

Problem/Question – Composite fiber reinforced polymer (FRP) anchors, typically called fiber anchors, are typically used in combination with wet-layup FRP laminate applications to improve end details, to provide additional anchorage of FRP laminate repairs, or to develop forces in FRP laminates across structural elements. Although commonly used in wet-layup FRP applications, guidelines on proper installation and inspection of FRP anchors are limited.

Response – This *PracNote* describes the techniques, tips and methods for installation and inspection of fiber anchors for use in conjunction with FRP reinforcing systems for concrete structural elements.

Keywords: anchors, FRP, laminate, installation, inspection

Applicability

The methods described below for installing fiber anchors are applicable to construction personnel and/or persons serving in a quality assurance role during installation and inspection of fiber anchors, when used in conjunction with FRP reinforcing systems, for repair and strengthening of concrete and masonry structures. This document does not address the design and manufacturing process of FRP anchors or the engineering approach for strengthening with the use of FRP anchors. This document does not detail the required safety procedures which should comply with all applicable documentation and standards.

Method for installation of fiber anchors

Tools & Equipment

- Containers for mixing and measuring the epoxy material
- Scale for weighing components, as needed
- Plastic trowel, spatula, or aluminum grooved roller
- Mechanical mixer with appropriate mixing blade
- Rotary-precussive hammer drill with carbide-tipped masonry and concrete hammer bit
- Steel bristle pipe brush equal to or greater than anchor hole diameter
- Appropriate vacuum collection system for concrete dust
- Vacuum nozzle capable of reaching full embedment depth of anchor hole
- Air compressor for blowing out holes (min. air pressure = 35 psi)

- 60cc syringe or similar plunger tool with tip capable of reaching full embedment depth
- Anchor insertion tool with length equal to full embedment depth (flat head screwdriver or similar)
- Steel wire for through-hole anchor applications to pull anchors through concrete elements.
- Protective release film such as 16-gauge vinyl
- Flat worktable or worksurface

Material

- Saturating epoxy – 2-part, low viscosity epoxy resin system for anchor saturation
- Putty – 2-part epoxy paste (pre-blended thickened epoxy or epoxy thickened onsite by trained applicators per manufacturer’s instructions).
- Fiber anchor of correct diameter and length. Fiber anchors can either be bundles of dry fibers (herein referred to as dry fiber anchors) or shop-fabricated

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anchors with a precured dowel end (herein referred to as precured dowel anchors).

Anchor Hole Procedure

Drilling:

Drill anchor holes with rotary hammer drill and carbide-tipped drill bit, conforming to ANSI B212.15-1994, of required diameter and depth (Fig. 1). The holes can be perpendicular or at an angle to the concrete surface, as specified by the project drawings.

1. Round or chamfer anchor hole edge, as specified in the project drawings, where anchor splay (or fan) will transition onto the concrete surface.



Figure 1 Typical drill and steel bristle brush for cleaning (left and center). Drilling with vacuum assistant (right).

2. Vacuum the concrete dust generated during drilling, whenever possible.

Cleaning:

1. Vacuum the concrete dust from the anchor hole using the appropriate tip to full embedment depth. Alternatively, blow the dust out of the hole using oil-free compressed air with a minimum pressure of 35 psi. Compressed air nozzle must reach the bottom of the hole.
2. Use the steel bristle pipe brush to clean out the hole walls. Perform 5 insertions.
3. Vacuum anchor hole.
4. Repeat Steps 2 and 3, as needed.

Anchor Hole Saturation Procedure

1. Mix saturating epoxy (for anchors installed vertically down) or putty (for horizontal and overhead installations) as instructed by the manufacturer (Fig. 2).

2. Prime anchor holes with epoxy or putty using a 60cc syringe with an elongated tip. Fill a vertically down hole with epoxy. To properly fill an overhead or horizontal hole, (see Fig. 3):

- Insert syringe tip to full embedment depth of the anchor hole.

- Begin filling with putty.
- Slowly backout the syringe towards the surface as the hole is filled.
- Refill syringe to continue the hole filling as needed.

3. Prime the surrounding concrete surface where the free end of anchor will be splayed (Fig. 3). Where the anchor splay is installed over FRP fabric, follow manufacturer's instructions for the fabric.

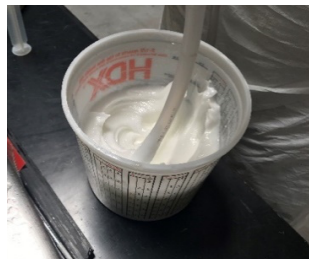
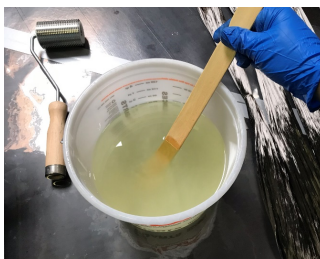


Figure 2 Mixing saturating epoxy (left) and putty (center) for anchor saturation and installation. A 60cc syringe, or similar is used to fill anchor holes 1/2 to 2/3 full (right).



Figure 3 Overhead or horizontal anchor holes are filled with putty with a syringe. Fill from the full depth, backing the syringe out as the hole is filled (left). Prime the surrounding area for the anchor placement (right).

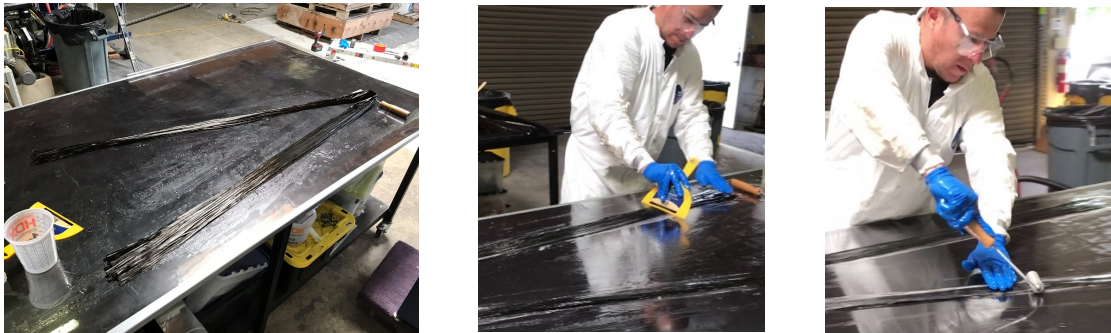


Figure 4 The dry fiber anchors are placed on a flat surface and saturated manually. A plastic trowel and/or grooved roller can be used to spread the epoxy over the anchor.

Anchor Installation Procedure

1. Dry fiber anchors:

- a. Place dry fiber anchor over protected worktable, spreading the anchor fibers open to promote saturation with the epoxy (Fig. 4).
- b. Hand-saturate the dry fiber anchor per the manufacturer's instructions.
- c. Fill the drilled hole 1/2 to 2/3 full with epoxy or putty with a syringe.
- d. Embed saturated anchor into the anchor hole to the specified depth with an appropriate anchor insertion tool (Fig. 5). The saturated dry fiber anchor is pushed into the anchor hole to the required embedment depth. At full embedment, residual epoxy or putty will be displaced from the hole.
- e. Maintain the embedded anchor at the bottom of the hole with the insertion tool and splay the free end of the anchor as specified on the project drawings (Fig. 6). This will ensure tension in the anchor and keep the fibers straight.
- f. Carefully remove the insertion tool.
- g. Use epoxy or putty, injected with the syringe, to backfill any gaps in the anchor created during

the previous step. Fill to the full depth of the insertion tool.

- h. Apply a coat of epoxy or putty over the splayed portion of the anchor, if required.
- i. Install fabric patch or additional layers of fabric over the splay end of the anchor as specified on the drawings.

2. Precured dowel anchors:

- a. Saturate the free fibers of the anchor thoroughly per the manufacturer's instructions.
- b. Fill the drilled hole 1/2 to 2/3 full with epoxy or putty using a bulk dispensing tool or by pouring the epoxy into the hole.
- c. Insert the precured dowel end of the anchor, turning it slowly, into the drilled hole and ensure embedment to the specified depth.
- d. Maintain the embedded anchor at the bottom of the hole and splay the free end of the anchor as specified on the project drawings.
- e. Install fabric patch or additional layers of fabric over the splay end of the anchor as specified on the drawings.

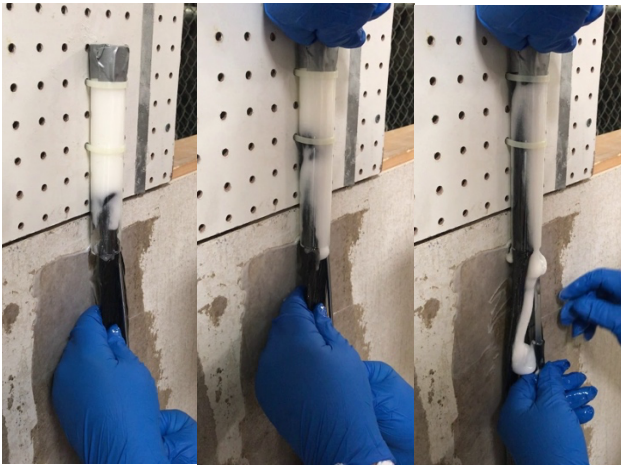


Figure 5 Using an insertion tool, the saturated dry fiber anchor is pushed into the anchor hole to the required embedment depth. At full embedment, residual epoxy will be displaced from the hole. For precured dowel anchors, an insertion tool is not required.



Figure 6 With the insertion tool in place to keep the anchor at full depth, spread the splay end of the anchor onto the substrate. Apply pressure to straighten the fibers with a plastic trowel or similar. Use the syringe to backfill any gaps left by the insertion tool.

Tips and enhancements to ensure successful installation for accurate and consistent results:

1. Maintaining the anchor fibers straight within the anchor hole is critical to developing the anchor system. The anchor fibers must be installed in a manner that can maintain straightness during the cure process. Any kinks in the fiber significantly reduce and/or terminate the continuity of anchor embedment into the concrete. Field installations must pay close attention to the anchor fibers during embedment into the anchor hole and maintain the fibers straight. This can be achieved by maintaining the anchor at the bottom of the hole with the

insertion tool while the opposite end is splayed onto the concrete surface.

2. Uniform contact area to the walls of the hole is also critical to anchor engagement. Gaps within the anchor hole (due to missing epoxy) will cause premature failure of the anchor system. It is critical to ensure that no air bubbles remain within the hole after anchor insertion.
3. The anchor hole shall be filled adequately with epoxy or putty before installing the anchor. This can be achieved by filling the cavity from the innermost depth of the penetration and moving outward towards the surface. A suitable syringe with flexible tubing, cut to the depth of the anchor hole, is sufficient for this process. After the anchor insertion tool is removed, the cavity from the tool must be completely backfilled with epoxy or putty.

Anchor Inspection Procedure

Relevant guidance for use during inspection of the fiber anchors and for documenting the overall quality of the FRP installation are provided in the following sections. These items are examples of the quality management systems used to document the application of wet-layup FRP materials. In general, the installation should be performed in accordance with an approved anchor installation procedure from the FRP manufacturer. The cleaning, saturation, and installation process should be documented. The site inspector and/or quality control specialist should provide final approval of the FRP work.

Anchor Installation Inspection and Documentation

Installation of fiber anchors should have appropriate inspection. The inspection should document the following, at a minimum, during the installation of FRP anchors: fiber anchor dimensions, drill bit type and size, cleaning bristle brush size, drilling and cleaning procedure, anchor hole diameter and depth, hole edge rounding or chamfering, anchor saturation and installation procedure, final anchor configuration, and material lot information. Preapproved qualification testing of the adhesive, fiber anchors and installation methods and/or in-field proof testing of fiber anchors should be required to validate the anchor system materials and installation procedures.

Assessment of Quality Management Plan

The following controls may be used to verify that the contractor has an appropriate quality plan in place during construction of FRP materials:

1. Contractor to provide proof of training certification from the FRP manufacturer for each installer on site.
2. QC and operating procedures for installation of the FRP system, including fiber anchors, to be submitted.
3. Products to be approved for use per the project requirements.
4. Product records to be available to trace components back to production.
5. Contractor to document production and quality processes.
6. Quality records to be approved by responsible personnel.
7. Measuring and testing equipment to be identified with current calibration records.
8. Environmental monitoring (Temperature / humidity) records to be maintained.
9. Products to be stored per the manufacturer's requirements.
10. Contractor's procedures to be consistent with the quality documentation submitted.
11. Duties and responsibilities of key positions in the application process to be identified.

Site Assessment of Installation Quality

The following questions may be used to verify that installation of the FRP system is in compliance with the project requirements for each completed repair location:

1. Was hole drilling and cleaning, and surface preparation performed in accordance with approved installation procedures?
2. Did the environmental conditions meet manufacturer's requirements for installation?
3. Did the contractor perform inspections and testing in accordance with approved installation procedures?
4. Was the sequence of fiber anchor and FRP fabric installation in accordance with approved installation procedures?
5. Have all identified defects been addressed per approved repair procedures?
6. Do the finished product and installation comply with the project specification and FRP manufacturer's quality documentation?
7. Have all other manufacturer installation instructions been followed?

Summary

While the use of wet-layup FRP materials and fiber anchors has become more widely adopted in the civil infrastructure industry, fiber anchor installation methods may vary by manufacturer. The goal of this *PracNote* is to provide basic guidelines on the installation of fiber anchors, in conjunction with wet layup FRP fabrics, in concrete structural elements. Relevant guidance is also provided in brief for inspection of fiber anchors and for documenting the overall quality of the FRP system installation.

References

Authors: Reymundo Ortiz (FRP Technical Manager, Structural Technologies, USA), Scott F. Arnold*, P.E. (Director of Engineering, Fyfe Company, USA), Aniket Borwankar (Senior Development Manager, Simpson Strong-Tie, USA)

Reviewers: Ravi Kanitkar (Principal, KL Structures, USA), Hayder Rasheed (Ph.D., Kansas State University, USA)

A *PracNote* (i.e., Practice Note) is a practice-oriented guide focusing on a single topic related to the application of fibre-reinforced polymer (FRP) composites in civil infrastructures and in the service of the engineering profession and society.