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Working with silica-fume concrete

Improving concrete with silica fume requires using the correct placing, finishing, and curing procedures

Elkem Chemicals, Inc.

Construction workers must be carefully trained to get the best results with silica-fume concrete. There is little or no bleeding in flatwork, so finishers must adjust the timing of finishing operations.

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Silica fume produces concrete that is stronger and more durable than conventional concrete. Field strengths of 14,000 psi have been achieved with this highly reactive pozzolan. Also, rebar corrosion is reduced because the reaction products of the extremely fine silica fume particles plug internal pores. This slows carbonation and helps keep chlorides out of the concrete. Because of these benefits, many engineers are now specifying silica-fume concrete for high-strength structural applications, abrasion-resistant surfaces, and structures exposed to deicing agents or salt water.

Adding silica fume isn't a substitute for good concreting practices, however. For best results, concrete suppliers must pay close attention to several production details. Also, contractors need to know how placing, finishing, and curing procedures differ from those used for conventional concrete.

Choosing the product form

Silica fume is available commercially in several forms: dry, densified dry, and slurried, each with or without chemical admixtures. Silica fume or products containing silica fume are available in bulk, drums, and bags, depending on the supplier. The form of the material impacts the handling of materials and the production of concrete, but has no significant effect on the properties of the fresh or hardened concrete.

Silica fume is often available in bulk or bags near the smelters where it is produced. Bulk silica fume can be transported and handled like portland cement or fly ash. Bagged silica fume can be used by emptying the bags directly into truck mixers. Bagged silica fume isn't commonly used, though, because of the dust it creates. Bulk and bagged silica fume are also costly to transport. Little fits in a truck because silica fume weighs only 12 to 15 pounds per cubic foot, compared with cement which weighs 94 pounds per cubic foot.

Transporting silica fume as a water-based slurry is more economical. The slurries offer ease of use once the required dispensing equipment is available at the batch plant. Because of the nature of the slurry and because the quantities used per cubic yard of concrete are greater, the dispensing equipment is larger and more complex than that used for chemical admixtures. Because the slurry may stiffen in storage, dispens-

file: admixtures

ers may be equipped with agitators.

Where installing dispensing equipment and using slurry is not practical, a dry, densified silica fume product with chemical admixtures is available. It weighs 35 to 40 pounds per cubic foot and is cost effective to transport. The densified product also creates little dust.

Producing the concrete

Three critical tasks must be performed with care when producing concrete containing silica fume: measuring, adding, and mixing. The routine aspects of concrete production also require extra care. For example, the amount of wash water in the truck should be accounted for in mixture calculations. Drivers should be careful not to add water to the drum when they wash dust from a truck after loading.

Measuring. The correct amount of silica fume must be added by the concrete supplier. In some specifications the silica fume is required as an addition to the portland cement while in others it is a replacement for the cement.

Measure silica fume with the same degree of accuracy as other concrete ingredients. Typically, accuracies of plus or minus one percent by mass or volume are specified. Recognize what is being specified and what is being measured: the silica fume itself or the commercial product containing silica fume. For example, the slurried products contain about 50 percent silica fume by weight while the dry products may be 100 percent silica fume.

The amount of water in a slurry must also be accounted for in the mixture proportions. You must reduce the weight of batched water to correct for the water in the slurry.

Adding. The type of material being used determines when to add the silica fume product. Make a few trial batches to find the best batching sequence for a particular plant. Dry silica fume can be added anytime during the production process, particularly if the batch plant can handle the dry material in bulk.

Add slurried products to a truck mixer first since these products contain much of the batch water. Adding slurried products to a truck last can result in head pack or poor distribution of silica fume throughout the load. For central-mixed concrete, add the slurry *after* all other materials are in the mixer.

Mixing. The silica fume must be uniformly distributed throughout the concrete. Within a single load, compressive strength variations of 3000 psi can result from poor mixing.

Follow American Society for Testing and Materials requirements for mixing (ASTM C 94) when using silica fume in truck-mixed concrete. The rated mixing capacity of the truck must not be exceeded. The volume of mixed concrete should not exceed 63 percent of the total volume of the drum. Equally important, an absolute minimum of 100 revolutions at a speed of at least 15 rpm is required. Start measuring mixing time after all ingredients, including the silica fume, are in the drum.

To determine whether you are mixing adequately conduct a mixer evaluation as specified in ASTM C 94. If such a test cannot be conducted, closely watch the concrete discharge from the truck mixer. Slump variations during discharge indicate poor mixing. For example, if the slump changes by several inches from the front to the back of the load during a continuous discharge, it's likely that the concrete was not mixed properly.

Concrete balls in the discharge also indicate poor mixing. Usually, more mixing or reducing the size of the load solves this problem. Truck mixers with worn fins are more prone to producing concrete balls. If the same truck consistently causes problems, don't use it.

Transporting, placing, and consolidating

Silica-fume concrete acts much like conventional concrete during transport, placement, and consolidation. However, depending on the amount of silica fume, the fresh concrete can be more cohesive and less prone to segregation than conventional concrete. Because of the increased cohesiveness, use a slump that is 1 to 2 inches higher than normal for the same type of placement. For overall ease of placing and finishing, make the slump as high as is practical.

Transport silica-fume concrete in any equipment used to transport conventional concrete. After discharge, the equipment should be cleaned the same way as for conventional concrete. But clean the trucks promptly! Chipping 12,000 psi concrete

SILICA-FUME CONCRETE NEEDS SUPERPLASTICIZERS

Using, silica fume in concrete requires using another innovation in concrete technology: superplasticizers, or high-range water-reducing admixtures. Silica fume has little use without them because its water demand is so high when used alone.

Silica fume is about one hundred times finer than portland cement. Just as with aggregates, decreasing particle size increases surface area and the water demand. Without a superplasticizer, silica fume dries up the mix. The extra water required to get a reasonable slump would increase the water-cement ratio, thus reducing strength and durability. You'd be better off using conventional, concrete with a lower water-cement ratio.

Silica fume products are available with and without preblended superplasticizers. If a product without a superplasticizer is used, you must add your own. Check with the silica fume supplier for recommended admixtures to use. If a product containing a superplasticizer is picked, it may be necessary to add more of the admixture or a standard water-reducing admixture to get the performance you need. Check with your silica fume supplier to ensure that the admixture you want to use is compatible with that in the product already.

When adding the superplasticizer, you may be using quantities much larger than are used in conventional concrete. Don't worry; remember that there is a huge surface area in the silica fume that must be wetted. For the best results, the superplasticizer should be added at the batch plant. Shoot for a 4- to 6-inch slump at the batch plant to ensure adequate mixing of the silica fume into the concrete. If necessary, final slump adjustments can be made at the jobsite by adding more admixture, not water.

from the mixing drum is an experience you won't want to repeat.

Silica-fume concrete can be placed successfully using any placement device such as a bucket, pump, or tremie. During placing, don't add water to the concrete to improve workability. Just as with conventional concrete, too much water reduces strength and durability. If a higher slump is needed, add controlled amounts of a water-reducing admixture at the batch plant or at the jobsite.

Consolidation by vibration is needed for silica-fume concrete even when a high-slump mixture is used. Concrete with a slump of 8 to 10 inches can be deceptive because it flows so well that workers may think vibration isn't needed. However, the increased cohesiveness caused by silica fume entraps air which *must* be removed by vibration, regardless of the slump.

Finishing

The biggest difference between conventional concrete and silica-fume concrete shows up during finishing. Adding up to 5 percent silica fume by weight of cement makes little difference, but adding higher amounts of silica fume reduces bleeding and may eliminate it. This makes silica-fume concrete more susceptible than conventional concrete to rapid surface drying and plastic shrinkage cracking.

Plastic shrinkage cracking can affect all concrete at two stages in the finishing operation. The first is during the period after initial screeding and bull floating but before final finishing. The second is after final finishing and before curing starts.

Plastic shrinkage is caused by rapid moisture loss from the surface of fresh concrete. If the lost moisture is not replenished by natural bleeding, tensile stresses develop and cracking results. A chart in the American Concrete Institute report "Hot Weather Concreting" (ACI 305) can be used to estimate how fast surface moisture will be lost. Humidity, wind, and the concrete and air temperature affect the evaporation rate.

The ACI report suggests that precautions against plastic shrinkage cracking are needed if the expected evaporation rate at the concrete surface approaches 0.2 pound per square foot per hour. This value is too high for silica-fume concrete. If the estimated evaporation rate approaches 0.1 pound per square foot per hour, cracking may occur. Here are some ways to prevent plastic shrinkage cracking:

- Erect windbreaks such as supported plastic sheets or temporary plywood walls. Large vehicles parked near the slab also can help reduce wind velocity.
- Use a light fog-spray of water to keep the concrete surface moist between finishing operations. Do not finish the concrete if water from the fog spray can be seen on the surface.
- Cover fresh concrete surfaces between finishing operations, using plastic sheets or moist burlap covered with plastic.
- Use a proprietary evaporation retarder to prevent moisture loss between initial and final finishing.
- Place floors and slabs after the walls and roof of a structure are in place.
- Start curing right after you're done finishing.
- Use fibers (polypropylene or steel) in the concrete.
- Dampen the subgrade and forms to prevent moisture loss at the base of the slab.
- Reduce concrete temperature by using cooled aggregates or water or by using ice to replace some of the batch water.
- Have an adequate crew and all required equipment on hand to place the concrete quickly and without interruption.
- Place the concrete late in the day to minimize exposure to direct sunlight and higher temperatures.

Sometimes the surface of the silica-fume concrete dries out and hardens faster than the underlying concrete but doesn't crack. This gives the fresh concrete a spongy consistency that is hard to finish. The same steps that prevent plastic shrinkage cracking also help prevent surface drying and hardening.

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Superplasticized silica-fume concrete flows well. But even with slumps of 8 to 10 inches thorough consolidation by vibration is always needed.

Finishing practices. Use the same tools and procedures that you use with conventional concrete. There may be a difference, however, in the timing of the finishing operations. The lack of bleeding makes it hard to determine when to get on the concrete. The chemical admixtures also affect timing because they often include retarders that delay setting.

There are two general recommendations regarding finishing. First, under-finish the concrete. This lowers finishing costs and the potential for plastic shrinkage cracking because curing is started sooner. By limiting finishing, the potential for dusting, scaling, and surface crazing is also reduced.

Second, conduct a trial placement so the finishing crews can perfect their approach to the silica-fume concrete. This is particularly important for finishers who are accustomed to working on wetter concrete surfaces. Trial placements are mandatory for floors requiring high silica fume content and a high degree of finishing. If the concrete application requires more than 10 percent silica fume, consider screeding, bull floating, and texturing, then immediately curing the slab. High quality finishes can be achieved on silica-fume flatwork by monitoring every detail of the placing, finishing, and curing process.

Curing

Concrete won't perform well unless it is cured properly. Improper curing is more harmful to silica-fume concrete than to conventional concrete. To get the most benefit from silica fume, cure the concrete longer than you would if conventional concrete were being used. Keep it moist with wet burlap, sheets of plastic, or a curing compound for at least seven days.

Start curing immediately after finishing. Remember, high amounts of silica fume produce concrete that does not bleed; you do not have to wait for the bleeding to stop before curing. On some projects where finishing after setting was not required, the curing compound was applied a few minutes after the pass of a vibrating screed.

If silica fume is being used in concrete requiring accelerated curing, you may have to modify the curing cycle. The concrete must reach an initial set before beginning the accelerated curing. The chemical admixtures often used with silica fume can affect the rate of setting.

Good results come from good practices

Silica fume offers tremendous potential for improving many properties of concrete. Silica fume would not be specified (and paid for) if the specifier didn't want to achieve better-than-normal concrete. To achieve high strength, durable silica-fume concrete, you must use correct practices because this concrete is less forgiving of any attempts to cut corners than conventional concrete.

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