Adjusting approach to suit material leads to success

Silica Fume for Concrete Bridge Decks

By Tarif M. Jaber

Placing and consolidating concrete containing silica fume is essentially the same as for concrete without silica fume. Because silica fume eliminates bleed water in concrete, finishing silica-fume concrete for bridge decks and other flatwork usually is done without the bleed water waiting periods associated with traditional finishing practices. Curing must begin immediately after finishing to protect the concrete from drying.

Coordination is key

Good coordination between the concrete contractor and the concrete supplier is critical. Relatively small changes in the fresh properties of the concrete can make significant differences in the effort necessary to get the concrete placed and finished to meet specifications. Some items to consider:

- *Slump, No. 1.* A good rule of thumb is to start at a slump that is about 40 to 50 mm higher than what would be used for concrete without silica fume in the same placement. This increase in slump compensates for the additional cohesiveness of the silica-fume concrete. Don't worry about segregation in this situation-it takes a large increase in slump to produce segregation in silica-fume concrete.
- *Slump, No. 2.* It is usually best to place at the highest slump that is practical for field conditions. Conventional concrete is normally placed on bridge decks with a slump range of 100 to 150 mm. The higher the slump, the easier it is to close the surface of the concrete during the screeding and bull floating operations. The limiting factor for bridge deck or flatwork placements will be any slopes involved in the placement. Use the highest slump that will hold on the slope that is being placed.
- *Stickiness.* First-time finishers of silica-fume concrete frequently report that it is "sticky and difficult to work

Good practices in placing, finishing, protecting, and curing silica-fume concrete include placing the material close to the finishing machine; vibrating to ensure good consolidation; and covering to protect and cure.

with." Silica-fume concrete actually looks and feels more cohesive than conventional concrete and therefore often is described as "sticky." Experience shows that the stickiness may result from the interaction of the silica fume and the chemical admixtures (water reducers and high-range water reducers called "supers") in the concrete. One approach is simply to substitute one chemical admixture for another of a different chemistry. Another is to remove about one-third of the super and replace it with an equal amount of a midrange water reducer. Don't be afraid to try different combinations of admixtures to get the best concrete possible for the project. Another factor that can contribute to stickiness is the grading of the aggregate. It may help to vary the fine-to-coarse aggregate ratio to include more coarse aggregate. In some cases, changing the source of the fine aggregate may help reduce stickiness.

Preplacement conference

A preplacement conference is important for any type of concrete work, but such a meeting is even more important for silica-fume concrete. This is the opportunity for the contractor to outline all plans for placing, protecting, finishing, and curing the concrete so everyone involved understands what will occur. It is also the time for the contractor to resolve any unanswered questions regarding the expectations

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of the owner and the engineer.

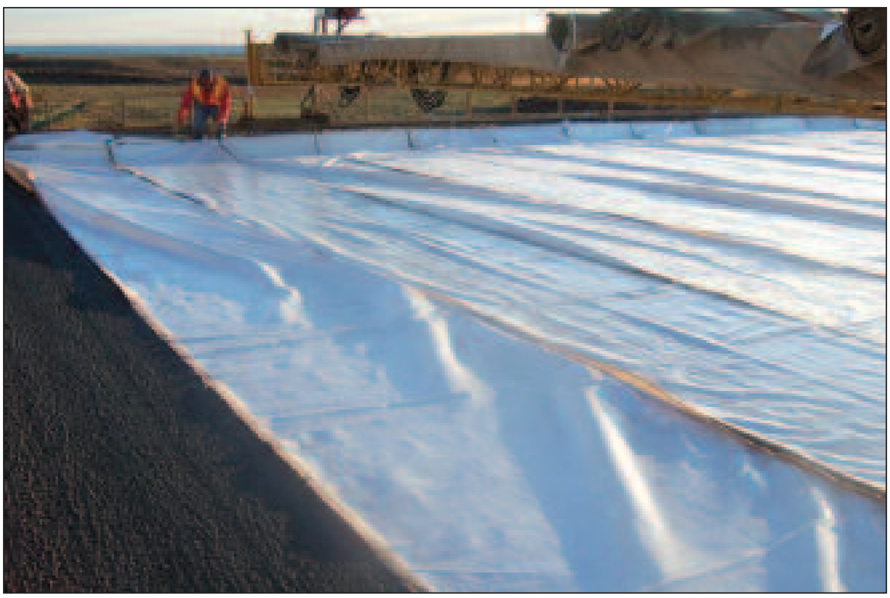
A key element to discuss is the rate of concrete delivery. A common problem is getting too much concrete onsite and having trucks back up. This is true particularly for bridge deck overlays or for silica-fume concrete toppings over precast elements where a small volume of concrete will cover a large surface area.

Test placement eliminates surprises

It is almost imperative that a test placement be conducted before concrete work actually starts on a project. This gives everyone the opportunity to get the "bugs" out of the system and to observe and approve all procedures. Representatives of all parties should be present: owner, engineer, concrete supplier, materials suppliers, pump operator, and, of course, the contractor. The contractor must commit to having the finishing crew that conducts the trial placement be the same crew to be used on the structure.

This is usually the first chance for the contractor's finishers to work with the concrete mixture and it is their chance to fine tune the concrete. The test placement is a good time to determine whether any adjustments to the concrete based upon weather or placing conditions will be required. For example, it may be appropriate to use a retarder or a nonchloride accelerator in the silica-fume concrete mixture, depending upon conditions.

It is also an opportunity to try different approaches and different tools for concrete finishing. Determine which tools work best to close and finish the surface to the degree required. The trial placement must be large enough to allow for realistic finishing techniques to be demonstrated. At the conclusion of the trial placement, one of two conclusions must be reached: 1) an acceptable finishing approach has been demonstrated and accepted, or 2) the need for an additional trial placement has been established. The owner's representatives should have



When bridge decks are placed in a single lane, it usually is possible to apply wet burlap and plastic immediately without any waiting period for the concrete to harden to allow workers to walk on it.

the authority to accept the concrete mixture and procedures demonstrated.

How it dries

Because of the very high surface area of silica fume, water demand becomes quite high combined with typically very low water contents of silica-fume concrete mixtures-there is little, if any, bleed water. As the silica fume content increases or as the water content decreases, bleeding will be reduced or eliminated. On the positive side, that means finishing can start earlier and be completed sooner. Additionally, bleed water will not accumulate under aggregate particles and under horizontal reinforcing bars. There will be no bleed water channels for chlorides or other intrusive materials to use as a "shortcut" to get into the concrete or reach the reinforcing steel.

On the negative side, the lack of bleeding means that silica-fume concrete flatwork, under the appropriate environmental conditions, will dry from the surface downward. That makes it more susceptible to plastic crusting and, eventually, plastic shrinkage cracking.

Four environmental conditions lead to drying of the concrete surface: air temperature, relative humidity, concrete surface temperature, and wind speed. Figure 4.1 in ACI 308R, "Guide to Curing Concrete," shows the relationship among these conditions to characterize the "evaporative environment" and can be used to estimate whether or not drying is likely to be a problem. Because it was developed many years ago, before the advent of silica-fume concrete, many recommendations for silica-fume concrete use a value of 0.5 kg/m2/hour, which is one-half the original value.

Difficulties can arise if measurements are not made as recommended or when weather data are obtained by calling the

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local weather office. The best approach is to combine the use of the chart with a little common sense. Is the placement in direct sun, is the wind increasing, is the humidity high enough to make workers uncomfortable? The more uncomfortable workers are from the temperature and humidity, the less likely that the concrete will dry out. Don't forget-it's always best to err on the safe side when deciding whether to provide protection against concrete drying out.

Protecting silica-fume concrete

Three of the more commonly used ways of protecting silica-fume concrete from drying too quickly are fogging, using an evaporation retarder, and using the one-pass finishing technique.

The goal of **fogging** is to maintain high humidity conditions above the concrete surface during the time from placement to application of curing. If environmental conditions cause a concern over drying, fogging should begin immediately after the concrete is placed by a finishing machine or after bull floating. Depending upon the type of placement and the degree of finishing required, it may be necessary to fog between finishing passes. Just as for any other conventional concrete placement operation, do not finish bleed water or fog water into the surface.

Evaporation retarders are probably the most abused material in concrete finishing. For many years, these products were promoted and sold as "evaporation retarders and finishing aids." This practice has been reduced, and most data sheets now refer to the products as only evaporation retarders. Apply the evaporation retarder after the bull floating is completed and do not disturb the product until floating begins. Remember, if any type of finishing tool is run across the surface after the evaporation retarder is applied, the film will be broken and will no longer keep in moisture. Also, using too much of these products and finishing the product into the surface can result in damage to the concrete.

One-pass finishing, also referred to as "fast-track finishing" or "assembly line finishing," is a technique that takes advantage of the lack of bleeding and eliminates the waiting period between placing and finishing. The overall process is based on two simple concepts-protect the concrete at all times and don't wait for the concrete to stiffen before applying the final texture and immediate cure.

This approach is becoming the preferred practice by many DOTs and favored by bridge contractors because it

Health issues

Silica fume is essentially a nonhazardous material. It falls into the general category of nuisance dust, which is similar to portland cement and many other fine powders. Care should be taken in all operations involving silica fume to avoid creating dust.

An appropriate dust mask or respirator must be worn when handling dry silica fume before and during its addition to the concrete. Personal protective equipment must be selected to meet the exposure and environmental conditions specified by U.S. law.

Selection of a mask or respirator must be made on the basis of exposure and environmental conditions. For guidance on selecting an appropriate mask, see http://www.cdc.gov/niosh/userguide.html.

eliminates fogging and evaporation retarders. Using fast-track finishing, the contractor finishes the work in less time and uses fewer workers, thus saving time and money. There is no need to worry about broken fogging equipment and missing the application of evaporation retarders; just focus on moving quickly from placing and finishing to protecting and curing.

Placing and consolidating

Silica-fume concrete has been successfully placed by all means of concrete placement methods, including direct discharge from mixer trucks, crane and bucket, tremie under water, and pumping. Given the nature of the applications where silica-fume concrete tends to be used, the vast majority has been placed by pump. Overall, do not expect to see any significant differences when placing and consolidating silica-fume concrete.

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Silica-fume concrete is a very fluid but cohesive material, particularly if the recommendations regarding increasing slump are followed. However, don't be fooled by the apparent workability-this concrete still needs to be adequately vibrated during placement. Do not assume that a vibratory screed will vibrate concrete in deeper sections such as beams cast integrally with slabs. An internal vibrator must be used in accordance with ACI recommendations. For more information, see ACI 309R, "Guide for Consolidation of Concrete."

Finishing bridge decks

Finishing silica-fume concrete bridge decks is very similar to finishing bridge decks without silica fume. The greatest difference is the lack of bleed water, which eliminates the waiting time needed to finish conventional concrete. This allows the contractor to move quickly from one step to the next and begin curing immediately after the concrete is placed and finished. In fact, too much finishing and surface manipulation may damage silica-fume concrete surfaces because there is no bleed water. Due to the equipment used, finishing bridge decks can be done under an even more compressed schedule than other flatwork.

Deck finishing procedures are the same for both full-depth placement and overlays. The only difference is the necessary surface preparation and the pos-

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sible requirement for a bond coat for overlay placements.

Before the date of placement, determine the degree of finish required (usually defined in the project specifications), conduct a preplacement conference, and conduct a trial placement. If it is an overlay, the next steps are to prepare the surface and apply a bond coat, if required. Finally, place the concrete, consolidate and finish, texture the surface, and protect and cure.

Surface preparation for overlays

As is true for any overlay material, proper surface preparation is critical for successful placement of a silica-fume concrete overlay. All unsound concrete must be removed and corroded reinforcement replaced or repaired as required by specifications. *Extreme care must be taken to ensure that any concrete left in place to which the overlay is expected to bond is undamaged.* Frequently, overlays fail just below the bond line because this concrete was damaged during removal operations. Generally, milling machines should not be used because of the potential for microcracking in the substrate. Shot blasting or hydro demolition techniques are preferred. See ACI 546.1R, "Guide for Repair of Concrete Bridge Superstructures," for a discussion of appropriate concrete removal techniques for overlay placements.

Another problem seen on concrete overlays, with or without silica fume, is that the surface of the underlying concrete has been too smooth for a good mechanical bond to take place. A rough surface with coarse aggregate particles exposed and surface amplitude of approximately 5 mm is recommended by the Silica Fume Association, (SFA). ASTM E 965, "Standard Test Method for Measuring Pavement Macrotexture Using Volumetric Techniques," (sometimes referred to as the "sand patch test") can be used to evaluate surface preparation. Another approach is to use the surface roughness samples prepared by the International Concrete Repair Institute.

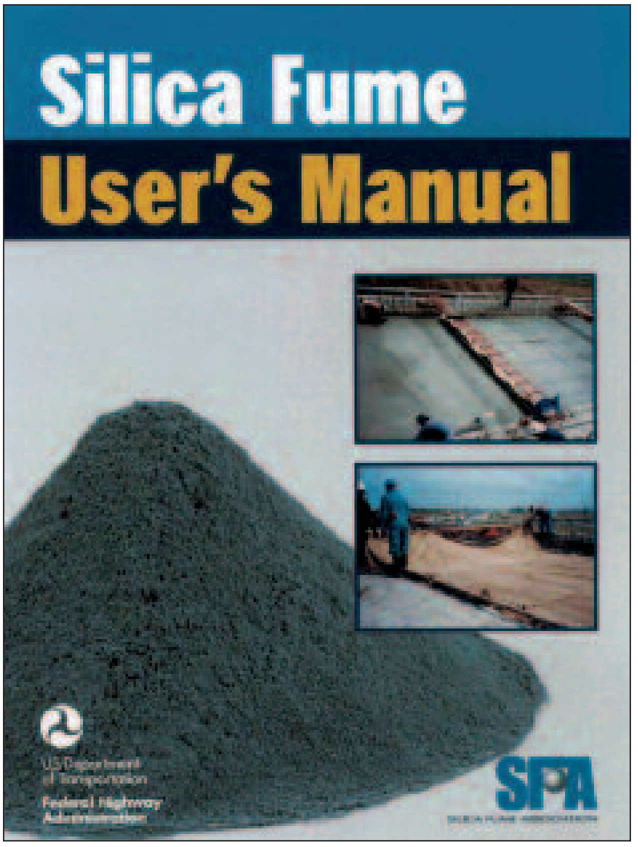
Different state DOTs specify different requirements for the use of a bond coat between an overlay and the underlying concrete. If a bond coat is specified, it should contain the same cementitious materials as the overlay concrete. There are two areas where the grout can become a problem. First, rather than using a small mixer to make weak grout on site, order the grout from the concrete supplier. Second, don't allow the grout to get too far ahead of the actual concrete placement. If this occurs, the grout will dry out and the bond enhancer actually becomes a bond reducer. For that reason, many States DOTs including New York and Virginia are not using bonding materials but allowing the grout from the silica-fume concrete itself to be broomed into the deck ahead of the placement. If this practice is followed, be sure to remove the aggregate that is not broomed into the deck. Since 1998, the New York DOT bridge deck overlay requirement calls for a minimum 24-hour soaking of the deck and placing the overlay on the surface saturated deck without any bond grout application.

For almost all bridge decks, concrete placement will be directly from a delivery vehicle or by a pump. If pumping, particularly if the pump is located beneath the bridge deck, consider measuring and calibrating slump and air losses through the pump before actual concrete deck placement. Pump boom configuration can have significant impact on the amount of slump and air losses.

Most bridge deck placements use a heavy-duty bridge finishing machine to strike off, consolidate, screed, and pan float the concrete to final grade. When these machines are set up properly, there is essentially no need for additional hand finishing. The only concern is that the concrete not be allowed to be placed on the deck too far ahead of the machine. Two states, Arizona and New York, require that the finishing machine be between 1.5 and 2.5 m from the discharged concrete on the deck.

State DOTs differ in their requirements for final texturing of bridge decks-some require brooming, some tining, and some require that the texture be sawn into the concrete after hardening or grooving. If a texture is to be applied at the time of concrete placement, be sure not to let the concrete dry out during the process.

Protecting and curing silica-fume concrete comprise the most critical steps for successful placement of bridge decks. If there are delays in the placing-finishing-texturing process, protect the concrete using fogging, evaporation retarders, or plastic sheeting as appropri-



This article is excerpted and condensed from Silica Fume User's Manual, published by the Silica Fume Association and Federal Highway Administration. The full manual in PDF format is available for free download at www.silicafume.org.

ate. Immediately after the final finishing step, whether this is the pass of the finishing machine or the texturing, begin curing. The term "immediately" can be open to interpretation. The Federal Highway Administration and SFA recommend that curing be started within 10 to 15 minutes after placement. Arizona DOT requires that wet curing immediately follows final finishing of concrete but no later than 10 minutes after concrete has been screeded and when finished surface is no more than 1.5 to 2.5 m away from the finishing machine.

Curing silica-fume concrete

The SFA strongly recommends that all silica-fume concrete bridge decks be wet cured. NCHRP 410 report on silica fume bridge deck curing recommends a minimum of seven days of uninterrupted wet curing. Any other means of curing or curing for a shorter duration can compromise the quality of the concrete. Remember, one of the main and critical approaches to successful silica-concrete projects is to enforce the phrase "under-finish and over-cure."

Final details

Don't forget that silica-fume concrete usually gains strength much faster than concrete without silica fume. Review the timing of joint cutting to ensure that joints are cut as soon as possible to prevent cracking. Resume wet curing after cutting joints.

Stress post tension strands when the concrete has developed the specified strength, not at the end of an arbitrary period. Silica-fume concrete gains strength rapidly and will be ready for stressing earlier than concrete without silica fume.

There have been problems applying traffic stripes to silica-fume concrete that has been cured using curing compound. This problem is most likely related to the curing compound rather than to the silica fume. When using a curing compound, be sure to verify that the curing material and paint are compatible or it will be necessary to remove the compound before painting. ■

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