COMPOSITE ARCH SUPERSTRUCTURE

**From Fairfield BRO 1448(38)

xx. DESCRIPTION. This work shall consist of designing, manufacturing, transporting, and erecting rigified fiber reinforced polymer tubular arches (RFTA) and filling the hollow tubes with expansive self- consolidating concrete (SCC), in accordance with these specifications and in reasonably close conformity with the geometry and dimensions shown in the Plans or established by the Engineer.

xx. DEFINITIONS. Terms and definitions included herein shall be defined as outlined in the Vermont Agency of Transportation Standard Specifications, with the following added terms:

(a) Composite Arch. A hollow arch tube structural framing member comprised of an advanced fiber reinforced polymer shell which functions as external reinforcement and stay-in-place formwork for concrete.

(b) Manufacturer. A firm licensed by Advanced Infrastructure Technologies for the manufacturing of the arches.

xx. MATERIALS. Materials shall meet the following requirements:

(a) Engineered Composite. The engineered composite material for the hollow arch tubes shall be designed to meet the specific requirements of the bridge.

The FRP shell shall be comprised of an advanced carbon and/or glass fiber reinforced polymer laminate in a tubular shape. The resin shall be a vinyl-ester. All reinforcement and resin materials shall be documented and traceable by batch. The arches shall be manufactured using a closed-mold, vacuum assisted resin transfer method (VARTM) of composite manufacturing.

(b) Expansive Self-Consolidating Concrete (SCC). SCC shall be used for filling the hollow composite arch structural tube concrete.

(1) Mix. The mix shall be in accordance with the following table:

Component	Notes
Water (All water to be added at plant.)	Per VTrans Subsection 745.01
Type II Cement	Per VTrans Subsection 701.02
Shrinkage Compensating Admixture (SCA) - Use of an SCA is mandatory to ensure that shrinkage does not occur during the curing process. (Expansive Cement at a rate of 10% by weight of total cementitious material.)	Expansive Cement (ASTM C 845 Type K) CTS Komponent® CTS Cement Manufacturing 11065 Knott Ave, Suite A, Cypress, CA 90630
Coarse Aggregate for Concrete (3/8 Inch Stone. Well graded with rounded aggregates.)	Per VTrans Subsection 704.02
Fine Aggregate for Concrete (Not less than 50% of total aggregate by volume.)	Per VTrans Subsection 704.01
High Range Water Reducing (HRWR) Admixture (As required to produce a slump-flow between 24" - 30". HRWR admixture to be added on site.)	EXP 950 W.R. Grace & Co.-Conn. 62 Whittemore Avenue Cambridge, MA 02140
Hydration Stabilizer (To ensure sufficient placement time, so no hydration begins before filling arches)	Daratard 17 W.R. Grace & Co.-Conn. 62 Whittemore Avenue Cambridge, MA 02140
Viscosity Modifying Admixture (VMA) – To meet stability and segregation requirements	Rheomac® VMA 358 BASF Corporation 100 Campus Drive Florham Park, NJ 07932

Alternative mix components proposed by the Contractor shall be submitted 60 days in advance of the first arch filling and shall be approved by the Engineer.

(2) Compressive Strength. The SCC shall have a minimum compressive strength at 28 days of 6000 psi.

(3) Air Content. The target air content shall be 3% (+/- 3%).

(4) Water/Cementitious Material Ratio (W/CM). W/CM shall be between 0.40 and 0.45.

(5) Visual Stability Index. The Visual Stability Index shall be between 0.0 and 1.0.

(6) Batching Recommendations. It is the responsibility of the Contractor and redi-mix supplier to batch the SCC concrete in a way that will provide a mix in conformance with the requirements of these specifications. The following batching procedure has

been used successfully, and is provided here for information purposes only:

1. Add 80% of mix water.

2. Add Shrinkage Compensating Admixture (SCA) and mix into slurry.

3. Add aggregates and cementitious materials.

4. Add final 20% of mix water.

Add chemical admixtures after either step 2, 3, or 4 at the discretion of the redi-mix supplier.

xx. GENERAL FABRICATION REQUIREMENTS.

(a) General. The following shall design and supply the RFTA superstructure units that meet these specifications:

Advanced Infrastructure Technologies (AIT)
20 Godfrey Drive
Orono, ME 04473
Telephone: 207-866-6526
Fax: 207-866-6501
Contact: Jonathan Kenerson
E-mail: Jon@aitbridges.com

AIT is hereinafter referred to as the Supplier. No substitutions for the above will be accepted.

(b) Quality Control. The Manufacturer shall demonstrate a level of quality control testing that satisfies the Agency as to its ability and commitment to produce RFTA superstructure units. The Fabricator shall submit a Quality Control Plan to the Agency's Structures Engineer for review and approval prior to the commencement of work. The plan shall clearly define the quality control procedures, personnel, frequency of activities, and remedial actions required.

xx. DESIGN REQUIREMENTS. The RFTA superstructure units shall be designed by AIT in accordance with the AASHTO Standard Specifications for Highway Bridges; LRFD Bridge Design Specifications, Sixth Edition, Dated 2012 and its latest revisions; the AASHTO LRFD Guide Specifications for Design of Concrete-Filled FRP Tubes, First Edition, dated 2012; and the VTrans Structures Design Manual, dated 2010.

xx. SUBMITTALS.

(a) Design. Three (3) copies of the bridge design shall be submitted to the Agency's Structures Engineer a minimum of 28 days prior to beginning any work. The design calculations shall substantiate that all proposed bridge components, including but not limited to the composite RFTA superstructure units and associated connections into the

reinforced concrete abutments, satisfy the requirements of the Contract Documents. The design calculations shall include an LRFR load rating for the seven standard axle configurations indicated in the load rating table in the Plans.

The design shall be submitted as Working Drawings to be reviewed for conformance in accordance with Subsection 105.03. The submitted documents shall be signed, stamped, and dated by a Professional Engineer (Structural or Civil) licensed in the State of Vermont. The Professional Engineer is responsible for ensuring that the design and details of the proposed superstructure and connections to the existing abutments conform to the requirements of the Contract Documents.

(b) Working Drawings. Working Drawings shall be submitted in accordance with Section 105 for any item of work requiring Fabrication or Construction Drawings under Section 105.

Construction Drawings for composite arch erection shall be submitted in accordance with Section 105. The erection plan shall include the necessary computations to indicate the magnitude of stress in the units during erection and to demonstrate that all of the erection equipment has adequate capacity for the work to be performed, and provisions for all stages of construction, including temporary stoppages.

Submittal of the erection plan is for the Agency's documentation only and shall in no way be construed as approval of the proposed method of erection. The Contractor shall follow the erection plan as submitted.

The time required for preparation and review of these submittals will be charged to the allowable Contract time. Delay caused by untimely submittals or insufficient data will not be considered justification for time extension. No additional compensation will be made for any additional material, equipment, or other items found necessary to comply with the project specifications as a result of the Engineer's review.

xx. INSPECTION. The RFTA superstructure units shall be inspected by the Agency in accordance with Subsection 106.04.

xx. FABRICATION. The composite arches shall be fabricated and stored according to the following requirements:

(a) Pre-Production Meeting. Unless the Engineer deems, in writing, that a pre-production meeting is unnecessary, then a pre-production meeting shall be held a minimum of seven (7) calendar days prior to beginning composite arch fabrication. The pre-production meeting shall be attended by, and including but not limited to, the Crew Supervisor, Plant Manager, Inspector or Inspector's Supervisor, and Project Manager and/or the Designer.

(b) Reinforcement Storage and Preparation. Fabrics shall be stored in a clean, dry environment in the original packaging. They shall be kept free from water, dirt, grease, grinding dust, and other foreign matter. The fabrics shall be cut on a clean cutting surface, free of any deleterious material that could adhere to the fabrics prior to layup. No splices shall be permitted in the longitudinal fabric. Splices shall be permitted in the hoop reinforcement.

(c) Chemicals. Vinyl-ester resins and other chemicals necessary for catalyzing the infusion matrix shall be stored in accordance with the manufacturer's recommendations.

(d) Vacuum Assisted Resin Transfer. Prior to vacuum infusion of the vinyl-ester matrix, the Manufacturer must thoroughly seal the tooling, and demonstrate that the sealed tooling can obtain a minimum vacuum pressure of 25 inches of mercury and pass a drop test with an allowable drop of no more than 1 inches 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 records of the promotion rates and the actual amount of catalyst used for each infusion.

The infusion tank must be charged with a sufficient amount of resin at all times to prevent air bubbles from entering the infusion port(s) in the tooling. Once the 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.

(e) Post-Processing. Once the laminate of the composite laminate has been allowed to harden, the arches shall be removed from the form with care so as not to induce stresses into the curing laminate. The laminate shall reach a minimum Barcol hardness value of 35 prior to demolding.

(f) Dimensional Tolerances. The finished arches shall conform to the tolerances and specifications set forth in the approved Working Drawings. The diameter shall not vary in any one section by more than 2 percent of the dimension given on the Working Drawings. The arches shall be checked for shape variations and shall be arranged such that the shape of two adjacent arches shall not vary from each other by more than 1.0 inches and no arch shall vary from the Working Drawing shape by more than 1 percent of the dimension.

(g) Rejection of Units. Arches may be rejected by the Engineer for irreparable deviations from the design and Working Drawings, including dimensional tolerances and uninfused sections.

(h) Repair of Units. Under-infused sections may be infused via a secondary surface infusion to provide proper resin saturation. All other repairs to damaged laminate sections shall be examined on an individual basis and must be approved by the Engineer as meeting the original design requirements.

(i) Labeling. All arches shall be clearly marked by the manufacturer with the mark number and date of fabrication of the arch in the location shown on the Working Drawings.

xx. SHOP TESTING.

(a) FRP Laminate. The FRP laminate comprising the shell shall be tested for tensile strength. Adequate supporting documentation and the appointed values for the mechanical properties shall be obtained from the Fabricator and provided to the Structures Engineer. A minimum of five (5) specimens shall be manufactured from each arch. A minimum of two (2) specimens per arch shall be tested. If the mean of the two (2) specimens from any arch fails to exceed the design value, at least three (3) more specimens from the corresponding arch shall be tested: the mean of the three (3) additional specimens shall meet or exceed the minimum design value. Results of all tests shall be submitted to the Project Manager at least ten (10) business days prior to arch delivery.

xx. HANDLING, STORING, AND SHIPPING.

(a) Handling. Care shall be taken when handling the hollow composite arches such that no damage is caused. When moved or placed by hand, arches shall be stabilized to prevent tipping over. Arches may be moved with a single nylon lifting strap. Each strap shall provide at least 3 inches of padded contact area.

(b) Storing. Hollow composite arches shall be stored to prevent damage.

(c) Shipping. Units shall not be shipped until the minimum strength is attained and these have been stamped by the Agency. A 48-hour advance notice of the loading and shipping schedule shall be provided. The units shall be secured on the vehicle in order that no cracking will occur during transport. The Contractor shall secure the necessary hauling permits.

xx. INSTALLATION.

(a) Installation Plan. A written installation plan (in conjunction with the construction of the Arch Slab on FRP

decking and FRP Mechanically Stabilized Earth Arch Headwalls) shall be submitted to the Engineer within 30 days following the bid award, and a minimum of 30 days prior to arch embedment within the abutment. The written installation plan shall provide, as a minimum, the following information:

(1) Construction plan, sequence, and schedule.

(2) Temporary storage conditions.

(3) Any temporary bracing plans.

(4) A list of all equipment to be used. Manufacturer performance data will be required for all pumping equipment.

(5) The intended method and sequence of placing the concrete. This shall include a written narrative and diagrams and/or photographs as necessary so that the process will be clearly defined.

(6) The name(s) of the responsible person/people in charge for the Contractor.

(7) A description of the inspection procedure for checking the arches after the concrete filling to ensure each arch has been completely filled. The description should outline the method of inspection and materials and methods to be used to fill any remaining voids.

(b) Methods, Equipment, and Erection. Cranes, lifting devices, and other equipment for composite arch erection shall be of adequate design and capacity to safely erect, align, and secure all members and components in their final positions without damage. The Contractor is solely responsible for the methods and equipment employed for the erection of the composite arch components.

(c) Arches. The hollow composite arches shall be installed in a vertical position with a maximum allowable variation of ±1/2" as measured by a self-leveling laser tool or plumb bob. Arches shall be embedded within the abutments at a depth specified by the Designer.

(d) Arch Filling Equipment.

(1) Concrete Placement Equipment. Acceptable equipment for concrete placement includes the use of a boom type concrete pump, a trailer pump, a concrete bucket and funnel, or a hopper hoisted from a crane. The Contractor shall have a backup method for placing SCC in any remaining unfilled portion of arch in the event of equipment failure. The backup method for placing the SCC shall be approved by the Engineer to

ensure capability of completing the arch filling within ten (10) minutes of equipment failure.

(2) The arches shall be filled with SCC through the fill holes. Fill holes are to be field drilled by the Contractor at the locations shown on the arch Fabrication Drawings. Concrete placement shall be completed using a method capable of directing concrete into a fill hole of 2.5 - 3.0 inch diameter, and regulating placement speed to prevent voids.

(e) Placing Concrete. Concrete shall not be deposited in the tubes until the Agency representative has approved placement. The concrete shall be placed in such a manner that:

(1) Concrete is uniformly consolidated.

(2) Abutments reach a minimum compressive strength of 2000 psi prior to filling the arches with SCC concrete.

(3) All arches are filled under the supervision of the Engineer.

(4) Each arch is filled with concrete in a continuous placement operation.

(5) Vibration is not allowed when filling the arches with SCC concrete.

(6) The arches are inspected for voids prior to overlay concrete slab placement.

(f) Cold Weather. When the concrete is cast in ambient air temperatures of 10°C (50°F) or less, the requirements of Subsection 501.07(b) shall apply.

(g) Technical Assistance. The Contractor shall have a representative from the Supplier present at the project site at the beginning of the arch installation and arch filling, at the beginning of the headwall construction, and during times deemed necessary by the Engineer to provide technical assistance to the Contractor in the event unusual problems or special circumstances arise.

xx. SCC FIELD TESTS. Field tests shall be performed in accordance with Subsection 501.06, with the following exceptions:

Flow tests shall be performed in accordance with ASTM C 1611, Procedure B. Do not tamp the self-consolidating concrete inside the cone. The concrete flow will be tested on the first 2 loads and at a minimum of every 40 cubic yards, including the yardage of the first two loads.

Air content tests shall me made in accordance with the pressure method in AASHTO T 153, except that the air meter shall be filled in one lift by using a scoop and dropping the concrete into the center of the pot from a distance of 6 inches from the top edge of the pot with no rodding. Only tap the sides of the pot if needed prior to running the test.

Trial batches shall be performed a minimum of 28 days prior to use to verify Compressive Strength, Slump Flow (at 30 minute intervals until initial set), Air Content, Placement Methods, and Visual Stability Index. Placement method testing shall use the proposed placement equipment and methods to test that slump flow is maintained for a time adequate to place the batch. The mix shall be placed through a representative “fill hole” of the same dimensions as the fill holes in the arches. Prior to trial batching, the mix design shall be submitted to the Engineer for review. The trial batching requirement may be waived at the discretion of the Engineer if the Contractor’s concrete supplier is experienced in the supply of SCC for related projects.

Each batch of SCC delivered to the project site shall be tested immediately prior to placing. Tests shall include slump flow (AASHTO TP 73), visual stability index (AASHTO TP 80), and air content in accordance with AASHTO T 152 meter Type B (do not rod, vibrate, or tap the bowl). Slump flow shall be verified every 30 minutes after the start of placement of each individual batch of concrete.

Initial samples for acceptance/rejection of a load may be taken directly from the truck; all subsequent samples shall be taken at point of placement (i.e. from pump hose).

xx. COMPOSITE ARCH INSPECTION, TESTING, AND REPAIR.

(a) Inspection. The following construction activities shall be subject to oversight or inspection by the Engineer:

(1) Initial placement of the arches in the abutment.

(2) Concrete embedment of the arches in the abutment.

(3) Filling of the arches with SCC concrete.

(4) Inspection of the arches for voids to ensure they have been completely filled. This should occur prior to any concrete FRP decking slab placement.

(b) Testing. The arches shall be tested in accordance with the written installation plan after the pumping of SCC concrete to ensure the cavity has been completely filled.

All tubes shall undergo auditory "tap" testing after SCC placement to inspect for voids. The sounding tool will be of sufficient weight and hardness so as to produce a distinct and unique sound when a void is encountered, but will have no sharp edges capable of damaging the tubes (e.g. the handle of a hammer).

(c) Repair. The only repairs permitted are those used to fill remaining voids after arch filling is complete. In the event that voids are discovered, these shall be pressure injected with grout using a hand-operated diaphragm pump. The maximum permissible hole size for grout injection shall be 3/4 inches.

Grout shall be Sika 212 grout (or approved equal) by:

Sika Corporation
201 Polito Avenue
Lyndhurst, NJ 07071
Tel.: 1-800-933-7452

xx. REJECTION OF UNITS. Arches shall be subject to rejection on account of not meeting any of the specification requirements. Individual arches may be rejected because of any damage to the hollow composite arches which is “severe” in the assessment of the Engineer, such that the damage compromises the ability of the member to meet the design strength. Any rejected arches shall be replaced with an undamaged member at the Contractor’s expense.

xx. METHOD OF MEASUREMENT. The quantity of Special Provision (Composite Arch Superstructure) to be measured for payment will be on a lump sum basis in the complete and accepted work.

xx. BASIS OF PAYMENT. The accepted quantity of Special Provision (Composite Arch Superstructure) will be paid for at the Contract lump sum price. Payment will be full compensation for designing and detailing superstructure components; making the required submittals; performing quality control testing; fabricating, furnishing, transporting, handling, and erecting the composite arch superstructure, including but not limited to the RFTA superstructure elements, filling with self-consolidating concrete, and connecting to the abutments; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Partial payment will be made as follows:

(a) An initial payment of 15% of the Contract lump sum price will be made when all Working Drawings have been submitted and marked conforming in accordance with Section 105.

(b) The next 70% of the Contract lump sum price will be paid on a prorated basis for the estimated duration of the Contract work remaining.

(c) The remaining 15% of the Contract lump sum price will be paid when construction of the Composite Arch Superstructure is completed to the satisfaction of the Engineer.

Corrugated FRP decking and reinforced concrete arch slab will be paid for separately under Contract item 900.645 Special Provision (Concrete Arch Slab on FRP Decking).

MSE headwalls and reinforced backfill will be paid for separately under Contract item 900.670 Special Provision (FRP Mechanically Stabilized Earth Arch Headwalls).

Payment will be made under:

Pay Item	Pay Unit
900.645 Special Provision (Composite Arch Superstructure)	Lump Sum