

FIP 1 – FIBER-REINFORCED CONCRETE

What is Fiber-Reinforced Concrete?

Since ancient times, fibers have been used to reinforce brittle materials. In fact, a pueblo house built around 1540—believed to be the oldest house in the U.S.—is constructed of sun-baked adobe reinforced with straw.¹ Fiber-reinforced concrete is a composite material that includes the use of fibers, whether in lieu of traditional reinforcement or in addition to it.

These fibers, typically classified into four different categories – steel, alkali-resistant glass, synthetic and natural fibers – come in different types of configurations and sizes.² They typically range from 1/4" – 2 1/2" in length, but natural fiber can be as short as 1/12". Alkali-resistant glass fibers can also be used as continuous strands, particularly in mesh or scrim constructions. Fiber-reinforced concrete has become widely used, stemming from the need for more durable, economically viable concrete.

Why Use Fiber-Reinforced Concrete?

There are many benefits of using fiber-reinforced concrete (FRC), both before it hardens and after. Some of these benefits include:

- **Reduced plastic cracks in concrete and improved green strength** to minimize breakage and culls.
- **Improved long-term serviceability of a structure or product:** Concrete is susceptible to degradation through corrosion, alkali-silica reaction, sulfate attack, cyclic freezing and thawing under saturated conditions, and mechanisms that result from the penetration of other aggressive solutions. Therefore, concrete durability can be improved by minimizing the ingress of water and other aggressive solutions. FRC helps to maintain tight crack control, thus reducing crack width and, consequently, water ingress.¹
- **Improved shatter resistance and impact strength** resulting from increased toughness (a measure of energy absorption capacity).³
- **Reduced spalling of high-strength, low-permeability concrete exposed to fire.**⁴
- **Improved scour and abrasion erosion resistance:** FRC has been used in hydraulic structures to repair abrasion-erosion damage in stilling basins, conduits, sluiceways and discharge laterals areas.
- **Replacement of conventional temperature and shrinkage reinforcement:** The use of fiber reinforcement in lieu of welded-wire reinforcement and small diameter bars used for

temperature and shrinkage reinforcement has proven to be an economically viable alternative.

- **Thickness reduction of concrete elements in slab-on-ground and tunneling applications:** In addition to these applications, alkali-resistant glass fibers have allowed the development of thin concrete (typically ½”) that has made possible many glass fiber-reinforced concrete (GFRC) products with the sustainability and durability offered by concrete—but with much lighter weight.
- **Increased joint spacing in slab-on-ground applications:** High-volume fractions of steel and synthetic macro-fibers have been used successfully to increase joint spacing in concrete slab-on-ground applications, often completely eliminating contraction joints.
- **Jobsite safety:** The use of FRC in lieu of conventional reinforcement in concrete minimizes tripping hazard, particularly in composite metal decks, and provides a safer working environment for construction workers.

How Do Fibers Work?

Fibers are added to concrete either during batching or at the jobsite, uniformly dispersed during mixing and, thus, integral to the concrete matrix at the time of placement. The uniform dispersion of fibers provides three-dimensional reinforcement within the concrete matrix, with immediate benefits in either fresh or hardened concrete, or both.

In fresh concrete, the uniform distribution of fibers in the concrete matrix disrupts the movement of bleed water to the concrete surface and the development of large and continuous bleed water channels. Consequently, fibers help in reducing bleeding, plastic settlement and cracking associated with plastic settlement. In addition, fibers strengthen the concrete matrix and arrest plastic cracks that try to form under adverse ambient conditions, leading to rapid evaporation of bleed water from a concrete surface. By arresting cracks before they can propagate through the concrete, fibers minimize cracking due to plastic shrinkage of concrete.

In hardened concrete, the primary benefits of fibers come from increased energy absorption and the post-peak, post-crack load-carrying capacity they provide. As a result of increased energy absorption or toughness, fibers improve the shatter resistance and impact strength of concrete. The improvement in post-peak, post-crack load-carrying capacity provided by FRC has led to the widespread use of fibers in lieu of conventional temperature and shrinkage reinforcement in many applications—in particular, slab-on-ground, mining and tunneling, and excavation support.

Where to Use Fiber-Reinforced Concrete?

Because of the flexibility that it provides, FRC has proven to be an economical and useful construction material. It can be used for the following applications:

- Cast-in-place concrete (e.g., slab-on-ground, composite metal deck, pavement, embankments)
- Wet-mix shotcrete (e.g., mining and tunneling)
- Precast concrete (e.g., architectural products, septic tanks, vaults)
- Manufactured concrete products (e.g., landscape products, shingles)

Overall, FRC improves the integrity and durability of concrete.

REFERENCES:

1. ACI 544.1 R-96 – Report on Fiber-Reinforced Concrete
2. ASTM C 1116 – Standard Specification for Fiber-Reinforced Concrete
3. ASTM C 1399-07a – Standard Test Method for Obtaining Average Residual Strength of Fiber-Reinforced Concrete
4. ACI 544.5 R-10 – Report on the Physical Properties & Durability of Fiber-Reinforced Concrete