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FIBER REINFORCEMENT FOR CONCRETE

An inherent characteristic of concrete is the tendency for it to crack (see *Concrete Solutions*, *March 2021 & September 2021*). Engineers specify the use of shrinkage and temperature reinforcement, commonly termed secondary reinforcement, to minimize crack width after concrete cracks. Traditionally, welded wire reinforcement (WWR) or light-gauge reinforcing steel bars (No. 3 or No. 4) have been used as shrinkage and temperature reinforcement. Fiber-reinforced concrete (FRC) has been used for the last several decades as a viable and cost-effective alternative to WWR or other types of steel used as secondary reinforcement.

TYPES OF FIBERS

There are four primary material categories of fibers used to produce FRC: steel, glass, synthetic and natural fiber materials. Steel and synthetic fibers are typically the most commonly used fiber material types found in ready mixed concrete applications. Synthetic fibers have been used in concrete since the early 1980's and are widely recognized in the industry today as being an effective form of reinforcement for crack control.

Typical glass fiber reinforcement

Synthetic fibers are engineered for a specific level of concrete crack control performance and can generally withstand the long-term alkaline environment of concrete without deterioration. They provide enhanced durability to concrete in the plastic and hardened states. There are two major types of synthetic fibers, namely MICROsynthetic and MACROsynthetic fibers.

Typical synthetic fiber reinforcement

Typical natural (cellulose) fiber reinforcement

SYNTHETIC MICROFIBERS

- Microsynthetic fibers are defined as fibers with equivalent diameters less than 0.012 inches
- They are comprised of polypropylene monofila-

ment and fibrillated nylon monofilament fibers

- The length range is 0.25 to 2.5 inches
- The general dosage range for most concrete applications is 0.5 to 3.0 lbs./cu. yd.
- Monofilament fibers are typically used to reduce plastic shrinkage cracks
- Fibrillated fibers can be used as either plastic shrinkage reinforcement or as shrinkage and temperature reinforcement in place of light-gauge welded-wire reinforcement, particularly in slab-on-grade applications.

Typical monofilament microfibers used for plastic shrinkage crack control are 0.75 inches in length and used at the dosage rates of 0.5 to 1.0 lbs./cu. yd.

Typical fibrillated microfibers used for plastic shrinkage crack control are 0.75 inches in length and used at dosage rates of 1.5 to 3.0 lbs./cu.yd.

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SYNTHETIC MACROFIBERS

- Macrosynthetic fibers are defined as fibers with equivalent diameters greater than 0.012 inches
- Currently almost all macrosynthetic fibers being marketed are classified as polyolefins (Polypropylene and Polyethylene fibers fall into this category)
- Most macrosynthetic fiber lengths range from 1.5 to 2.5 inches
- Depending on the application, macrosynthetic fibers are used at a dosage range between 3 and 13 lbs./cu. yd, with a typical range of 3 to 7.5 lbs./cu. yd. in most slab-on grade applications
- Macrosynthetic fibers are intended to increase the post-cracking residual strength and toughness of concrete
- Macrosynthetic fibers serve as a good substitute for WWR and steel bars used as shrinkage and temperature reinforcement

- Most macrosynthetic fibers utilized in FRC consist of one of the four following geometrical design: tape, stick or rope

Typical "tape" macrosynthetic structure

Typical "stick" macrosynthetic structure

Typical "rope" macrosynthetic structure

COMPARISON BETWEEN SECONDARY STEEL WWR AND LIGHT GAUGE BAR VS. SYNTHETIC FIBERS

With respect to application, the primary difference between WWR and synthetic fibers is their location within a slab. The Wire Reinforcement Institute (WRI) and Concrete Reinforcing Steel Institute (CRSI) recommend that WWR must be located in the upper third of a 4 to 6-in. thick slabs, positioned approximately 2 in. below the surface. In thicker slabs, the reinforcement must be low enough so that it will not interfere with saw cutting. ACI 302.1 "Guide for Concrete Floor and Slab Construction" recommends shrinkage and temperature reinforcement in slabs on-ground to be positioned in the upper third of the slab thickness for maximum effectiveness. In contrast to traditional steel shrinkage and temperature reinforcement, synthetic fibers are uniformly distributed throughout the concrete and provide three-dimensional reinforcement.

The following table highlights the differences between synthetic fibers and traditional shrinkage and temperature reinforcement:

Synthetic Fibers		Traditional Steel Shrinkage and Temperature Reinforcement	
Concrete can be placed directly from the ready-mix truck using chutes		**Concrete has to be pumped or placed by buckets and wheelbarrows in order to prevent displacement of the reinforcement**	
Fibers are a part of the concrete mixture and will be distributed three-dimensionally		**Two-dimensional and ineffective when not positioned properly, which is the case when supports are not placed correctly or people walk on them after placing. The reinforcement ends up mostly at the bottom of the slab .**	

Delivered in a ready-mixed concrete truck and does not need any additional labor or time in the field		**Steel reinforcing is labor intensive and time consuming to install**	
Non-corrosive and alkali-resistant		**Can corrode if exposed to environment and chemicals**	
Safer for workers placing concrete		**Can be a tripping hazard**	
Does not need any support		**Needs chairs or other kinds of support to stay in place**	

FIBER REINFORCED CONCRETE IN PRACTICE AND SLAB FINISHING TIPS:

PLASTIC CONCRETE REQUIREMENTS

- When using fibers, an apparent slump loss can be expected
- The use of water-reducing admixtures may be required to achieve a desirable slump when placing FRC
- For fiber dosages greater than 4 lbs./cu. yd., utilize all available water to achieve the targeted slump during initial mixing without exceeding the water/cement ratio for the mix
- When utilizing macrosynthetic fibers, a maximum slump of 6 to 8 inches is recommended
- Slumps greater than 8 inches could lead to segregation during consolidation and may result in an increased amount of visible fibers

Slump loss can be expected when adding fibers to a concrete mix

PUMPING FIBER REINFORCED CONCRETE

- Minimize the amount of flexible pump hose and all sharp angles when possible
- When discharging concrete, mixer truck chutes should be approximately 12 inches or higher above the pump hopper to facilitate continuous flow
- Rounded grates or other suitable circular tubes over the pump grates will reduce concrete and fiber build up

Rounded pump hopper grates significantly reduce the amount of FRC build up

PVC pipe or a cut hose placed over conventional straight slit grates can be used as a "quick solution" for a rounded grate system

PLACEMENT PRACTICES

- Place the concrete as close to the final resting position as possible
- If raking is required, use a concrete come along style rake
- Avoid using tined rakes as they will pull fibers from the plastic concrete

CONSOLIDATION

- The use of laser and vibratory screeds have been shown to work well with FRC
- Vibration will bring additional paste to the surface to aid in coating the fibers while also improving the finishing characteristics
- Vibration will also reduce the likelihood of visible fibers on the surface

SLAB BLEEDING CHARACTERISTICS WITH FRC

- Fibers interrupt bleed water channels and can produce a more uniform water sheen on the slab surface compared to conventional concrete
- Fibers may slow down the rate and the amount of bleed water depending on the fiber type and dosage
- Do not finish fiber-reinforced concrete when bleed water is still visible on the surface as this could result in a poor surface finish

FINISHING (TIMING WINDOW)

- Start finishing when the bleed water sheen is no longer present and concrete can support foot traffic
- Finishing can typically begin with a slight foot indentation of approximately 1/8 inch or less

Footprint on the left represents a premature finishing indicator. The one on the right represents a more appropriate time to begin finishing.

FINISHING—BULL FLOATING

- Avoid overworking the slab surface during bull floating operations
- Overworking the surface will increase the amount of visible fibers on the surface
- If a laser vibratory screed is used, bull floating may not be necessary depending on local conditions

FINISHING—BROOM FINISH

- Keep the broom angle relative to the slab surface at a maximum of 45 degrees
- Broom with a single pass in one direction only as this will create a more uniform appearance and will result in less fibers being pulled from the surface
- Periodic broom bristle cleaning will help to avoid fiber build up that may lead to surface irregularities

FINISHING—HARD TROWEL FINISH

- The use of float pans on ride-on or walk behind machines are highly recommended as they enhance the finishability of FRC
- Float pans should be used until noticeable resistance is observed with the finishing machine
- A final pass with finishing blades should occur after pan removal
- To avoid fiber pullout from the slab surface, finishing blades should be kept as flat as possible before increasing the tilt angle of the blades

START USING FIBERS TODAY

Fibers are a great way to improve concrete performance and durability. Their use can save money and time on the installation of welded wire mesh and rebar. By eliminating steel reinforcement and the inherent tripping hazard it creates, the jobsite is safer. For additional information or assistance with jobsite questions, contact your CalPortland ready mix concrete sales representative today.

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