

Technical Advisory

Fiber Reinforced Concrete (FRC) Tip Sheet

DMS-4550

What are Fibers?

Fibers are classified into several types that define their composition. Generally, most fibers used on TxDOT projects will be either polymeric, which defines their composition as polypropylene (monofilament or fibrillated), polyethylene, polyester, acrylic, and aramid, or steel, which includes both high and low strength steel or stainless. Other types of fibers include, but are not limited to, natural (e.g., cellulose or grass), alkali resistant glass, asbestos and carbon (e.g., high modulus or high strength) [1].

Macro Versus Micro Fibers

Fibers are also generally classified into two categories: macro-fibers and micro-fibers. Macro-fibers are sometimes referred to as structural fibers and are intended to carry load and, therefore, used to replace traditional reinforcement in certain non-structural applications as well as minimize or eliminate both early and late age cracking. Typical lengths for macro-fibers are greater than or equal to 1.5 in.

Micro-fibers are generally used to minimize early age cracking. This category of fibers is generally classified according to their length, although sometimes the diameter or aspect ratio are considered.

When fibers are used instead of wire mesh or steel rebar, macro-fibers must be used. Prequalified fiber sources can be found on the Department's [Material Producer List \(MPL\)](#) titled "Fibers for Class A and Class B Concrete Applications."

Why Use Fibers?

The use of fibers is anticipated to save time, reducing the overall cost of the project. It is also possible to save money on the material cost, especially if the cost of steel rises to levels comparable to those in 2008.

The 3-D orientation of fibers in concrete creates a similar, if not better, reinforcing matrix as normally reinforced concrete. According to ACI 544.1, "fibers may also enhance the properties [of concrete] including the tensile strength, compressive strength, elastic modulus, crack resistance, crack control, durability, fatigue life, resistance to impact and abrasion, shrinkage, expansion, thermal characteristics, and fire resistance [3]." In addition, fibers also increase the toughness of concrete which is the measure of the energy absorption capacity of the material. In practical terms, toughness is a measure of how much damage or distortion a material can sustain while still serving a useful purpose.

Figure 1: Concept of Toughness

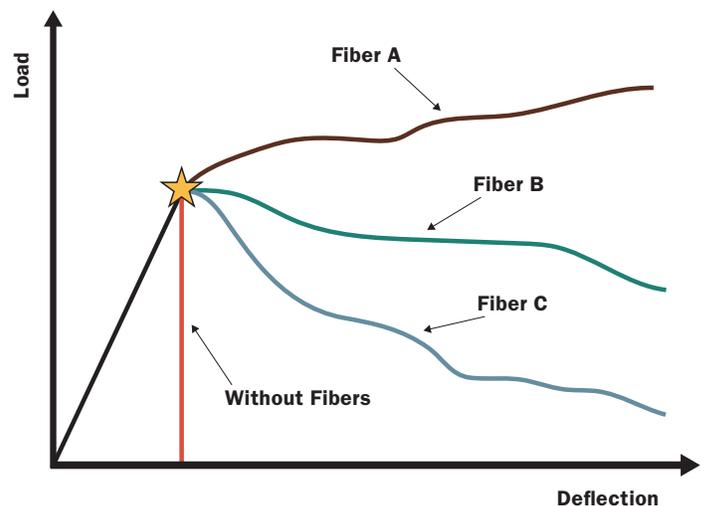


Figure 1 illustrates four different scenarios that either include or do not include fibers. The area under each curve is referred to as the toughness. The specimen that was not fiber reinforced split in half after the initial crack (shown as the red star) and could no longer carry any load; this specimen exhibited the least toughness of the four specimens. The specimens that are fiber reinforced have considerable load bearing capacity after the initial

crack; Fiber A exhibited the most toughness, Fiber B exhibited less toughness than Fiber A, and Fiber C exhibited less toughness than Fiber B but more than the specimens without fibers.

Mixture Design Considerations

The inclusion of fibers into concrete tends to reduce the slump of concrete. Although the reduction in slump is “apparent,” meaning it appears to suffer from a loss of workability or appears very stiff, the concrete can actually become very fluid with vibration. This design is not easily finished. Note, the addition of fiber increases surface area and contributes to the apparent slump loss. Steel fibers do not tend to affect the workability as much as polymeric fibers. Generally, the expected reduction in slump for polymeric fibers is about 1 in. for every 2 to 3 lb. per cu. yd. of fiber. However, this also depends on the fiber product; some polymeric fibers tend to produce more workable mixtures than others.

American Concrete Institute (ACI) 544.3 recommends modifying the mix design to increase the sand content by using a maximum coarse aggregate factor of 0.55 [2]. The additional mortar fraction allows the mixture to become more fluid as more mortar is available to coat the fibers. In addition, the use of superplasticizers or mid-range water reducers will assist in increasing the workability without the addition of water. It is recommended that trial batches are performed, including currently approved mixture designs, to ensure that any adjustments necessary are made to ensure a workable mixture is provided.

Mixing Fibers in Ready Mix Truck

The most efficient method of adding the fiber to the ready mix truck is at the ready mix plant. Each fiber producer will have their own method of fiber addition. Consultation with the fiber producer is recommended before using fibers and should include proper training for dosing, batching, mixing, and stocking the fibers. Some producers recommend the fibers are added to the truck before adding any materials (e.g., rock, sand, cement, or water) into the truck. The upfront addition allows the coarse aggregate to disperse the fibers more efficiently, creating less concern for fiber balls. Others may require adding the fiber at the end after all of the materials have been added at charge speed, before the addition. *Adding the fiber at the jobsite is not recommended; the probability of the fiber balling is increased primarily due to the lack of mixing. If adding the fiber at the jobsite is the only option, it is recommended a minimum of 100 revolutions at mixing speed are achieved before discharge.*

ACI 304R.4.5.2 requires 70 to 100 revolutions at mixing speed and an additional 30 revolutions before discharge. These requirements are the minimum required revolutions with fiber reinforced concrete (FRC). *Because adequate mixing is the key to avoid balling, it is recommended at least 200 revolutions (including the additional 30 revolutions at charge speed) are obtained before discharge.*

Placing and Finishing of FRC

To become comfortable and proficient, at placement and finishing of FRC, takes time and experience. Fibers (especially the polymeric type fibers) tend to protrude and are difficult to push below the surface. As discussed previously, the concrete will appear to be less workable than it actually is. Adding additional water to the concrete will not increase the workability in the same manner as traditional concrete and should be avoided. *Some fibers will be visible after finishing; however, this is expected.* Adding finish water will not increase the tendency for the fibers to lay flush with the surface. Steel or magnesium floats and trowels are recommended; wood tends to tear the surface. Overworking the surface should be avoided; this may cause crazing of the surface. Jitterbugs have been used successfully to help push the fibers below the surface. If a broom finish is required, a stiff bristle broom is recommended. Hold the broom as close as possible to the concrete surface. Only one pass in one direction is recommended.

Vibration is essential to ensure adequate consolidation is achieved. Poor consolidation may occur without vibration.

Testing FRC

Fibers are submitted by the producer for prequalification testing to the requirements of DMS-4550. Once approved, the product and minimum required dosage are added to the Department’s MPL.

For fibers that are not listed on the Department’s MPL, contact the Rigid Pavements and Concrete Materials Section at (512) 506-5858 to seek approval and test methods. Unapproved fibers will be subjected to the testing described in DMS-4550.

Field Testing FRC

No additional testing is required if the fibers are published on the Department’s MPL and are used at or above the minimum listed dosage. For compressive strength, the specimens should be made in accordance with Tex-447-A, Part I (ASTM C31) and should be made in the same fashion as concrete that does not contain fibers.

Tests to Determine Fiber Dosage from Fresh Concrete

ASTM C 1229 provides guidance to determine the dosage of fibers present in the concrete. This test was originally developed for glass fibers. Although acceptable, it may be difficult to perform in the field.

An alternative method is to use a known volume of concrete, and similar to ASTM C 1229, wash the concrete over a No. 8 (2.38 mm) sieve and extract the fibers. The known volume container can be the bucket of the pressure meter or the unit weight bucket; it is recommended that at least 0.25 ft³ is used. 1) Fill the bucket as if performing the intended test, vibrating each lift with an external or internal vibrator. 2) For the final lift, care should be taken to ensure the bucket is not significantly overfilled and is as close to level as possible before striking off the surface. 3) The concrete

should then be poured and washed over a No. 8 (2.38 mm) sieve.
4) The fibers should then be extracted, dried and weighed. A scale with an accuracy of 0.1 g should be used to measure the mass of the dried fibers. The amount of fibers is calculated as follows:

$$\text{Amount of Fibers (lb./yd}^3\text{)} = F/B (0.059525)$$

Where:

F = Weight of fiber in grams

B = Volume of container in ft³

Note: the typical amount of fibers obtained from a 4 lb./yd³ concrete batch and a 0.25 ft³ bucket should equate to about 16.8 grams.

This method of determining fiber dosage is provided as a tool for verification and is not required by the Guide Schedule. This method may also be run in conjunction with Tex-472-A to ensure uniform distribution of fibers when necessary.

Summary

Macro fibers listed on the Department's MPL may be used as a replacement for wire mesh or reinforcing bar in Class A and Class B concrete applications. The use of fibers as a replacement of traditional reinforcement in non-structural applications is expected to provide at least a comparable (if not superior) product while potentially decreasing material and labor costs. Project testing of prequalified fibers is not required however, this document provides a procedure for field verification of fiber content to use when deemed necessary.

References

[1] Portland Cement Association. Fiber Reinforced Concrete. ISBN 0-89312-091-X. Library of Congress catalog card number: 90-60944. 1991. Pg 2.

[2] American Concrete Institute. Guide for Specifying, Proportioning, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete. ACI 544.3R-93. 1993.

[3] American Concrete Institute. Report on Fiber Reinforced Concrete. ACI 544.1R-96. 1996.

Contact Information

For questions about the contents of this article or any concrete issues, please contact the Rigid Pavements and Concrete Materials Section at 512-506-5858.