Macro Polymeric Fibers for Slabs On Ground

They can increase joint spacing and reduce curling—But will the floor be hairy?

By Jerry A. Holland, Robert M. Simonelli, and Wayne W. Walker

Macro polymeric fibers (MPF), also known as high-volume synthetic fibers (HVSF), have been used in numerous slabs on ground providing amazing performance for various applications. However, there are many myths and misconceptions about what they will and will not do. This article is meant to clear up some of these misunderstandings and document some MPF slabs that have performed extremely well for four to eight years under difficult conditions. MPF has provided outstanding performance in other applications as well—such as walls, suspended slabs, and shotcrete—but slabs on ground will be the focus here.

MPF versus LVSF

Traditional low-volume synthetic fibers (LVSF) have been available in the United States since the late 1970s, whereas MPF have been available since the early 90s and have been used significantly for almost 10 years. MPF are different from LVSF in some ways but similar in others. In general, there is nothing magical about the plastics that both are made from; any differences in their chemical and mechanical properties are unimportant. However, MPF are longer and thicker than LVSF. For instance, most LVSF brands are 0.375 to 0.75 inches in length, but most MPF are 1.5 to 2.25 inches long. The most important difference between MPF and LVSF is the typical dosage ranges for each. The geometry and other properties of MPF, plus improvements in concrete mix proportioning and admixtures, have allowed for higher dosages than LVSF. Typical dosage ranges for LVSF are 0.5 to 1.6 pounds per cubic yard (pcy), while MPF dosages commonly range from 3.0 to 7.5 pcy. The benefits of LVSF are primarily during the first 48 hours or so, but those of MPF continue for the life of the slab.

Do they work? If so, how?

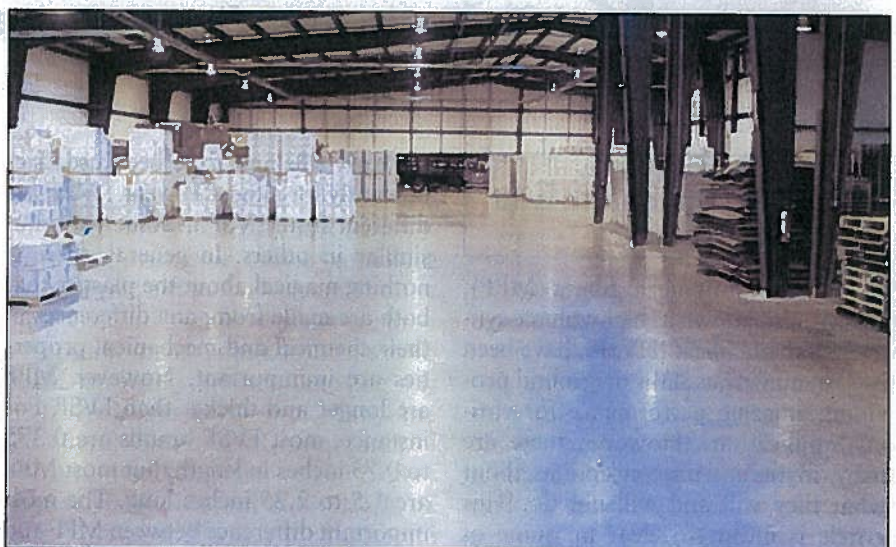
In the early days of using LVSF, it was believed that significant benefits would accrue if a much larger amount of fibers could be put into the mix. However, at anything more than about 3.0 pcy, there were major issues with mixing, workability, and finishability. At 3.0 pcy, there was improvement in some areas of performance but usually not enough to justify the increased cost and difficulties. Now with good mix proportioning and user-friendly fibers, it is possible to have up to about 7.5 pcy of MPF and still have surprisingly good mixability, placeability, workability, and finishability. In addition, jointless slab placements up

122x10-foot truck driveway flaring to a 43-foot-width with no joints and only one tight crack after four years. Photo: Alicia Simonelli

to 168 feet long have been in place without visible cracking or significant curling for several years.

Extended joint spacings, limited visible cracking potential, and reduction of curling can be due to several factors, including the following. As the slab tries to curl over time, microcracking is probably occurring, especially in the top of the slab, thereby allowing some relaxation of the slab without visible cracking. Also, the fibers tend to reduce the segregation and bleeding of the plastic concrete that occurs to some extent in all slabs. Finally, the concrete in the top of the MPF slab is more like that of the bottom than the typical slab, thus, this factor in curling is reduced in significance.

Concrete is very strong when it is squeezed in compression but very weak when it is being pulled apart in tension. A good rule of thumb is that it is about 10 times as strong in compression as it is in direct tension. Thus, whenever you see a crack in a slab on ground, it is due to more applied tensile stress (from linear shrinkage, restraints, curling, loads, etc.) than its tensile strength. Once microcracking or macrocracking occurs, MPF can start taking the tension and keep the cracks much tighter than they would have been without the fibers. A sufficient quantity of MPF allows the concrete to have all of the normal advantages of concrete without many of the disadvantages; conversely, it can allow the concrete to have some of the advantages of asphalt without many of its downsides.



Top: 66x46-foot distribution center entrance pavement 6 inches thick, no joints, and one tight crack after four and a half years. Photo: Gordon Stallings
Bottom: 127x60-foot warehouse floor slab 6 inches thick and no joints or cracks after more than four years. Photo: Jeff Lovett

Mix design and batching considerations

The same things that make for a good slab mix design without MPF also make for a good one with MPF. Care should be taken to avoid mix designs with significantly gap-graded aggregates. Enough sand and cementitious materials must be used in floor mixes to have a tight, burnished surface but no more than necessary because more will only increase shrinkage and curling potential. Most floor mixes in North America typically are oversanded, thus, too little sand usually is not a problem. At levels of MPF more than about 4.0 pcy, and especially at 7.5 pcy, consideration should be given to using a low to moderate dosage of a good polycarboxylate water reducer. However, do not try to reduce the water content; sufficient water will be needed for mixing and later finishing operations. One advantage to MPF is that they are very forgiving with respect to shrinkage, curling, and cracking potential as water content and other components change.

Preconceptions about slump don't apply when working with MPF. At high MPF dosages in a properly proportioned mix, the slump test results can be reduced easily by 2 to 3 inches, as compared to the same concrete without the MPF, but without a similar reduction in workability, finishability, and pumpability. The reason for this is that the long MPF keeps the concrete from slumping down when the slump cone is removed but does not do so nearly as much when energy (in the form of vibration, pumping, etc.) is applied to the concrete. For high-tolerance troweled floors, a final slump of 4½ to 5 inches is ideal and will behave like a higher slump when energy is applied.

Batching sequence is critical. The MPF supplier's recommendations should be strictly followed. It's a mistake to plasticize concrete to high levels (such as more than 8 inches for some materials) and then introduce the MPF. The result is poor mixing.

Pumping, placing, and finishing considerations

A properly proportioned mix that will pump well without fibers also will pump well with up to 7.5 pcy of MPF. The only significant pumping consideration is that some of the longer fibers may tend to build up on the typical pump rectangular bar grate. Grates with round bars have prevented this, however. Follow the MPF supplier's recommendations and work closely with the pumper, and the pump manufacturer to eliminate this potential issue.

Many of these projects had burnished, steel-troweled finishes with very little fiber visibility. Other applications had exterior broom finishes, also with very little fiber visibility. A good-looking broom finish requires keeping the broom clean and moving it continuously in only one direction; reversing the broom direction makes the fibers stand up like soldiers, which then become extremely difficult to lie down again.

Considerations for troweled finishes are the following. For bull floating, use a channel float with rounded edges instead of a check rod. If a dry shake hardener will be used, a wide wood bull float still should be used. When high F_F numbers are specified, do not depend on later bump cutting with a highway straightedge. Instead, use large riders with pans, if possible, to achieve the tolerances; after completing 90 degree passes, diagonal passes help substantially. When power floating, the surface may look somewhat hairy at first, but keep floating and the fibers will disappear with a properly proportioned mix. Use power equipment as much as feasible and minimize hand work near edges and penetrations. Do not use added water near edges and penetrations. When aesthetics are especially important, consider having a small amount of dry shake hardener (of the same color and shade as the floor) available to use at edges and penetrations to help cover the fibers and match adjacent floor surfaces if necessary.

Top: One of four 90x30-foot industrial facility experimental floor slabs. After eight years, only cracked slab had shortest fibers with lowest dosage. Photo: Bob Grace
Bottom: 168x84-foot roller skating rink unbonded 4-inch topping slab and no joints or cracks after more than four years. Photo: Tom Baggett

Cost considerations

MPF will increase the cost of the concrete mix, but the offsetting costs should be considered as well, especially the life-cycle costs. The number of joints can be reduced by 50% to 80%, or more. Joints are expensive, and good joints (sawing, filling, dowels, etc.) are even more so. At high levels of MPF, reductions of expected curling have been seen from ⅓ to ⅔. In certain designs, this lower curling stress has been taken into account so thinner slabs and extended dowel spacing were used in order to further offset the added cost of the MPF. When long-term life-cycle costs are considered, MPF slabs cost less than a typical jointed slab.

Other considerations

Substantially increasing the joint spacing may cause wider openings than non-MPF slabs with joints at typical spacings of 10 to 15 feet. Thus, if there will be significant wheel traffic, provide a very good dowel system—such as with plate dowels—at construction and contraction joints, properly fill them, and maintain the joints. Because large MPF slab panels will move a small amount, a good planar, low-friction base should be used to minimize restraint.

Background for case histories

When reading the following case histories, keep in mind the American Concrete Institute's (ACI) recommendations. For 4- to 6-inch-thick slabs, ACI recommends joint spacings from 8 to 15 feet for somewhat square slab panels, based on a number of factors such as concrete shrinkage potential. Another recommendation is that the maximum slab aspect ratio (length to width) should be 1.5:1 in order to minimize the possibility of transverse cracks. An additional concern is that of significant temperature drops from a slab's original as-cast temperature, which causes slab contraction that greatly increases its chance for cracking. All these projects had a MPF dosage of 7.5 pcy. Additional information can be found in "A Jointless, Crack-Free Walkway" by Cecil L. Bentley, Sr., Wayne W. Walker, and Jerry A. Holland (Concrete Construction, March 2007), which featured a 69-foot walkway with a re-entrant corner that still has not cracked in five years with more than 100° F temperature drops.

> **MPF slabs have a proven record for having low curling and cracking potential.**

Truck driveway

The three authors conducted an experiment by designing and constructing a jointless, 4-inch-thick driveway for truck and auto traffic at one of the author's houses. The result was a 122-foot-long slab that was typically 10 feet wide (12:1 ratio) and flared out to a width of 43 feet near one end (see opening photo). The mix design was worked out with the local concrete supplier using standard materials. The slab was constructed mostly by hand in more than 100° F heat. After four years and drops of 70 degrees in temperature, only one very tight crack exists at one end due to very soft fill soil and trucks being driven off the unthickened slab edge.

Distribution center entrance pavement

One of the most challenging projects was a jointless 6-inch-thick replacement slab at a distribution center entrance that serves almost 2,000,000 square feet of storage space. The tractor trailers are funneled into a single lane with almost constant traffic. The original pavement and subsequent replacements and repairs failed primarily because of deep very soft soil and constant, heavy traffic. Because of the entrance's importance, the slab had to be back in service in seven days. Only a shallow, tapered replacement of the soft soil could be done because of the potential of undermining the adjacent guard house and pavement. If the thickness design had been according to AASHTO, a 9-inch pavement would be required, but with the inclusion of MPF, a 6-inch slab was chosen (the difference in bending strength if the concrete were the same is even greater than it appears because it is actually the difference between [9]2=81 and [6]2=36). The 66x46-foot slab developed one tight crack with no issues after four and a half years of use.

Warehouse floor

An "L-shaped" 6-inch-thick warehouse slab to support frequent lift truck traffic was constructed in two placements of 127x60 feet and 115x85 feet with no contraction joints. The authors predicted the slab to crack at the dock leveler pits in the shorter placement due to the way the pit had been constructed previously. It did occur and has lengthened due to differential settlement of inadequately compacted fill soil under one half of the slab. But after four years there is only the one crack, which has remained tight with no spalling.

Industrial facility floor

An interesting experiment was conducted on a slab supporting significant loads and frequent lift truck traffic at an industrial facility. Four 90x30-foot slab placements 6 inches thick were cast by relatively untrained workers. The variables were fiber dosages of 3.75 pcy versus 7.5 pcy and fiber lengths of 1.5 inches versus 2.25 inches. Sawcut contraction joints were planned but not completed by the time the site was visited again. So the decision was made not to make the sawcuts and see how much cracking would occur. Eight years later, the only placement to crack was the one with the lower dosage rate and the shorter fiber length. There is one tight crack near the middle of its length, but it is causing no problems.

Roller skating rink with unbonded topping

An owner was unhappy with his 168x84-foot oblong roller skating rink floor because of the joints, a failing polymer coating system, poor aesthetics, and other issues. The solution was an unbonded 4-inch topping with no joints on a double polyethylene slip sheet. After more than four years, there are no visible cracks, plus the aesthetics and flatness are highly satisfactory to the owner.

Heavy-duty retail store unbonded topping

A retail store with heavy loads and small, hard-wheeled traffic required a nominal 2-inch-thick topping with some areas being as little as 1½ inches thick for architectural reasons. ACI recommends a minimum thickness of 3 inches for heavy loads like these. However, the base slabs varied substantially in elevation and floor surfaces and there were environmental concerns about removing them. The topping surface had to be at a certain elevation, very flat, burnished, and aesthetically pleasing. A double polyethylene slip sheet unbonded the topping, but significant elevation differences still provided substantial restraints to shrinkage. But four years later, there are only a few, tight, serviceable cracks. An interesting side note is that a similar topping without MPF was installed more than a year later and within two weeks severe corner cracks developed.

Conclusions

MPF slabs have a proven eight-year track record for having low curling and cracking potential, minimizing joints and maintenance, and being reasonably user friendly and cost effective. Procedures for structural design, mix design, batching, placing, and finishing good MPF slabs are essentially the same as for typical slabs, but how to optimize the benefits of MPF have been discussed. If the potential of MPF slabs is recognized and properly utilized, the effects could be revolutionary. ■

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