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FYFE® TYFO® FRP SYSTEMS

CSI Sections:
03 01 00 Maintenance of Concrete
03 01 30 Maintenance of Cast-in-Place Concrete

1.0 RECOGNITION

Tyfo FRP Systems recognized in this report have been evaluated for use in strengthening concrete diaphragms, chords, and collectors. The structural performance properties of the Tyfo FRP Systems comply with the intent of the provisions of the following codes and regulations:

- 2021, 2018, 2015, and 2012 International Building Code® (IBC)
- 2021, 2018, 2015, and 2012 International Residential Code® (IRC)
- 2022 California Building Code (CBC) – attached Supplement
- 2022 California Residential Code (CRC) – attached Supplement
- 2023 City of Los Angeles Building Code (LABC) – attached Supplement
- 2023 City of Los Angeles Residential Code (LARC) – attached Supplement

2.0 LIMITATIONS

Use of the Tyfo FRP Systems recognized in this report is subject to the following limitations:

2.1 The design and installation shall be in accordance with this report; the IBC or IRC; the FyfeFRP, LLC Installation Inspection Manual WI-6.02, dated May 2022; the FyfeFRP, LLC Quality Control Manual WI-3.01, dated August 2024; and the FyfeFRP, LLC Design Manual, Version 12, dated August 2024. Where there is a conflict, the most restrictive requirements shall govern.

2.2 Complete construction documents, including plans, shop drawings, and calculations verifying compliance with this report, shall be submitted to the building official for approval. The construction documents shall 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.

2.3 Diaphragm shear strengthening with FRP shall only apply to the following structural elements:

- Cast-in-place, composite concrete topping slab diaphragms on precast floors or roofs at least two inches thick, provided the cast-in-place topping slab interface is clean, free of laitance, and intentionally roughened.
- Cast-in-place, non-composite concrete topping slab diaphragms at 2½ inches (63.5 mm) thick, provided the cast-in-place topping slab is detailed for continuous seismic load path to vertical lateral-force-resisting elements.
- Only the topped concrete portion of non-prismatic diaphragm systems shall be considered effective for seismic shear strength, such as in concrete over metal deck or waffle slab applications, unless specific component testing is provided to justify alternative values.
- Monolithically cast-in-place concrete diaphragms.

2.4 Copies of the FyfeFRP, LLC Installation Inspection Manual WI-6.02, dated May 2022; the FyfeFRP, LLC Quality Control Manual WI-3.01, dated August 2024; and the FyfeFRP, LLC Design Manual, Version 12, dated August 2024 shall be submitted to the building official with each project.

2.5 Special inspection for the application of the Tyfo FRP Systems shall be provided in accordance with Section 3.3 of this report.

2.6. Measures shall be taken to mitigate thermal stresses that may develop from Tyfo FRP Systems' exposure to direct sunlight. For example, at roof diaphragm applications, shade or emissive coating may need to be provided to minimize the potential for temperature elongation or shrinkage.

2.7 The Tyfo FRP components recognized in this report are manufactured by FyfeFRP, LLC, in Houston, Texas**.**

3.0 PRODUCT USE

3.1 Design

3.1.1 General: The Tyfo FRP Systems shall be designed to resist tensile forces while maintaining strain compatibility between the composite and the substrate. The Tyfo® FRP Systems shall not be relied upon to resist compressive forces. The owner and the registered design professional shall be responsible for determining, through analysis, the capacity and demands of the structural elements to be enhanced with the Tyfo FRP Systems. Under the IRC, Tyfo FRP Systems may be used where an engineered design is submitted in accordance with Section R301.1.3.

3.1.2 Composite Design Values: The design values for the Tyfo FRP Systems are as listed in Sections 4.2.4 through 4.2.7 of this report, and documented in the FyfeFRP, LLC Design Manual, Version 12, dated August 2024.

3.1.3 Design Provisions: The design equations used in the Design Manual are based on structural testing and general principles of structural analysis. All designs shall comply with the requirements in the IBC and this report in addition to the FyfeFRP, LLC Design Manual Version 12, dated August 2024.

3.1.4 Load Combinations: The LRFD or strength design load combinations shall be in accordance with IBC Section 1605. Strength reduction factors shall comply with IBC Chapter 19, ACI 318, and the FyfeFRP, LLC Design Manual, Version 12, dated August 2024.

3.1.5 Diaphragms:

3.1.5.1 Potential Applications: The Tyfo FRP Systems shall be applied to concrete diaphragm sections to enhance their shear strength. The compressive strength of the existing diaphragm elements, f'_c, shall be a minimum of 2,500 psi (17.2 MPa). Clear spacing between Tyfo FRP strips shall not exceed 18 inches (457.2 mm) nor three times the strengthened element thickness.

3.1.5.2 Structural Design: Design shall comply with IBC Chapter 19, ACI 318, and the FyfeFRP, LLC Design Manual, Version 12, dated August 2024.

3.1.6 Collectors and Chords:

3.1.6.1 Potential Applications: The Tyfo FRP Systems shall be applied to concrete collector and chord elements to enhance their tension capacity.

3.1.6.2 Structural Design: Design shall comply with IBC Chapter 19, ACI 318, and the FyfeFRP, LLC Design Manual, Version 12, dated August 2024. Tyfo FRP Systems' reinforcement is effective in strengthening tension design actions only and shall not be relied upon for compression strength. Collector elements shall be evaluated for compression in accordance with ACI 318. It shall be permitted to assume an effective concrete element width equal to the Tyfo FRP Systems strip width plus the depth of the diaphragm thickness on each side of the collector element where occurs.

3.1.7 Fiber Anchors:

3.1.7.1 Potential Applications: The Tyfo SCH Fiber Anchors shall be used to transfer tensile and shear forces from the Tyfo System laminates into concrete (embedded fiber anchors) or alternately, to transfer tensile forces from a Tyfo System laminate, through an obstruction and back to a Tyfo System laminate (splice fiber anchors). Care shall be taken to avoid damage to (prestressed) post-tensioned reinforcement, where present in diaphragms, by post-installed Tyfo SCH Fiber Anchors.

3.1.7.2 Structural Design: Design shall comply with Chapter 19 (ACI 318) of the IBC and the FyfeFRP, LLC Design Manual, Version 12, dated August 2024. The design tensile force and corresponding dry fiber weight of the fiber anchor are suggested to be equivalent to 1.5 times the required tension force to be transferred in order to be considered as fully developed.

3.1.8 Bond Strength: All bond-critical applications shall require the substrate to be properly prepared such that the tested bond strength exceeds the tensile strength of the substrate. The recorded value shall be at least 200 psi (1378 kPa) for concrete. The number of tests and locations shall be specified by the registered design professional and approved by the building official. Testing in accordance with ASTM D7522 or ASTM D4541 may be used to estimate the bond strength. The bond strength has been evaluated for environmental exposures, including dry heat at 140ºF (60ºC).

3.1.9 Special Detailing and Load Path Considerations: A complete seismic load path shall be provided from the strengthened elements to the vertical support elements in the seismic force-resisting system.

3.1.9.1 The design professional shall submit design calculations and related details to the building official for approval based on principles of mechanics for diaphragm openings, holes, and penetrations.

3.1.9.2 The design professional shall detail additional anchorage at any areas of known stress concentration or horizontal irregularities, such as the corners of large openings or re-entrant corners.

3.1.9.3 The strengthening of each orthogonal direction shall be considered independently and shall not be assumed to contribute to the other direction.

3.1.9.4 The use of Tyfo FRP Systems for force transfer across cold joints or between precast panels is beyond the scope of this report.

3.2 Installation: The installation shall be performed by FyfeFRP, LLC certified and trained applicators in accordance with the FyfeFRP, LLC Installation Inspection Manual WI-6.02, dated May 2022, and the FyfeFRP, LLC Quality Control Manual WI-3.01, dated August 2024.

3.2.1 Saturation: The carbon or glass fibers used in both the fabrics and anchors shall be combined in compliance with the required weight and/or volume ratios as defined in the FyfeFRP, LLC Installation Inspection Manual WI-6.02, dated May 2022. The saturation may be achieved with an automated saturator machine or by manual methods.

3.2.2 Application: The saturated fabrics and anchors shall be applied in accordance with the FyfeFRP, LLC Installation Inspection Manual WI-6.02, dated May 2022, by personnel who have been trained and certified by FyfeFRP, LLC.

3.2.3 Finishing: The installed system shall receive a final protective layer of the thickened Tyfo S epoxy as described in Section 4.2.3 of this report.

3.2.3.1 Paint: Various paints may be applied for additional aesthetic or weather protection considerations.

3.2.4 Cure Time Prior to Loading: The installed Tyfo FRP Systems shall be allowed at least 48 hours of cure time at an average temperature of 70°F (21.1°C) prior to any loading of the structural member.

3.3 Special Inspection: Special inspection and testing are required for materials preparation, substrate preparation, and application of the Tyfo FRP System. Special inspection during the installation of the system shall comply with IBC Sections 1704 and 1705; 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); the FyfeFRP, LLC Installation Inspection Manual WI-6.02, dated May 2022; and the FyfeFRP, LLC Quality Control Manual WI-3.01, dated August 2024. Special inspectors shall provide written documentation demonstrating their qualifications for inspection of Fiber-Reinforced Polymer (FRP) Systems in accordance with IBC Section 1704. The responsibilities of the special inspector shall be prepared in accordance with AC178 and ACI PRC 440.2, for inclusion in the evaluation report. Testing shall comply with Section 4.2 of EC-038, AC178, and ACI PRC 440.2.

4.0 PRODUCT DESCRIPTION

4.1 Product Information: The Tyfo FRP Systems are externally bonded advanced composite materials composed of both glass and carbon fiber reinforced polymers (FRP). The high-strength dry fibers are combined with polymer resins and cured in ambient conditions.

4.2 Material Information:

4.2.1 Tyfo FRP Systems: The Tyfo FRP Systems are comprised of Tyfo carbon or glass fibers in the form of fabrics or anchors saturated with Tyfo resins. All materials shall comply with the requirements listed in the FyfeFRP, LLC Quality Control Manual WI-3.01, dated August 2024.

4.2.2 Tyfo Fabrics: The Tyfo SCH, SEH, BC, and BCC fabrics are unidirectional or biaxial carbon or glass fabrics. Standard fabric rolls measure 24 inches wide (610 mm) (91.44 m) by 300 linear feet (91.44 m) but roll dimensions may vary.

4.2.3 Tyfo Resin: The Tyfo S epoxy is a two-component resin used to both saturate the fibers and bond the fabrics and anchors to the concrete substrate. The epoxy is shipped in 5-gallon buckets or 55-gallon drums containing Components A and B of the resin. The components are mixed in the field at a ratio of 100:42 by volume for five minutes in a low-speed (400-600 rpm) mixer and cured under ambient conditions. The pot life is 3-to-6 hours at 68°F (20°C).

4.2.4 Tyfo SEH-51A System: The unidirectional (0°) glass fiber reinforced polymer has a minimum ultimate tensile strength of 66 ksi (460 MPa), a minimum tensile modulus of 3,730 ksi (25.7 GPa) when reported in accordance with ACI 440.2, or a minimum tensile modulus of 3,400 ksi (23.4 GPa) when reported in accordance with ASTM D7290, and an ultimate elongation of 1.8 percent. The corresponding laminate thickness is 0.05 inches (1.3 mm).

4.2.5 Tyfo SCH-41 System: The unidirectional (0°) carbon fiber reinforced polymer has a minimum ultimate tensile strength of 131 ksi (903 MPa), a minimum tensile modulus of 14,600 ksi (100.7 GPa) when reported in accordance with ACI 440.2, or a minimum tensile modulus of 12,660 ksi (87.3 GPa) when reported in accordance with ASTM D7290, and an ultimate elongation of 0.9 percent. The corresponding laminate thickness is 0.04 inches (1.0 mm).

4.2.6 Tyfo SCH-41-2X System: The unidirectional (0°) carbon fiber reinforced polymer has a minimum ultimate tensile strength of 131 ksi (903 MPa), a minimum tensile modulus of 14,600 ksi (100.7 GPa) when reported in accordance with ACI 440.2, or a minimum tensile modulus of 12,660 ksi (87.3 GPa) when reported in accordance with ASTM D7290, and an ultimate elongation of 0.9 percent. The corresponding laminate thickness is 0.08 inches (2.0 mm).

4.2.7 Tyfo SCH-41S System: The unidirectional (0°) carbon fiber reinforced polymer has a minimum ultimate tensile strength of 131 ksi (903 MPa), a minimum tensile modulus of 14,600 ksi (100.7 GPa) when reported in accordance with ACI 440.2, or a minimum tensile modulus of 12,660 ksi (87.3 GPa) when reported in accordance with ASTM D7290, and an ultimate elongation of 0.9 percent. The corresponding laminate thickness is 0.04 inch (1.0 mm).

4.2.8 Tyfo SCH-41S-2X System: The unidirectional (0°) carbon fiber reinforced polymer has a minimum ultimate tensile strength of 131 ksi (903 MPa), a minimum tensile modulus of 14,600 ksi (100.7 GPa) when reported in accordance with ACI 440.2, or a minimum tensile modulus of 12,660 ksi (87.3 GPa) when reported in accordance with ASTM D7290, and an ultimate elongation of 0.9 percent. The corresponding laminate thickness is 0.08 inch (2.0 mm).

4.2.9 Tyfo BCC System: The biaxial (plus-minus-45°) carbon fiber reinforced polymer has a minimum ultimate tensile strength of 87.8 ksi (605.3 MPa), a minimum tensile modulus of 7,270 ksi (50.1 GPa) when reported in accordance with ACI 440.2, or a minimum tensile modulus of 6,070 ksi

(41.9 GPa) when reported in accordance with ASTM D7290, and an ultimate elongation of 1.45 percent. The corresponding laminate thickness is 0.034 inch (0.86 mm).

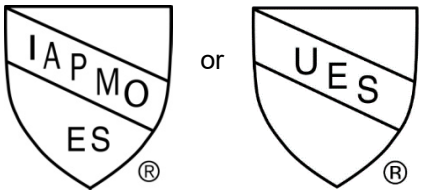
4.2.10 Tyfo BC System: The biaxial (plus-minus-45°) glass fiber reinforced polymer has a minimum ultimate tensile strength of 38.4 ksi (264.7 MPa), a minimum tensile modulus of 2,610 ksi (18.0 GPa) when reported in accordance with ACI 440.2, or a minimum tensile modulus of 2,040 ksi (14.1 GPa) when reported in accordance with ASTM D7290, and an ultimate elongation of 1.88 percent. The corresponding laminate thickness is 0.034 inch (0.86 mm).

4.2.11 Tyfo SCH Fiber Anchor: The unidirectional (0°) carbon fiber reinforced polymer anchor (up to ⅞-inch diameter) has a minimum ultimate tensile strength of 131 ksi (903 MPa), a minimum tensile modulus of 14,600 ksi (100.7 GPa) when reported in accordance with ACI 440.2, or a minimum tensile modulus of 12,660 ksi (87.3 GPa) when reported in accordance with ASTM D7290, an elongation at break of 0.9 percent. and a minimum ultimate shear strength of 50 ksi (345 MPa). The minimum bond shear strength is 3,000 psi (20.7 MPa) in uncracked concrete. The minimum bond shear strength is 2,300 psi (15.9 MPa) in cracked concrete with a crack width of 0.012 inch (0.31 mm). The minimum bond shear strength is 1600 psi (11.0 MPa) in cracked concrete with a crack width of 0.020 inch (0.51 mm). The bond shear strengths have been evaluated for exposures to an elevated temperature of 140°F (60°C). Fiber anchors are shipped in boxes containing the specified number of anchors of a particular diameter and length.

4.2.12 Storage: For the fabrics, anchors, and resins, there shall be no water contamination during storage. Temperatures shall be from 60ºF (15ºC) to 100ºF (38ºC). Resin is susceptible to crystallization at temperatures below 50ºF (10ºC). If crystallized, epoxy shall be reheated until clear. Store fabric rolls flat, not on ends, at temperatures below 100ºF (38C). The shelf life shall not exceed two years for the resin and ten years for the fabrics and anchors.

5.0 IDENTIFICATION

Tyfo FRP Systems are identified by the FyfeFRP, LLC name and trademark, product name, expiration date, and evaluation report number (ER-595). Either IAPMO UES Mark of Conformity may also be used as shown below:



IAPMO UES ER-595

6.0 SUBSTANTIATING DATA

6.1 Data in accordance with IAPMO UES EC-038-2022, Evaluation Criteria for Diaphragm Strengthening Using Fiber Reinforced Polymers, Adopted May 13, 2022.

6.2 Data in accordance with ICC-ES AC125, Acceptance Criteria for Concrete and Reinforced and Unreinforced Masonry Strengthening Using Externally Bonded Fiber-Reinforced Polymer (FRP) Composite Systems, revised November 2021, editorially revised March 2024.

6.3 Report on advances in retrofit and testing of reinforced concrete shear members: Part 1 – Seismic retrofit of deficient members with fiber-reinforced polymer sheets; Part 2 – Building scale performance evaluation using hybrid simulation.

6.4 Report of data on the seismic retrofitting of damaged reinforced concrete shear members using the Tyfo FRP System including hybrid simulation.

6.5 Report of tests and analysis concerning the retrofit of reinforced concrete members using advanced composite materials.

6.6 Report of tension tests and analyses on Fyfe Tyfo SCH Carbon Fiber Anchor System, in accordance with ACI 355.4.

6.7 Report of shear tests and analyses on Fyfe Tyfo SCH Carbon Fiber Anchor System, in accordance with ACI 355.4.

6.8 Test reports submitted are from laboratories in compliance with ISO/IEC 17025.

7.0 STATEMENT OF RECOGNITION

This evaluation report describes the results of research completed by IAPMO Uniform Evaluation Service on FyfeFRP, LLC Tyfo FRP Systems to assess conformance to the codes shown in Section 1.0 of this report and serves as documentation of the product certification. Products are manufactured at locations noted in Section 2.7 of this report under a quality control program with periodic inspections under the supervision of IAPMO UES.

For additional information about this evaluation report please visit www.uniform-es.org or email us at info@uniform-es.org

CALIFORNIA SUPPLEMENT

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1.0 RECOGNITION

The FyfeFRP, LLC Tyfo FRP Systems as evaluated and represented in IAPMO UES Evaluation Report ER-595 and with changes as noted in this supplement are satisfactory alternatives for use in buildings built under the following codes:

- 2022 California Building Code (CBC)
- 2022 California Residential Code (CRC)

2.0 LIMITATIONS

Use of the FyfeFRP, LLC Tyfo FRP Systems recognized in this report supplement is subject to the following limitations:

2.1 FyfeFRP, LLC Tyfo FRP Systems shall comply with the provisions applicable to the 2021 IBC or 2021 IRC in IAPMO UES ER-595.

2.2 Use of the systems in the exterior design and construction of new buildings located in a Very High Fire Hazard Severity Zone as defined in CBC Section 702A is beyond the scope of this report supplement.

2.3 Use of the systems in the exterior design and construction of new buildings located in a Very High Fire Hazard Severity Zone as defined in CRC Section R337.2A is beyond the scope of this report supplement.

2.4 California Department of Health Care Access and Information (HCAi) (formerly OSHPD) and Division of State Architect (DSA) provisions shall be observed where applicable.

2.5 Systems used in existing concrete structures under the jurisdiction of HCAi (OSHPD) shall comply with CBC Section 1911.3. Diaphragms, collectors, and chords recognized in this supplement comply with Exception 2 as alternative systems.

2.6 Systems used in existing concrete structures under the jurisdiction of HCD, DSA, or HCAi (OSHPD) shall comply with CBC Section 1911A.3. Diaphragms, collectors, and chords recognized in this supplement comply with Exception 2 as alternative systems.

2.7 This supplement expires concurrently with ER-595.

CITY OF LOS ANGELES SUPPLEMENT

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1.0 RECOGNITION

The FyfeFRP, LLC Tyfo FRP Systems as evaluated and represented in IAPMO UES Evaluation Report ER-595 and the California Supplement and with changes as noted in this supplement are satisfactory alternatives for use in buildings built under the following codes:

- 2023 City of Los Angeles Building Code (LABC)
- 2023 City of Los Angeles Residential Code (LARC)

2.0 LIMITATIONS

Use of the FyfeFRP, LLC Tyfo FRP Systems recognized in this report supplement is subject to the following limitations:

2.1 FyfeFRP, LLC Tyfo FRP Systems shall comply with the provisions applicable in the California Supplement.

2.2 Use of the systems in the exterior design and construction of new buildings located in a Very High Fire Hazard Severity Zone Wildland–Urban Interface Fire Area as defined in CBC Section 702A is beyond the scope of this report supplement.

2.3 Use of the systems in the exterior design and construction of new buildings located in a Very High Fire Hazard Severity Zone Wildland–Urban Interface Fire Area as defined in CRC Section R337.2A is beyond the scope of this report supplement.

2.4 Prior to installation, calculations and details demonstrating compliance with this report supplement and the 2023 LABC or 2023 LARC shall be submitted to the structural plan check section for review and approval. Building design calculations and details shall be prepared, stamped, and signed by a California registered design professional.

2.5 Design, installation, and inspection shall be in accordance with Chapters 16 and 17 of the LABC or the LARC, as applicable, due to local amendments to these chapters.

2.6 Special Inspections are required in accordance with LABC Section 1705.3, Concrete Construction. Continuous inspection shall be provided in accordance with AC178. The continuous inspection shall be performed by registered deputy building inspectors.

2.7 Structural Observation is required in accordance with LABC Section 1704.6.

2.8 Systems used in existing concrete structures shall comply with LABC Section 1911.1.

2.9 The Tyfo FRP Fiber-reinforced Composite System may be used without weather protection in accordance with LABC Section 1402, subject to the review and evaluation for site-specific exposure conditions by the California registered design professional.

2.10 This supplement expires concurrently with ER-595.