

SPECIAL SPECIFICATIONS

SECTION 03910S

FIBER REINFORCED EPOXY COMPOSITE MATERIAL

PART 1 - GENERAL

- 1.01 This specification is intended for use in defining the minimum requirements of structural strengthening using a fiber reinforced composite system. The scope of work related to this section requires the design and installation of a fiber reinforced composite system to absorb the **partial** energy release given off by an accidental detonation of the hydrogen tanks. The concrete wall surrounding the hydrogen tank on two sides shall be reinforced with a fiber reinforced composite system capable of absorbing enough energy to reduce the overpressure to a nearby facility to 1 psi or lower while minimizing the amount of debris and shrapnel generated after detonation. Delta Structural Technologies, Inc. is the recommended subcontractor to perform both the design and installation of the fiber reinforced composite system.
- 1.02 The composite fabric system subcontractor shall furnish all materials, tools, equipment, transportation, necessary storage, labor and supervision required for the proper installation of the composite system.
- 1.03 The composite system shall be installed by individuals certified by the material manufacturer by means of written verification. Certified applicator shall have a minimum of two years experience in performing composite retrofits.
- 1.04 SUBMITTALS

The installer's submittal shall include the following information:

- A. Manufacturer's product data, specifications and recommended installation procedures showing compliance with all project requirements, including (1) system environmental durability testing by an independent testing agency, (2) large scale structural testing results of the proposed composite material on representative test specimens, conducted and reported by an independent testing facility, (3) cyclic freeze/thaw testing results, (4) certification from the system manufacturer of the material and section properties for the supplied material, (5) an independent evaluation of the proposed composite system such as ICBO, or similar system evaluation. If the system is approved by ICBO, the installer shall provide the Evaluation Report number in the name of the system and system's manufacturer to verify performance.
- B. The material supplier shall submit complete shop drawings for each installation of the composite system. The shop drawings shall contain details of the number and thickness of layers, joint and end details and locations to be applied as per Part 3 of this specification.
- C. System manufacturer's Quality Control Manual in compliance with ICBO AC10, "Acceptance Criteria for Quality Control Manuals."

- D. Design calculations shall be sealed by a Registered Professional Engineer. Calculations shall be based on required tension force and strain limits to ensure strain compatibility with the existing structure.
- E. A list of a minimum of one hundred (100) completed composite strengthening projects completed with the manufacturer's composite system. The list should include at a minimum, the dates of work, type, description and amount of work performed.
- F. A list of a minimum of five (5) completed composite strengthening projects performed by the certified applicator. The list should include at a minimum, the dates of work, type, description and amount of work performed, and the name and telephone number of a contact person at the agency or company for which the work was completed. In addition, provide the names of the applicator's key personnel (superintendent and assistant) who will perform the actual work. The superintendent and assistant shall have a minimum experience of 1-year involvement in directing projects such as this.

1.05 PERFORMANCE

- A. Material supplier shall design the composite system to safely achieve the required structural performance per the design criteria provided by Sandia National Laboratories (SNL) while ensuring strain compatibility.
- B. Material supplier shall have past experience in the installation and actual testing of composites in shock tube for blast testing of composites.

1.06 PRODUCT DELIVERY, STORAGE, AND HANDLING

- A. Deliver epoxy materials in factory-sealed containers with the manufacturer's labels intact and legible with verification of date of manufacture and shelf life.
- B. Store materials in a protected area at a temperature between 35°F and 100°F.
- C. Products shall be stored according to the manufacturer's requirements and shall avoid contact with moisture.

1.07 PRE-QUALIFICATIONS

The composite system shall be installed by a certified applicator of the composite fabric system with a minimum of two years experience in performing similar composite retrofits. The following firms met the requirements for pre-qualification.

- A. Delta Structural Technology, Inc.
18109 Ammi Trail
Houston, Texas 77060
(281) 821-3006
- B. Fyfe Company, L.L.C.
6310 Nancy Ridge Drive, Suite 103

San Diego, CA 92121-3209
(858) 642-0694

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

For the design of the composite systems, the following strain limits shall be maintained for the design of the composites.

Flexure static loads;	0.002
Flexure dynamic blast loads;	0.008
Shear	0.004

The design of the composites shall be in accordance to ACI 440 in the application of the C_E environmental reduction factor to the Elastic Design Modulus to determine the design modulus in the use of the design of composites, or the reductions factors established by the System Manufacturer.

2.02 MATERIALS

Approved Tyfo[®] Fibrwrap[®] System to be supplied by Fyfe Company LLC - Nancy Ridge Technology Center - 6310 Nancy Ridge Dr, Suite 103, San Diego, CA 92121. Tel: (858) 642-0694, Fax: (858) 642-0947, info@fyfeco.com, www.fyfeco.com.

Products include:

- A. Composites: Tyfo[®] carbon fabric
Tyfo[®] glass fabric
Tyfo[®] anchors
- B. Epoxy primer/saturant: Tyfo[®] S epoxy to be combined with the fabric to form the Tyfo[®] Fibrwrap[®] composite. Tyfo[®] WP epoxy can be used as a primer on damp substrates.
- C. Epoxy adhesive: Tyfo[®] TC epoxy.
- D. Primer/filler: Tyfo[®] WS thickened epoxy for protective final coating and filling voids or detailing.
- E. Finish paint: Tyfo[®] HS or required finish paint to be color matched to existing structure.

2.03 OTHER MATERIALS

- A. Provide other materials as needed for the proper installation of the complete composite system as selected by the contractor in conformance with these specifications.

PART 3 - EXECUTION OF WORK

3.01 The work described under this specification shall be performed by an applicator with proven past experience utilizing the manufacturer's system. The applicator company shall be certified by the manufacturer through written verification and shall provide a quality control procedure in compliance with the manufacturer's installation requirements. Contact manufacturer listed in Section 2.02 for a list of certified applicators.

3.02 Surface Preparation

A. Contact Critical Application:

- This application is for columns and other elements that allow full encasement of the element and are not bond-critical.
- The surface to receive composite shall be free from fins, sharp edges and protrusions that will cause voids behind the installed composite or that, in the opinion of the Engineer, will damage the fibers. Existing uneven surfaces to receive composite shall be filled with epoxy filler or other material approved by the Engineer. Filling of large voids in surfaces to receive composite shall be paid for as an extra to the contract work of installing the composite system (small pinholes or micro-bubbles in the concrete surface or resin, do not require special detailing). The contact surfaces shall have no free moisture on them at the time of application. If moisture cannot be avoided, use the manufacturer's suggested wet prime epoxy.

B. Bond Critical Applications:

- Applications that do not allow encasement of the element such as beams, slabs, and walls.
- Application surfaces shall have all foreign materials removed and be abraded by sand blasting, high pressure water blasting, or grinding the surface to 1/16" minimum amplitude. Application areas must be cleaned to remove all dust and unsound materials.
- Anchorage (if required) will require the drilling of holes during the abrasion process prior to cleaning of the prepared substrate.
- ASTM D4541-98 can be used to verify the tensile strength of the concrete prior to the application of the composite system.

C. Round off sharp and chamfered corners to receive the composite system to a radius of 1 inch ($\pm 0.25"$) by means of grinding or forming with the system's thickened epoxy. Variations in the radius along the edge shall not exceed 1/2" for every 12" of length.

3.03 Procedures for Application

A. Preparation work for project: Visit site to insure that all surface preparation (if required) is acceptable and the patchwork is complete and cured. Review project specifications and drawings in detail.

- B. Verify ambient and concrete temperatures. No work shall proceed if the temperature of the concrete surface being repaired is less than 35 °F or greater than 100 °F. The temperature of the epoxy components shall be between 35 and 100°F at the time of mixing or as specified on the component labels. When air temperature is outside the prescribed range, other measures must be employed to ensure components' temperature is maintained within this range.
- C. Prepare the epoxy matrix by combining components at a weight (or volume) ratio specified on the manufacturer's labeled units, with an allowable tolerance of ±10%. The components of epoxy resin shall be mixed with a mechanical mixer until uniformly mixed, typically 5 minutes at 400-600 rpm. Components that have exceeded their shelf life (as designated on the material label) shall not be used.
- D. Saturation of the fabric shall be performed and monitored according to manufacturer's specified fiber-resin ratio. A previously calibrated saturator can be used to achieve the specified ratio. Fabric shall be completely saturated prior to application to contact surface in order to assure complete impregnation of fabric. Saturation shall be supervised and checked by the certified installer.
- E. Both the epoxy resin and fabric shall be measured accurately, combined, and deposited uniformly at the rates shown on the approved working drawings and per manufacturer's recommendations. The composite system shall be comprised of fibers completely saturated with epoxy resin per proper ratio.
- F. Quality control procedures: Record batch numbers for fabric and epoxy used each day, and note locations of installation. Measure square footage of fabric and volume of epoxy used each day. Label test specimens from each day's production and submit modified ASTM 3039 test results, as they are made available. Complete report and submit to Owner and system manufacturer. Ensure that the testing data results meet or exceed the values used in the design of the composite system. The bond strength of the installed composite system can also be verified for bond critical applications by the ASTM D4541-98 field test.
- G. Fabric sampling procedure (12" x 12" or as required): From a standard epoxy mix saturate fabric according to specified fiber-resin ratio. On a smooth, flat, level surface covered with polyethylene sheeting, or 16 mil plastic film, prime with epoxy resin, then prepare sample by placing two layers of saturated fabric oriented in the same direction. Apply additional topping of epoxy. Cover with plastic film and squeegee out all bubbles. Samples shall be stored in a sample box and not moved for a minimum 48 hours after casting. The prepared, identified samples shall be given to a pre-approved and experienced testing laboratory. Laboratory shall precondition samples for 48 hours at 140 °F before testing (see Section 3.05C for testing requirements).
- H. Installation Procedures:
 - 1. Prepare surface as required.
 - 2. Clean surface per specification.
 - 3. Clean up and protect area adjacent to element.
 - 4. Using a roller or trowel, apply one prime coat of thickened epoxy resin to the prepared surface (2 mil. min.). Allow primer to become tacky to the touch.

5. Saturate fabric with epoxy matrix through calibrated saturator or according to manufacturer's specified fiber-resin ratio.
6. Apply composite system per the project drawings and specifications.
7. Apply Tyfo[®] WS thickened epoxy (if required) to smooth the substrate prior to the installation of the composite system.
8. Apply composite to the prepared substrate by hand lay-up, using methods that produce a uniform, constant tensile force that is distributed across the entire width of composite. Under certain application conditions, the system may be placed entirely by hand methods assuring a uniform, even final appearance. Gaps between composite bands may not exceed 1/2 inch in width in the fabric's transverse joint unless otherwise noted on project drawings. A lap length of at least 6 inches is required at all necessary over-laps in the longitudinal direction of the fabric.
9. Apply subsequent layers, continuously or spliced, until designed number of layers is achieved, per project drawings.
10. Using a roller or hand pressure, insure proper orientation of fibers, release or roll out entrapped air, and ensure that each individual layer is firmly bedded and adhered to the preceding layer or substrate.
11. Apply a final coat of thickened epoxy. Detail all fabric edges, including butt splice, termination points, and jacket edges, with epoxy.
12. Finish: Paint Tyfo[®] WS paint to be color matched to existing structure. Apply as specified between 24 and 72 hours after final application of epoxy. If after 72 hours the epoxy is cured, the surface must be roughened by sanding or brush blasting. Dust and residue shall be removed prior to application of paint coats.

I. Curing of composite system

Epoxy curing temperatures shall be maintained in the temperature range designated for the formulation used. Temperature cure ranges and times to be determined by manufacturer.

3.04 PROCEDURE MODIFICATIONS

- A. Installation procedures may be modified to achieve maximum results, subject to approval by the engineer of record or Owner. Procedure modifications shall be discussed with the engineer of record and Owner prior to implementing the modifications.

3.05 FIELD QUALITY CONTROL

(See *Fyfe Co. LLC Quality Control Manual*)

A. Installers:

Record batch numbers for fabric and epoxy used each day, and note locations of installation. Measure square footage of fabric and volume of epoxy used each day. Complete report and submit to Owner and system manufacturer.

B. Inspection:

Certified Special Inspector, approved by Sandia National Laboratory, shall periodically observe all aspects of preparation, mixing, and application of materials, including the following:

1. Material container labels
2. Surface Preparation
3. Mixing of epoxy
4. Application of epoxy to the fiber
5. Application of composite system
6. Curing of composite material

The composite casing shall be completely inspected by the Deputy Inspector during and immediately following application of the composite.

The contractor shall monitor the mixing of all epoxy components for proper ratio and adherence to manufacturer's recommendations.

C. Laboratory Testing:

SAMPLING AND TESTING--Record lot number of fabric and resin used along with the location of installation. A "sample batch" shall consist of two 12 inch by 12 inch "samples" of cured composite. A minimum of two "sample batches" shall be made daily. The two "sample batches" will be taken at appropriate times during the day as to ensure the maximum material deviance in the components of the composite. Testing laboratory shall pre-condition samples at 140 degrees Fahrenheit for 48 hours before testing. "Samples" shall be tested, at random, at owner's discretion and cost.

Tested samples shall be tested per ASTM D3039. The 12" x 12" panel shall have 5-coupons, 3/4" x 9", removed and tested for their material properties in the longitudinal (glass or carbon fiber) direction. Tests shall conform to ASTM procedures and manufacturer's published testing methods. Only pre-qualified and experienced testing laboratories shall be used.

Testing results shall be made available within 3 weeks of sample submission. The testing shall provide average values, based on nominal layer thickness, of the following:

1. Ultimate tensile strength
2. Tensile modulus
3. Percent elongation

Acceptable minimum values for ultimate tensile strength, tensile modulus, and elongation are the reduced typical test values used for the design of the composite system. Any values below these design values are considered a failure and require remedial measures (see section 3.05 E).

15% of all “sample batches” are suggested to be tested. If one 12” x 12” “sample” fails (on average), specimens from the same “sample” will be tested. If these specimens also fail (on average), the other 12” x 12” from the same “sample batch” will be tested. In the extreme case that this sample also fails, the remaining “sample batch” for that day will be tested and appropriate remedial measures, per Section 3.05E, taken to ensure integrity of the system at locations from the failed “sample batch”. In addition, 25% of the remaining “sample batches” will then be tested by the same criteria.

D. Repairs:

All defects (including bubbles, delaminations, and fabric tears) spanning more than 5% of the surface area, or as specified by the owner or engineer, shall be repaired.

Two types of repairs shall be performed:

1. Small defects (on the order of 3” diameter) shall be injected or back filled with epoxy. Two small holes shall be drilled into the bubble to allow injection of the epoxy and escape of entrapped air.
2. Bubbles less than 6” in diameter shall be either repaired by injecting with epoxy, or removal. The proper method for the location to be determined by the applicator and approved by the engineer of record.
3. Bubbles and delaminations greater than 12” in diameter shall be repaired by removing and re-applying the required number of layers of the composite and the required finish coatings.

The engineer of record shall approve all repair procedures.

Small entrapped air pockets and voids naturally occur in mixed resin systems and do not require repair or treatment.

E. Remedial Measures:

In the event that material testing, per Section 3.05C, determines a “sample batch” to possess insufficient material properties, remedial measures shall be taken. Any structural member where the installed composite system has material properties determined to be below the minimum specified values, additional layers shall be installed until the composite thickness is increased by the same percentage as the deficiency of the material’s tensile modulus.

END OF SECTION