $(2Fe_2O_3 + FeO + CaO + MgO + K_2O + Na_2O)$	2-3

12.1.8.3 Polymer Matrix Systems

The producer shall require chemical characterization tests of the matrix material. The producer's material specification shall define the combinations of acceptable test techniques and test results required to adequately demonstrate the material's conformity and process capability. Techniques for chemical characterization are not universal but are strongly dependent upon the resin formulation. Therefore, test methods adapted to each material shall be developed appropriately considering the sensitivity of the method to detect deviations in formulation.

A representative of the Department may obtain verification samples at the

source or at the composite manufacturing facility. The polymer resins shall be stored such that contamination and environmental degradation do not occur. A certification for each LOT of resin is required and resins shall be identified by the resin producer's LOT number. A LOT is defined as the entire volume of material produced under uniform conditions and represented by the LOT number.

A. Thermosetting Resins

A typical material specification for thermosetting resin systems identifies upper and lower limits on the concentration of reactive functional group(s), viscosity, color, and moisture content. The characterization tests shall measure and identify the amount of individual constituents of the resin system such as the basic epoxide, curing agent, accelerator, hardener, reaction time, and the conversion of reactants upon resin mixing. Also, storage, fiber impregnation, and other processes relevant to the production of finished products shall be identified.

B. Thermoplastic Resins

Thermoplastic resins typically require evaluation of the incoming material that includes monitoring the melt index and density to ensure conformity with material requirements. For post-consumer resins, additional requirements must be met. These include moisture content and quantification of any other contamination level, as well as meeting quality targets for the final products. The quality of the final product can be measured with a variety of test methods, including melt index, tensile strength, density, or quantitative chemical analysis: by color (colorimetry), differential scanning calorimetry (DSC), or infrared spectroscopy.

12.1.8.4 Preimpregnated Materials (Prepreg)

In applications where prepreg tape, fabric, or roving are primary constituents of the composite produced, it is necessary to test for the chemical, physical, and mechanical fiber and matrix dominated properties identified in the applicable prepreg material specification. QCP procedures previously described in ***Section 12.1.6.1*** for resins and fibers may be used to control the quality of incoming prepreg raw materials. Chemical characterization shall be performed on resin extracted from the prepreg material intended for production, where applicable.

12.1.8.5 Adhesives

The QCP procedures recommended for structural adhesives are similar to those utilized for resin matrix systems; that is, the procedures shall provide assurance that each incoming batch or lot conforms to the chemical, physical, and mechanical properties identified in the material specification.

12.1.8.6 Coatings

The producer of the coatings shall provide certification indicating compliance with the manufacturer's requirements. A copy of the certification of compliance shall be maintained by the producer in the Quality Control file. The Verification Inspector may sample the coating material at any time.

12.1.9 QUALITY CONTROL OF COMPOSITE MANUFACTURING

The QCP shall establish, implement, and verify that (1) the parameters affecting material integrity and process capability are operating under controlled conditions; and (2) individual items, batches, or LOTs conform to specified quality standards. To ensure that the QCP objectives have been met, process procedures shall clearly define specific materials, tooling, equipment, cure cycle parameters, quality standards, operator qualifications, storage and handling requirements, traceability records, and any other relevant documents or requirements.

The producer shall develop integrated quality and production control procedures for operations that define product configuration, selection of materials, tooling and facility equipment, calibration, sequence of manufacturing operations, critical in-process parameters and processing tolerances, and conformity to quality standards.

The producer shall establish a program to properly train and qualify operators. This program shall measure operator performance to production standards and provide for qualification as necessary.

Before production, manufacturing processes shall be qualified by demonstrating that the combination of materials, tooling, equipment, procedures, and other controls making up the process will produce parts having consistent material properties that conform to design requirements. As part of the process qualification, appropriate destructive inspection and NDI of appropriate tool proofing specimens shall be conducted to determine

conformity to specified design requirements. Destructive tests of specimens verify conformity to the specified physical and mechanical properties. NDI of specimens verifies that discrepancies caused by manufacturing procedures remain within allowable limits.

12.1.9.1 Fabrication Equipment

Inspect manufacturing equipment daily and at the beginning of each production run. Inspect all components that are an integral part of the manufacturing equipment. Check all adjustable components for proper adjustment for the type and size of composite being produced.

12.1.9.2 Calibration of Equipment

Ensure that all equipment is checked and calibrated for compliance with the requirements of applicable ***FDOT Specifications***. Calibrations must be performed at least annually or more frequently if conditions merit.

12.1.9.3 Quality Control of Composite Manufacturing Process

After the initial process qualification, testing for conformity to design requirements shall continue regularly to ensure that the manufacturing process, materials, and associated tooling continue to operate in a state of control and produce conforming product.

A. The following are manufacturing controls unique to the manufacturing of parts such as laminate and wet layup, filament winding, pultrusion, and other molding methods that a QCP shall include:

    1. Laminate layup

        a. Standards and methods shall be established to ensure the proper orientation, stacking, and nesting of the plies during lay up operations. The programs that control tape head and table motions, and tape feed and tape stacking, shall be addressed in the QCP. Standards shall be established for such in-process variables as tape orientation, gaps, and overlap.

        b. For automatic and hand layup methods, controls shall be established for in-process variables that affect the cured laminate quality, for example, resin content, ply compaction, laminate density, porosity that may result from debulking, pre-bleeding, and bagging operations.

2. Wet layup

    a. Procedures shall be established to ensure the correct material selection, orientation, and stacking, or nesting of the plies during wet layup operations.

    b. Procedures shall be established to control in-process variables such as resin content, aeration, and air pockets.

3. Filament winding.

    a. Preimpregnated filaments for dry winding shall be stored and handled according to procedures similar to those for other prepreg materials to ensure that the material's original properties have been maintained, especially material flow and tack to ensure proper bonding for subsequent winding operations.

    b. Establish procedures to ensure that the working life of the resin system exceeds the anticipated winding time and to ensure gelation does not take place before completion of winding.

    c. Establish procedures to control machine-dominant parameters such as feed rate, feeder arm and mandrel motions, mandrel dwell angle, number of circuits per pattern, total number of circuits for complete coverage, number of plies per layer, winding angle, fiber tension and alignment, bandwidth, fiber/resin ratio, etc.

    d. Establish procedures to control process variables during the winding operation such as resin viscosity, fiber wetting, fiber tension, fiber bandwidth and alignment, air entrapment, degree of compaction, fiber damage, etc.

4. Pultrusion.

    a. Establish procedures to control pultrusion start-up, steady state, and shutdown operations including compliance of material produced during start-up and shutdown operations.

    b. Establish process procedures that define operating limits for important process parameters critical to product quality such as line speed, die temperature profile for the particular operating

conditions and resin system, clamping pull-through lead, resin temperature, die input temperature, material orientation for preform operation, and material tension.

5. Other Molding Methods.

   a. For techniques such as resin injection, compression, and transfer molding processes, specifications shall define the limits for all critical process parameters that determine product quality. Such parameters are, for example, resin mix, feed-rate and feed temperature, mold temperature, and back pressure or vacuum. In addition, molding process specifications shall identify the timing and sequence of automatic operations. These critical parameters shall be defined in the process specification and identified in the associated production records.

B. Curing process.

1. Develop procedures to control the critical parameters of the process, namely chemical reactions of the resin and consolidation of the plies to achieve manufacturing consistency and quality parts that are of uniform consolidation, within void tolerances, and of correct fiber volume.

2. Procedures shall define the relationship of the variables (time, temperature, pressure) in the cure cycle (and post-cure cycles) that control compaction and consolidation and cure reaction. These control variables shall include the acceptable limits and the appropriate action to be taken when such limits are exceeded. For example, submit cured parts through the QCP for evaluation and disposition.

12.1.10 QUALITY CONTROL TESTING AND INSPECTION OF COMPOSITES

12.1.10.1 General

Perform the quality control inspections and/or testing specified in the applicable AASHTO and ASTM Standards for each type of composite, unless modified by the Specifications. Additional tests applicable to specific composite products shall be identified by the producer as part of their quality control/quality assurance program.

12.1.10.2 Quality Control Tests

The QCP shall include the test methods, inspections, and minimum frequencies that are used as the basis of acceptance for each type of composite. Dimensional checks for length, width, thickness, and diameter shall be made and recorded at the minimum frequency of twice daily. Composite density (i.e., weight per linear foot) shall be either continuously monitored or determined twice daily. Tests of composite stiffness, environmental crack resistance and impact resistance shall be made for each production run or whenever production of a new lot begins of supply changes or when the manufacturing process changes. The Director, Office of Materials may approve or direct modifications to the frequency of tests based on the performance history of the producer.

Index tests derived from existing test methods may be developed and implemented by the producer for quality control/quality assurance purposes subject to the approval of the Director, Office of Materials.

12.1.10.3 Test on Composite Joints/Connections

When requested by the Department, perform a joint/connection test in accordance with ASTM D4762*,* as applicable, at the pressures appropriate for the application. Perform these tests in the presence of the Quality Control Manager. Notify the SMO with enough prior notice to witness the testing.

12.1.11 APPEARANCE AND INSPECTION OF FINISHED COMPOSITES

Perform final inspection of the finished composites before the application of the QC approval label. Final acceptance requirements and QCP procedures shall provide added assurance that the completed structure meets its functional and design requirements. Minor deficiencies may be repaired in accordance with the repair methods included as part of the approved QCP, or by approval of the Director, Office of Materials.

Acceptance of a LOT of composite components:

A. All tests and inspection results shall meet the requirements of the contract documents.

Final acceptance records shall provide evidence that the following production and QCP activities have been completed:

1. Incoming material acceptance;

2. Production and assembly controls;

3. Maintenance of tooling and facility equipment;

4. Calibration of inspection and laboratory test equipment;

5. Inspection acceptance of functional characteristics at detail and assembly levels;

6. Nondestructive inspection acceptance;

7. Configuration control; and

8. Any other requirements

B. The producer has completed all patching and repair work.

C. The Quality Control Manager has labeled the composites.

D. The list of the composites and producer's certification statement is included with each shipment of the composites to the project site.

E. Prior to shipment, a certification, notarized by the producer, is sent to the project indicating that the composites meet contract documents.

12.1.12 HANDLING AND STORAGE

Composite materials and structures require specific handling procedures to protect them from damage during production and storage. Accordingly, procedures for handling and storing composite materials and structures shall be established and followed. These procedures shall be an integral part of the producer's QCP and shall provide protection during receiving inspection, material storage, material handling, manufacturing process, cure cycle, final inspection, and final product storage. Clearly identify rejected components and do not store them in the same area with compliant composites.

12.1.13 QUALITY CONTROL LABELS

The producer's Quality Control Manager shall affix a label to each section of composite, indicating that the manufactured composite meets the requirements of the ***Contract Documents***. The producer's QC approval label

shall be indelible and legible, and applied to each composite before its shipment from the manufacturing facility to the project site.

The label shall include the producer's identity, LOT number and the date of final quality control inspection. The date of final quality control inspection shall be written in indelible ink or be mechanically imprinted. The label shall consist of a pre-printed polymer sticker or as may be approved by the Director, Office of Materials. An example of the label shall be included in the QCP.

12.1.14 SHIPMENT

Address the producer's shipping policy as part of the QCP.

Ensure that each shipment of composites to the project site is accompanied with a signed or stamped delivery ticket providing the description and the list of the products. The list of the products with each delivery ticket shall include as a minimum, project number, date shipped, lot numbers, identification, and quantity.

12.1.15 DOCUMENTATION

The Quality Control Manager shall maintain the following documentation for a period of three years after the delivery of the composites to the project site. The documentation shall as a minimum include the following items:

A. A copy of the QCP

B. Approved design/shop drawings (if applicable)

C. Applicable ASTM and AASHTO Standards

D. ***FDOT Specifications*** *and* ***Design Standards***

E. The names of all quality control personnel and qualifications

F. All material certification records

G. Equipment calibration records, including composite forming machines and test equipment

H. LOT numbers for the materials and composites produced

I. Number and type of composites in each LOT

J. All applicable test data

K. Record of the list of the delivered composites

L. Record of all deficiencies found as a result of quality control/quality assurance activities and the corrective action taken. A copy of the deficiency reports shall also be maintained for the three-year period as described above.

12.1.16 TRAINING

The producer shall establish and implement a training program for all personnel that perform testing of product used for Department projects. The training must include knowledge of all ***Specifications*** related to the products being manufactured. All training shall be documented and provided to the Department upon request. The producer's training must be approved by the Department.

12.1.17 FORMS

12.1.17.1. There are no forms associated with this procedure.