STANDARD SPECIAL PROVISIONS
SECTION 509
COMPOSITE TUB GIRDER

509.01 Description

This work shall consist of furnishing and erecting Composite Tub Girders (CT Girders) to the dimensions shown on the plans and according to the requirements of the Standard Specifications and these Special Provisions. CT Girders for incorporation into the project shall include the FRP CT Girders, shear bolts, utility support connection plate, and high strength bolts used to attach the bent plate for utility support channel as detailed on the Plans. Anchor bolts, shim plates, masonry plates, sole plates, and bearings will be paid for separately under separate pay items.

509.02 Quality Control / Quality Assurance

At least thirty (30) calendar days prior to fabrication, the Contractor shall submit to the Department a Quality Control/Quality Assurance (QC/QA) Plan for fabrication of the CT Girders. Fabrication of the CT Girders shall not commence until the QC/QA Plan has been reviewed and commented upon by the Department.

509.03 Definitions

Terms and definitions found within this document shall be defined as outlined in the Standard Specifications, with the following added terms:

Composite Tub Girder (CT Girder): A structural member consisting of a Fiber Reinforced Polymer (FRP) lamina composed of glass fiber, carbon fiber, foam core, and resin.

Shear Bolt: A member with one end embedded in the concrete deck and the opposing end bolted through the top flange. A plurality of shear bolts are utilized to provide a positive connection to the bridge deck and to facilitate composite bending behavior between the CT Girder and the concrete deck.

Closure Plate: A member permanently bonded across the top flange of the CT Girder to provide transverse and torsional stability and prevent concrete from entering the girder.

Utility Support Connection Plate: A member permanently installed on the inside surface of the girder and designed to provide support for the bent plate that supports the utility channel and hangers.

Preforms: Individual element components of materials to be incorporated into the CT Girder, e.g. glass fiber fabric, carbon fiber fabric, foam core.

Tooling: The molds or forms that are used in the fabrication of CT Girders.

Manufacturer: The supplier of the CT Girders is Advanced Infrastructure Technologies, LLC (AIT) of 55 Baker Boulevard, Brewer, ME 04412.

509.04 Materials

Materials shall conform to the following. Any substitutions to the materials specified below must be submitted to the Department for approval.

1) Reinforcement: The CT Girder fiber reinforcement shall be comprised of a mix of carbon fiber fabric, glass fiber fabric, foam core, and a resin matrix.
    a. Carbon Fiber Fabric: Carbon fibers shall be standard modulus fibers. Tensile strength, tensile modulus, and strain of the fibers shall be documented in accordance with the manufacturer's test specifications. In lieu of material testing, a Certificate of Conformance may be submitted to the Department for approval.
        i. Unidirectional Carbon Fiber Reinforcement specifications:
            1. Physical Properties
                a. Minimum Aerial Weight 36.3 oz/yd^2 1.23 kg/m^2

    Acceptable Manufacturers include:
    1) Vectorply
    2) Flotex
    3) Approved equal

    b. Glass Fiber Fabric: Glass fibers shall be E-glass manufactured in accordance with ASTM D578 and tested in accordance with ASTM D2343. In lieu of material testing, a Certificate of Conformance may be submitted to the Department for approval.
        i. Unidirectional Glass Fiber Reinforcement specifications:
            1. Physical Properties
                a. Minimum Aerial Weight 41.5 oz/yd^2 1.41 kg/m^2
        ii. Biaxial Glass Fiber Reinforcement specifications:
            1. Physical Properties
                a. Minimum Aerial Weight 24.2 oz/yd^2 0.82 kg/m^2

    Acceptable Manufacturers include:
    1) Vectorply
    2) Textech
    3) Approved equal

    c. Foam Core: The foam core shall be comprised of medium density closed cell foam with an average density of 5.9-6.6 lbs/cubic foot as determined by ASTM D1622 and a compressive strength within 200-300 lbs/square inch as measured by ISO 844 or ASTM D1621.
    Acceptable Products include:
    1) Airex T92.100 as manufactured by 3A
    2) Approved equal

    d. Resin: The matrix used in the manufacturing of CT Girders shall be an epoxy-vinyl ester resin with a dynamic viscosity between 100 and 400 centipoise at 77° Fahrenheit and appropriate for resin infusion using the Vacuum Infusion Process (VIP). Clear casting tensile strength and tensile modulus

shall be documented in accordance with ASTM D638. Clear casting flexural strength and modulus shall be documented in accordance with ASTM D790. Heat distortion temperature shall be documented in accordance with ASTM D648. In lieu of testing, a Certificate of Analysis may be submitted in the QA documentation. If the resin is not pre-promoted, then it should be promoted in accordance with the manufacturer's recommendations. If the resin material is pre-promoted, then no additional promotion is necessary. The resin shall be catalyzed in accordance with the manufacturer's recommendations. Prior to infusing with the resin, gel time tests shall be conducted in the infusion environment to determine the desired dosage rate to produce the required gel time necessary to ensure proper wet out and saturation of fibers.

Acceptable Products include:

1) DERAKANE 610 C-150 P as manufactured by Ashland
2) Approved equal

Additional non-structural layers of glass veil such as a 1.5 oz/yd^2 continuous strand mat may be used to enhance resin infusion. Additional non-structural layers of resin distribution media may be placed around the reinforcement to promote more efficient means of infusion.

2) Shear Bolts: The shear bolts shall be comprised of ASTM F3125 Grade A490 Type 1 bolts. Heavy hex nuts shall conform to ASTM A563 Grade DH and washers shall conform to ASTM F436 Type 1.

3) Closure Plate: The closure plate shall be comprised of FRP stock flat sheets, with dimensions in conformance to the Plans, bonded to the top flange of the girder using a structural adhesive. The closure plate shall be bonded to the top flange of the CT Girder using 2 - 3/8" beads of structural adhesive on each top flange.

4) Structural Adhesives: Structural adhesives shall be used where indicated on the Working Drawings. Structural adhesives shall be a two-component, medium viscosity, methacrylate or urethane suitable for bonding FRP.

   Acceptable Products include:

   1) Pliogrip 7770 as manufactured by Ashland
   2) Plexus MA560-1 as manufactured by ITW
   3) Approved equal

5) Utility Connection Plate: The utility connection plate on the inside of the CT Girders shall consist of ¼" hot-dip galvanized A36 plates with four ¾" A325 hot-dip galvanized bolts tack welded to the plate as indicated on the Working Drawings. The plate shall be bonded to the inside surface of the CT Girder using structural adhesive as indicated on the Working Drawings.

509.05 Equipment

A vacuum pump capable of sustaining a pressure equal to or greater than 25 inches of mercury shall be required for the vacuum infusion of the CT Girder. The vacuum system shall be outfitted with a reservoir system to accumulate any over filling of the matrix in the mold and protect the vacuum pump.

509.06 Working Drawings

Prior to beginning fabrication, the Contractor shall submit complete Working Drawings to the Department for review and comment in accordance with Section 105.7 Working Drawings of the Standard Specifications. Each drawing shall provide adequate space for review and comments. If the Working Drawings have significant discrepancies, revised sets must be submitted until details comply with the contract requirements.

As a minimum, Working Drawings shall include:

1) Layout drawings identifying piece marks and orientation in the structure (including a north arrow)
2) Individual piece drawings indicating the length, depth, width, and thickness of piece, along with the spacing of shear bolts, location of piece marks, weight, location of all holes and/or inserts, location of lifting points, and any other information necessary to adequately fabricate each girder.

509.07 Fabrication

The Manufacturer shall notify the Fabrication Engineer a minimum of two weeks prior to the start of work. In addition, the Manufacturer shall provide the Fabrication Engineer with a copy of the production schedule. If the production schedule changes, notify the Fabrication Engineer no less than 3 working days prior to the initial start-up date.

The Quality Assurance Inspector's (QAI) presence is required for, but not limited to, the following activities: batching of matrix resin, infusion of part, and final inspection. The QAI's office shall meet the requirements of Section 504.09 - Facilities for Fabrication Inspection.

CT Girders shall be fabricated and stored according to the following requirements:

1) Preform Storage and Preparation: Glass and carbon fiber fabrics, foam core, and non structural media material used to aid in resin flow shall be stored in a clean, dry environment in the original packaging until ready for use. They shall be protected from water, dirt, grease, grinding dust, and other foreign matter. The fabrics shall be cut on a clean cutting surface, free of any corrosive or deleterious material that could adhere to the fabrics prior to layup in the tooling. Cut-outs within the fabric to accommodate details of the infusion process and/or details of the finished CT Girder shall be clearly indicated on the Working Drawings.

   Lap splices in the fabric will be permitted in the longitudinal direction of the girder. Longitudinal lap splices shall be no less than 6 inches in length. Lap splices in the fabric will be permitted in transverse direction. Transverse lap splices shall be no less than 2 inches in length.

   Foam core shall be machine cut to full depth sections and may be butt jointed together longitudinally. Gaps in the joints between adjacent pieces of foam shall not exceed ¼ inch prior to pulling vacuum on the tooling.

   Vinyl ester resins and other chemicals necessary for catalyzing the infusion matrix shall be stored in a temperature controlled environment, and in accordance with the manufacturer's recommendations for each component.

2) Tooling: The tooling shall be capable of fabricating girders to the dimensions required by the contract plans and Working Drawings within all allowable tolerances. The tooling surfaces shall be manufactured of sufficient thickness and stability so that they will remain true to shape under the vacuum infusion pressures and the weight of the part. Clamps, pins, and other connecting devices shall be designed to hold the tooling rigidly in place during placement of the preforms and application of the vacuum pressure for infusions as well as allow removal of the girder without damage to the laminate. If metal tooling is used it shall be free from rust, grease or other foreign matter. Radius corners shall be built into the tooling to the dimensions and tolerances shown on the contract plans and Working Drawings. No sharp corners will be allowed. The tooling shall be designed with monolithic joints and/or seals to facilitate an airtight chamber capable of sustaining 25 inches of mercury of pressure without any leaks for the duration of the infusion process. Prior to placing preforms, the tooling shall be cleaned and coated with a release agent common to the practice of composite manufacturing.

   The CT Girders shall be manufactured to the dimensions shown on the Plans and Working Drawings. Measurements of the product shall be recorded and compared to the design plans and the tolerances allowed. The dimensional tolerances for the CT Girders shall be as follows:

Maximum Allowable Dimensional Tolerances for CT Girders

CT Girder Component or Dimension	Tolerance
Thickness of FRP laminates	± 3/16”
Depth, overall	± 1/4”
Width, overall	± 1/4”
Length (string line measurement along bottom of beam)	± 1/4” per 25’, max ± 3/4”
Variation from specified elevation and squareness or skew	± 1/8” per 12”, max ±3/4”
Sweep	± 1/2”
Camber variation from design camber	± 1/8” per 10’, max ±3/4”
Tipping and flushness of beam seat bearing area	± 1/8” per 24”
Shear connector location, longitudinal	± 1”
Shear connector location, transverse	± 1/2”

3) Vacuum Infusion Process: Prior to vacuum infusion of the vinyl ester matrix, the manufacturer must thoroughly seal the tooling and demonstrate that the sealed tooling can obtain the minimum workable vacuum pressure of 25-inches of mercury and for that pressure to not drop by more than one-inch of mercury over a period of five minutes. Chemical additives and catalysts to be combined with the vinyl ester resin shall be measured by weight, or the corresponding volume, based on the batch weight of the vinyl ester resin. The manufacturer shall maintain documentation of the promotion rates and the actual amount of catalyst used for each infusion. Once catalyzed, the matrix shall be placed in the infusion tank within ten minutes. An extension of this time may be granted by the Quality Assurance Inspector if sufficient gel time data is available to show proper wet out will occur prior to the matrix gelling. The infusion tank must be charged with a sufficient amount of resin at all times to prevent air bubbles from entering the infusion ports in the tooling. Once resin is introduced into the tooling, the infusion process shall continue uninterrupted until it has been demonstrated that all evacuation ports have a surplus of resin flowing past the finished surface of the tooling and that no less than the predicted volume of resin has been introduced into the tool.

A Barcol hardness tester may be used to determine the cured state of the composite. The girder should not be removed from the tooling unless a Barcol hardness reading of 35 or more can be obtained in multiple locations along the length and section of the girder. In the absence of tests used to determine the cured state of the resin matrix, the tooling shall remain in place, under at least 25-inches of mercury for at least 6 hours after all evacuation lines have been clamped and the infusion process is considered to have been completed.

Subscale witness panels representative of the full depth CT Girder laminate shall be tested in accordance with the specified ASTM Standards in conformance with the minimum properties outlined in the table below. Adequate supporting documentation for the properties shall be obtained from the Manufacturer and provided to the Department. The following properties shall be tested using at least five samples cut from the first infused girder end. If the experimental values tested exceed the minimum allowable values below, the production lot is approved and no further testing is required. If the experimental tested values fall below the values listed below, each subsequent CT girder shall have witness panels tested until the average of all tested values exceeds the minimum values below. If the average of all tested values falls below the minimum values below, the production lot shall be rejected.

PROPERTY	UNITS	ASTM TEST METHOD	MINIMUM
Tensile Strength	psi	D3039	58,000
Compressive Strength	psi	D6641	49,000
Shear Strength	psi	D3518	8,500

Tensile strength witness panel coupons shall be representative of the bottom flange laminate. Compressive strength witness panel coupons shall be representative of the top flange laminate. Shear strength witness panel coupons shall be representative of the web face sheet laminate.

4) Post Processing: Once the laminate has been allowed to cure, the CT Girder may be removed from the tooling and all post processing work may begin. This will include, de-bagging, removal of peel ply, sanding, grinding, cutting, drilling, machining, attachment of shear bolts, closure plate, and utility support connection plates.

509.08 Handling, Storage, and Transportation

The CT Girder complete with closure plate may be placed upright, upside down, or on its side, as necessary for drilling and post-processing of the finished piece. Care shall be taken in the handling of the CT Girder so as to not damage the surface finish of the laminate.

Prior to moving any CT Girders to storage, it shall be clearly marked with the mark number which indicates the date of fabrication and the location shown on the Working Drawings. All CT Girders shall be stored in an upright position on suitable dunnage, not in contact with the ground, at the support points shown on the Working Drawings. The CT Girders may be stacked. When stacking, the CT Girders shall be maintained in the upright position at all times and each beam shall be supported with cribbing at the same location as the girder below.

CT Girders shall not be released for shipment until all dimensional tolerances have been checked. If the CT Girders are to be stored on site, the same provisions outlined above for storage at the manufacturer's facility shall apply.

Transportation will be the responsibility of the Contractor. The Manufacturer will be responsible for loading the CT Girders on the Contractor's truck. The Contractor is responsible for securing and transporting the CT Girders from 55 Baker Boulevard, Brewer, ME 04412 to the project site. All CT Girders shall be shipped upright and supported by cribbing at the locations shown in the Working Drawings.

If the CT Girders are damaged during transport, handling, and/or storage prior to their incorporation into the structure, the damaged CT Girders shall be repaired or replaced by the Contractor at the Resident Engineer's discretion and at no additional cost to the Department.

509.09 Erection

The CT Girders shall be erected to the lines and grades as indicated in the Plans and in accordance with the requirements of these Special Provisions. At least 30 days prior to erection, the Contractor shall submit an Erection Plan indicating lifting methods, erection sequence, and any other pertinent information. Penetrations in the CT Girder for construction purposes shall be shown on the Erection Plan and will not be permitted unless approved by the Engineer of Record.

Girders shall be placed on clean bridge seats and tops of bearing devices. Any shifting of the girders shall be done while they are free of the supports.

Girders shall be handled with a suitable hoisting device or crane of sufficient capacity to handle the members. Nylon slings or other approved methods shall be used to prevent damage to the surface of the girders. Lifting anchors sized and located in accordance with the Working Drawings may be used to hoist the girders only if explicitly stated on the Working Drawings.

The Contractor shall provide temporary bracing of the girders to prevent rotation along the girder centerline until the backwall concrete has been cast.

The Contractor is responsible for providing and installing the bent plates and utility c-channels for all utility support connections.

509.10 Method of Measurement and Basis of Payment

Item No. 509.743 Composite Tub Girder - Fabrication will be paid for at the lump sum price. Payment shall be compensation for fabrication of the CT Girders. Related materials and work include fabrication and post-processing of the CT Girders, installation of closure plate, shear bolts, internal utility support connection plates and bolts for connecting to the FRP, storage at the manufacturer's lot and all submittals related to this work.

Item No. 509.744 Composite Tub Girder – Erection will be paid for at the lump sum price. Payment shall be compensation for transportation, storage, handling, temporary bracing, erecting, bent plates, utility channels, and all submittals required for approval prior to execution of this work. Anchor bolts and bearings will be paid for separately under separate pay items.

Payment will be made under:

Pay Item		Pay Unit
509.743	Composite Tub Girder – Fabrication	Lump Sum
509.744	Composite Tub Girder – Erection	Lump Sum