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ESR-3028

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DIVISION: 03 00 00—CONCRETE
SECTION: 03 01 00—MAINTENANCE OF CONCRETE

REPORT HOLDER:

FREYSSINET, INC.

44880 FALCON PLACE, SUITE 100
STERLING, VIRGINIA 20166

EVALUATION SUBJECT:

CONCRETE STRENGTHENING USING THE FOREVA® TFC FIBER-REINFORCED POLYMER COMPOSITE SYSTEMS

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ICC-ES Evaluation Report

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DIVISION: 03 00 00—CONCRETE
Section: 03 01 00—Maintenance of Concrete

REPORT HOLDER:

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EVALUATION SUBJECT:

CONCRETE STRENGTHENING USING THE FOREVA® TFC FIBER-REINFORCED POLYMER COMPOSITE SYSTEMS

1.0 EVALUATION SCOPE

Compliance with the following codes:

- 2015 and 2012 *International Building Code®* (IBC)
- 2015 and 2012 *International Residential Code®* (IRC)

Properties evaluated:

- Structural
- Durability
- Fire resistance
- Interior finish

2.0 USES

The Foreva® TFC Fiber-reinforced Polymer (FRP) Composite Systems are used externally to strengthen normal-weight reinforced concrete structural elements as an alternative to those systems permitted in the IBC. The systems are also used as an interior finish. For structures regulated under the IRC, the Foreva® composite systems may be used where an engineering design is submitted in accordance with Section R301.1.3 and approved by the code official in accordance with IRC Section R104.11.

3.0 DESCRIPTION

3.1 General:

The Foreva® TFC Fiber-reinforced Composite Systems are externally bonded fiber reinforced polymer (FRP) systems applied to normal-weight concrete substrates. The systems consist of carbon fabrics combined with resin which, in combination, create the FRP composite system.

3.2 Material:

3.2.1 General: All materials must comply with the approved specifications outlined in the Freyssinet quality documentation (hereinafter referred to as the QCM), Revision A, dated March 2015.

3.2.2 Fabric Sheets: The bi-directional Foreva® TFC 75, 150, 200, and 300, and the unidirectional Foreva® TFC UD 350 /75, 350/150, 350/200, and 350/300 fabric sheets are made from carbon fibers. Standard rolls of fabric are available in widths of 3, 6, 8, and 12 inches (75, 150, 200, and 300 mm) and in lengths up to 164 feet (50 m). The rolls of fabric are packaged in boxes.

3.2.3 Polymer Matrix: The Foreva® Epx TFC is a two-component epoxy resin used for impregnating the dry fabric sheets and binding the fibers together for the transfer of stresses. Foreva® Epx TFC is an ambient cure epoxy. Components A (resin) and B (hardener) of the matrix are shipped either in 11 lbs (5 kg) or in 4 lbs (1.8 kgs) containers. They are mixed with 70 percent Part A and 30 percent Part B mixture proportions at the jobsite prior to application.

3.2.4 Composite Systems:

3.2.4.1 Foreva® TFC 300: The Foreva® TFC 300 is a carbon fiber composite system, consisting of the Foreva® TFC 300 fabric sheet and resin described in Sections 3.2.2 and 3.2.3, with the following cured properties: In the primary direction (0º), the composite has a design tensile strength of 180 ksi (1,240 MPa), a nominal tensile modulus of 15,230 ksi (105,000 MPa), and a corresponding elongation of 1.2 percent. The layer thickness is 0.02 inch (0.508 mm). The density of fibers in the primary direction is 350 grams/m^2. The secondary direction in Foreva® TFC (90º) is not participating in the resistance of the Foreva® TFC 300 composite system. The density of fibers in the secondary direction is 150 grams/m^2. The width of the fabric is 300 mm (12 in).

3.2.4.2 Foreva® TFC 200: The Foreva® TFC 200 is a carbon fiber composite system, consisting of the Foreva® TFC 200 fabric sheet and resin described in Sections 3.2.2 and 3.2.3, with the following cured properties: In the primary direction (0º), the composite has a design tensile strength of 180 ksi (1,240 MPa), a nominal tensile modulus of 15,230 ksi (105,000 MPa), and a corresponding elongation of 1.2 percent. The layer thickness is 0.02 inch (0.508 mm). The density of fibers in the primary direction is 350 grams/m^2. The secondary direction (90º) in Foreva® TFC is not participating in the resistance of the Foreva® TFC 200 composite system. The density of fibers in the secondary direction is 150 grams/m^2. The width of the fabric is 200 mm (8 in).

3.2.4.3 Foreva® TFC 150: The Foreva® TFC 150 is a bi-directional carbon fiber composite system, consisting of the

Foreva® TFC 150 fabric sheet and resin described in Sections 3.2.2 and 3.2.3, with the following cured properties: In the primary direction (0º), the composite has a design tensile strength of 180 ksi (1,240 MPa), a nominal tensile modulus of 15,230 ksi (105,000 MPa), and a corresponding elongation of 1.2 percent. The layer thickness is 0.02 inch (0.508 mm). The density of fibers in the primary direction is 350 grams/m^2. The secondary direction (90º) in Foreva® TFC is not participating in the resistance of the Foreva® TFC 150 composite system. The density of fibers in the secondary direction is 150 grams/m^2. The width of the fabric is 150 mm (6 in).

3.2.4.4 Foreva® TFC 75: The Foreva® TFC 75 is a bi-directional carbon fiber composite system, consisting of the Foreva® TFC 75 fabric sheet and resin described in Sections 3.2.2 and 3.2.3, with the following cured properties: In the primary direction (0º), the composite has a design tensile strength of 180 ksi (1,240 MPa), a nominal tensile modulus of 15,230 ksi (105,000 MPa), and a corresponding elongation of 1.2 percent. The layer thickness is 0.02 inch (0.508 mm). The density of fibers in the primary direction is 350 grams/m^2. The secondary direction (90º) in Foreva® TFC is not participating in the resistance of the Foreva® TFC 75 composite system. The density of fibers in the secondary direction is 150 grams/m^2. The width of the fabric is 75 mm (3 in).

3.2.4.5 Foreva® TFC UD 350/300: The Foreva® TFC UD 350/300 is a carbon fiber composite system, consisting of the Foreva® TFC UD 350/300 fabric sheet and resin described in Sections 3.2.2 and 3.2.3, with the following cured properties: In the primary direction (0º), the composite has a design tensile strength of 180 ksi (1,240 MPa), a nominal tensile modulus of 15,230 ksi (105,000 MPa), and a corresponding elongation of 1.2 percent. The layer thickness is 0.02 inch (0.508 mm). The density of fibers in the primary direction is 350 grams/m^2. The secondary direction (90º) in Foreva® TFC UD is constituted by glass fibers (Hot melt 70 Tex Glass Polyamid) welding the carbon fibers in the primary direction and it is not participating in the resistance of the Foreva® TFC UD 350/300 composite system. The width of the fabric is 300 mm (12 in).

3.2.5 Foreva® TFC UD 350/200: The Foreva® TFC UD 350/200 is a carbon fiber composite system, consisting of the Foreva® TFC UD 350/200 fabric sheet and resin described in Sections 3.2.2 and 3.2.3, with the following cured properties: In the primary direction (0º), the composite has a design tensile strength of 180 ksi (1,240 MPa), a nominal tensile modulus of 15,230 ksi (105,000 MPa), and a corresponding elongation of 1.2 percent. The layer thickness is 0.02 inch (0.508 mm). The density of fibers in the primary direction is 350 grams/m^2. The secondary direction (90º) in Foreva® TFC UD is constituted by glass fibers (Hot melt 70 Tex Glass Polyamid) welding the carbon fibers in the primary direction and it is not participating in the resistance of the Foreva® TFC UD 350/200 composite system. The width of the fabric is 200 mm (8 in).

3.2.6 Foreva® TFC UD 350/150: The Foreva® TFC UD 350/150 is a carbon fiber composite system, consisting of the Foreva® TFC UD 350/150 fabric sheet and resin described in Sections 3.2.2 and 3.2.3, with the following cured properties: In the primary direction (0º), the composite has a design tensile strength of 180 ksi (1,240 MPa), a nominal tensile modulus of 15,230 ksi (105,000 MPa), and a corresponding elongation of 1.2 percent. The layer thickness is 0.02 inch (0.508 mm). The density of fibers in the primary direction is 350 grams/m^2. The secondary direction (90º) Foreva® TFC UD is constituted by glass fibers (Hot melt 70 Tex Glass Polyamid) welding the carbon fibers in the primary direction and it is not participating in the resistance of the Foreva® TFC UD 350/150 composite system. The width of the fabric is 150 mm (6 in).

3.2.7 Foreva® TFC UD 350/75: The Foreva® TFC UD 350/75 is a carbon fiber composite system, consisting of the Foreva® TFC UD 350/75 fabric sheet and resin described in Sections 3.2.1 and 3.2.2, with the following cured properties: In the primary direction (0º), the composite has a design tensile strength of 180 ksi (1,240 MPa), a nominal tensile modulus of 15,230 ksi (105,000 MPa), and a corresponding elongation of 1.2 percent. The layer thickness is 0.02 inch (0.508 mm). The density of fibers in the primary direction is 350 grams/m^2. The secondary direction (90º) in Foreva® TFC UD is constituted by glass fibers (Hot melt 70 Tex Glass Polyamid) welding the carbon fibers in the primary direction and it is not participating in the resistance of the Foreva® TFC UD 350/75 composite system. The width of the fabric is 75 mm (3 in).

3.2.8 Storage Recommendations: The materials must be stored in a clean, dry area at an ambient temperature between 41 ºF (5 ºC) and 86 ºF (30 ºC). The lifetime of the resin when stored under these conditions in unopened containers is 4 years. When properly stored under these conditions, the Foreva® TFC 75, 150, 200, and 300 and the Foreva® TFC UD 350/75, 350/150, 350/200, and 350/300 fabric sheets have an unlimited shelf life**.**

4.0 DESIGN AND INSTALLATION

4.1 Design:

4.1.1 General: Design of the Foreva® TFC composite systems must be based on required tensile loads at designated concrete strain values. The strength design requirements for concrete must be in accordance with Chapter 19 of the IBC. The owner and registered design professional must be responsible for determining through analysis, the strengths and demands of the structural elements to be enhanced by the Foreva® TFC Composite Systems, subject to the approval of the code official.

4.1.2 Composite Design Properties: Structural design properties for the systems are found in the Foreva TFC System Design Criteria Report (Design Manual), dated April 18, 2013.

4.1.3 Design Details: Design of the Foreva® TFC composite systems is based on test results and principles of structural analysis as set forth in Section 1604.4 of IBC. The bases of the design include strain compatibility, load equilibrium and limit states. All designs must follow procedures as detailed in the IBC; in the ICC-ES Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber-Reinforced Polymer (FRP) Composite Systems (AC125) dated August 2014, and in the Foreva® TFC System Design Criteria Report (Design Manual), dated April 18, 2013.

4.1.4 Design Strength: Design strengths must be taken as the nominal strength, computed in accordance with Section 4.1.2 of this report, multiplied by strength reduction factors provided in Section 21.2 of ACI 318-14 (2015 IBC) or Section 9.3 of ACI 318-11 (2012 IBC).

4.1.5 Load Combinations: The load combinations used in design must comply with Section 1605 of the IBC. Strength reduction factors must comply with Chapter 19 of the IBC.

4.1.6 Columns:

4.1.6.1 Potential Applications: The Foreva® TFC Composite Systems are applied to columns to enhance their axial strengths. The columns may be circular or rectangular.

4.1.6.2 Structural Design Requirements: Concrete column design must comply with the Design Manual (DM) and with Chapter 19 of the IBC.

4.1.7 Beams and Slabs:

4.1.7.1 Potential Applications: The Foreva® TFC Composite Systems are applied to concrete beams to enhance flexural and shear strength for gravity load resistance only, and applied to slabs to enhance flexural strength for gravity load resistance only.

4.1.7.2 Structural Design Requirements: Concrete beam and slab design must comply the DM and with Chapter 19 of the IBC.

4.1.8 Walls:

4.1.8.1 Potential Applications: The Foreva® TFC Composite Systems are applied to concrete walls to enhance out-of-plane flexural strength, only if walls are subjected to uniformly distributed loads (a behavior similar to horizontal slabs subjected to gravity loads).

4.1.8.2 Structural Design Requirements: Wall design must comply the DM must and with Chapter 19 of the IBC.

4.1.9 Bond Strength: Where the performance of the FRP composite material depends on bond, the bond strength of the FRP composite material to the concrete must not be less than 200 psi (1,378 kPa). Bond testing must exhibit failure in the concrete substrate. Testing in accordance with ASTM D7234, C297 or D7522 can be used to estimate the bond strength of bond-critical installations.

4.2 Installation:

4.2.1 The Foreva® TFC Composite Systems must be installed on structural elements as detailed in the manufacturer's document "Installation Instructions" dated April 24, 2015 by certified applicators. A copy of these installation instructions must be submitted to the code official for approval of each project that uses the Foreva® TFC Composite Systems. The on-site quality control procedures are detailed in the installation instructions.

4.2.2 Saturation: The fibers and the matrix must be combined in accordance with an established weight-and-volume ratio as given in the installation instructions dated April 24, 2015, using the calibrated TFC saturator or manual methods.

4.2.3 Application: Manual methods must be used to apply the saturated composite fabric prior to cure of the epoxy. Surface preparation, fiber orientation, and removal or air bubbles and voids, must take place in accordance with specifications noted in the installation guide.

4.2.4 Finishing: The composite systems may be painted to satisfy aesthetic and environmental considerations.

4.2.5 Flame Spread: When applied to structural elements to satisfy requirements of the applicable code, five (5) plies of the Foreva® TFC Composite Systems (without any additional coating or finishing) yields a flame-spread index less than 75 and a smoke-density of 450, which corresponds to the Class B flame-spread classification in accordance with Section 803.1.1 of the IBC.

4.3 Special Inspection: Special inspection must comply with the applicable requirements in Sections 1704 through 1707 of the IBC. Special inspection during the installation of the system must be in accordance with the ICC-ES Acceptance Criteria for Inspection and Verification of Concrete and Reinforced and Unreinforced Masonry Strengthening Using Fiber-reinforced Polymer (FRP) Composite Systems (AC178), dated December 2013. Inspection must also comply with the installation instruction document of the Freyssinet. A statement of special inspection must be prepared in accordance with Sections 1704.3 of the 2015 and 2012 IBC.

5.0 CONDITIONS OF USE

The Foreva® TFC Composite Systems described in this report comply with, or are suitable alternatives to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions:

5.1 Design and installation must be in accordance with this report, the manufacturer's instructions, and the IBC.

5.2 Copies of the Freyssinet Installation Instructions, dated April 24, 2015, and Freyssinet Design Manual, dated April 18, 2013, must be submitted to the code official for approval on each project that uses the system.

5.3 Complete construction documents, including plans and calculations verifying compliance with this report, must be submitted to the code official for each project at the time of the permit application. The construction documents must be prepared and sealed by a registered design professional where required by the statutes of the jurisdiction in which the project is to be constructed.

5.4 The fire-resistance rating of the assembly must comply with Chapter 7 of the IBC and is not reduced by the application of the Foreva® TFC Composite Systems. The structural load-carrying capacities of fire-resistance-rated assemblies must be based on the design of the concrete without the Foreva® TFC Composite Systems in accordance with the IBC. Fire-resistance of assemblies with structural load-carrying capacities increased beyond the levels permitted by the IBC is beyond the scope of this report.

5.5 Special inspection must be provided in accordance with Section 4.3 of this report.

5.6 Use of the Foreva Composite Systems for applications where FRP system is in constant contact with soil, fuel and drinking water is outside the scope of this report

5.7 Application of the systems to concrete members at a fabricator's facility must be by an approved fabricator complying with Section 1704.2.2 of the IBC or at a job site with continuous special inspections in accordance with Section 1704.4 of the IBC.

5.8 Foreva® TFC materials must be manufactured by Freyssinet Inc. in Sterling, Virginia, under a quality control program with inspections by ICC-ES.

6.0 EVIDENCE SUBMITTED

Data in accordance with the ICC-ES Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber-Reinforced Polymer (FRP) Composite Systems (AC125), dated August 2014; including reports of fire-resistance tests and surface burning tests.

7.0 IDENTIFICATION

Foreva® TFC Composite Systems components (fabric and epoxy system) are labeled with the Freyssinet name and address, product name, expiration date and the evaluation report number (ESR-3028).