Anchoring GFRP reinforcing bars and rods in metal pipe tabs for tensile testing

Problem/Question – Mounting, anchoring or "potting" composite reinforcing bars and other fiber reinforced rods in steel tubing or tabs is required for successful testing of tensile strength and modulus, and for continuous strain testing of these products. The requirements for mounting, tabbing or potting (or anchor installation, as it is sometimes known) are well described in various test methods published by ASTM, CSA and ACI, which require such tabs for successful completion of the test. However, aside from basic instructions provided by the standards documents, little guidance is available for successful and compliant mounting.

Response – This *PracNote* describes several techniques, tips and methods for ensuring correct and successful potting of glass fiber reinforced polymer (GFRP) reinforcing bars and smooth rods. Several key pieces of equipment or modified tools that are helpful in making a successful tab are also described.

Keywords: tensile testing, potting, tabbing, anchoring, grout, GFRP, reinforcing bar, rod

Applicability

The method of mounting GFRP reinforcing bars and smooth rods described is appropriate for, and based on, the requirements of the following standards. The method described may be appropriate for other standards that have similar objectives and scopes. All of these standards require full cross-section testing of the as-produced bar or rod.

- ASTM D7205/D7205M-06 (2016) *Standard Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars*, ASTM International.
- ACI 440.3R-12 (2012) *Guide Test Methods for Fiber-Reinforced Polymer (FRP) Composites for Reinforcing or Strengthening Concrete and Masonry Structures*, American Concrete Institute.
- CSA S807 (2010) *Specification for Fibre Reinforced Polymers*, Canadian Standards Association.

Method for mounting reinforcing bar/rod specimens

Equipment

- Assembly rack with clips to hold the specimens centered and in a vertical position
- Containers for mixing and measuring the potting material
- Scale for weighing mortar components as needed
- Mechanical mixer
- Spatula
- Plastic bags for pouring the mix

Material

- Potting compound such as expansive mortar or grout. Selection of potting compound is described further below.
- Schedule 40 steel pipes per Table 1 – two lengths are required per bar/rod specimen.

Table 1 Recommended pipe tab dimensions

Nominal bar/rod size	Schedule 40 steel pipe diameter	Length
#2 (6.4 mm)	19 mm (¾")	250 mm (10")
#3 (9.5 mm)	19 mm (¾")	250 mm (10")
#4 (12.5 mm)	25 mm (1")	250 mm (10")
#5 (15.9 mm)	32 mm (1 ¼")	250 mm (10")
#6 (19.1 mm)	32 mm (1 ¼")	300 mm (12")
#7 (22.2mm)	32 mm (1 ¼")	300 mm (12")
#8 (25.4 mm)	38 mm (1 ½")	350 mm (14")
#9 (28.6 mm)	38 mm (1 ½")	350 mm (14")
#10 (31.8 mm)	38 mm (1 ½")	350 mm (14")

Specimens

- Each bar/rod specimen is cut to the correct length using a saw and mounted in the appropriate

anchorage. The bar/rod length should be the required gauge length plus the required embedment length (Table 1) at each end.

Procedure

1. Seal one end of the pipe to be used as the tab so the potting compound will be contained prior to setting. Methods for sealing this end are further described in this document.
2. Weigh out correct amounts of potting compound.
3. Mix potting compound or grout as instructed by the manufacturer.
4. Pour the mixture into the pipe to about 75% full and insert bar/rod specimen. Turn (twist) the bar/rod slightly until is until the rebar reaches the end of the pipe and is centered in the pipe.
5. Store the specimen in an upright position to prevent the grout from running out or the bar/rod to become off center as seen in Fig. 1.

Figure 1 Grouted tabs.

6. Allow grout to cure before inverting the specimens and mounting the other end using the same procedure.
7. When potting compound is fully cured, the bar/rod is ready for testing.

Tips and enhancements to ensure successful tabbing for accurate and consistent test results

1. A good quality expansive mortar or grout compound is critical and can significantly impact the success and repeatability of testing by ensuring a strong, uniform and consistent bond between the tab and the test specimen. Several brands and types of grout have been shown to work well with the bar/rod and pipe tab combinations shown in Table 1; these include, but are not limited to, those produced by Hydro-Stone, Pilgrim's MagmaFlo, compounds from RockFrac, formulations from Da-Mite, and expansive mortars from Dexpan. One should experiment with different types to find which gives the most success for specific laboratory conditions and potting techniques. Lower viscosity mortars or grouts are often easier to pour between the tube and the specimen but also usually have lower expansion, resulting in poorer of bonding to the tab. It is important to find a balance between potting compounds that may be reliably poured and those that give good adhesion.
2. It is critical to ensure the homogeneity of the potting compound mix. There should be no lumps of dry components such as fillers or sand; the water must be uniformly mixed. Similarly, if the compound is a two-part system, it is imperative that the parts be thoroughly mixed. As with all systems, it is critical to follow the manufacturer's mixing and preparation instructions closely.
3. The tubing used for tabbing can have a dramatic impact. The test methods call for schedule 40 steel pipe, but thicker schedule 80 pipe and cold-rolled seamless tubing have been used with higher rates of success due to their resistance to bulging when more expansive grouts are used. Using thicker tubing results in more internal pressure between the tube and the bar/rod and provides better grip on the test specimen.
4. It is critical to clean the tubing before use to remove any rust, grease, oil or laitance on the inside of the tubing. Such contamination between the tubing and the potting compound will result in slippage and possibly failure between the potting compound and the tab.
5. Some laboratories have found that using a thicker tab and threading the inside of the tube with a standard pipe or square thread tap results in improved bond between the potting compound and the tab due to the improved mechanical interaction affected by the grooves of the thread. If this method is used, be certain to clean any cutting fluid or lubricant and any remaining metal chips thoroughly from the inside of the tube to prevent slippage. If an appropriate length tap is not available to allow threading of the entire tab length, threading only the first 100-150 mm from each end of the tube has been shown to also improve bond over in comparison to not threading at all. An example is shown in Fig. 2.

Figure 2 Tab with threaded interior.

6. Pouring the grout in the small annular space between the tube and the bar/rod can be quite difficult and messy. Some laboratories have found that by pouring grout into an appropriately sized zip-seal bag and cutting the bottom corner off they can easily apply the grout to the tube as a baker might when icing a cake. Others have found that using a flexible beaker with a spout and squeezing the container to make a more pointed and precise spout during the pour is helpful. One should experiment with various methods to find the most suitable option.
7. Sealing the end of the tube and permitting centering of the rod in that end can be accomplished by applying a PVC cap over the end with a socket drilled in the inner surface to capture and center the bar/rod before pouring the grout. These caps may leak if not tightly fitted to the end of the tube, so some laboratories use a pipe clamp to tighten them on the tube prior to pouring. Other labs have done this sealing much more simply by placing a Teflon or polyethylene spacer ring like a washer in the end of the pipe to center the rod and sealing the tube with duct tape. In either case, the PVC caps or the plastic spacer rings are reusable. With the advent of 3D printing for making a small number of parts, it is also possible to print an end cap with seals that will precisely center the rod and thoroughly seal the tab end without the need for clamping. This approach adds precision and reduces set up time while maintaining reusability, but it does add some cost to the test. Examples are seen in Fig. 3.

Figure 3 Tab end cap.

8. Centering of the specimen is just as important at the top of the tab as it is at the bottom of the tab. As such, a PVC cap with an appropriately sized and centered hole is typically cut in half and clamped onto the tab with the specimen sticking through to maintain centering during the cure of the grout. As with the bottom cap, it is possible to use a 3D printed part in this position for more precision, better seal and easier or faster installation. A demonstration of this is pictured in Fig. 4.

Figure 4 Tab top caps.

9. It is important to remove entrained air from the grout during the pour prior to its set-up. Using a small vibrator on the exterior of the tube or a vibrating table is helpful. By preventing voids, the bond performance is improved and the likelihood of failure at the tab due to poor bonding or consolidation is lower. If using a top cap to center the specimen, leave the vibrating device on during the installation of the cap to ensure that no air is trapped during the upper centering. Care should be taken since over-vibration can result in segregation of the grout.
10. The expansive grout or potting compounds typically have a limited pot life during which they can be poured without causing entrapped air voids or incomplete filling of the tube, or before the compound is no longer pourable. It is important to determine the number of tabs that can be poured within this pot life and mix an appropriate amount of material. It is not recommended to perform this task under direct sun or in excessive heat. In cases where the temperature of the area where the work will take place is higher than desirable, storing the container of mixed grout in a cool water bath when not in use to reduce overall temperature and extend pot life is helpful.
11. It is critical that the temperatures generated by the curing process for the potting compound not exceed the glass transition temperature (T_g) of the composite to be tested. If too much heating becomes an issue, one can seal the ends of the anchor to prevent dilution of the potting compound and immerse the anchor in a bucket of cool water to remove some of the heat of reaction. This especially can be an issue for larger bars.

12. It is almost impossible to hold the bar/rod and tab by hand as you pour and then maintain a vertical position throughout the cure time of the grout. As such, a good fixture to hold the bar(s)/rod(s) during the pour and cure is critical. Several effective and simple designs have been used by a variety of laboratories as shown in Fig. 5. Nonetheless, tabbing is best accomplished by two individuals.
13. It is very important that the first tab be fully cured prior to inverting the specimen to install the second tab. Handling the specimen prematurely can result in cracking, which could cause failure between the specimen and the potting compound or the potting compound and the tube. Allowing 24 hours cure prior to starting the second tab is recommended.
14. It is notoriously difficult to achieve good bond between the tab and smooth rods such as dowel rods; typically, some preparation of the embedded portion of the specimen is required. Begin by removing the glossy surface resin layer from the bar/rod with an abrasive such as 80 grit sandpaper, apply a thin layer of a simple two-part epoxy and then, before the epoxy cures, topcoat the epoxy with sand. Once cured, this provides some mechanical bond between the specimen and the grout and has been shown to be adequate in most cases.
15. Remove any caps, clamps or tape used to seal the tube and/or center the bar/rod from the specimen before testing. Failure to do so could cause a point defect at the point of contact with the specimen being tested that could prompt a premature failure. In addition, it is important to remove any potting compound that has spilled onto the outside of the tab and clean the surface to avoid any potential for slippage in the grips of the test fixture.
16. Accurate identification of the specimen is critical to the integrity of the data. If tabbing multiple types of specimens at the same time, be sure to accurately and correctly label each specimen to allow for proper identification throughout the testing process.

Figure 5 Examples of mounting racks for multiple tab assembly.

Summary

While potting methods are described in the various test methods and industry standards, there are several key techniques and equipment improvements that can help increase the success of the tabbing function. Many of these may be accomplished at little or no cost. Most will help improve the efficiency of tabbing operations, allowing an operator to tab more specimens in a day. The examples provided in this *PracNote* can be helpful in ensuring test results that are representative of the actual physical performance of the composite reinforcing bars/rods gaining popularity for use in reinforcing concrete today.

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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.