INSIDE: CONCRETE SURFACES \\ WORLD OF CONCRETE

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CONCRETE CONSTRUCTION

The Year's Most Influential People

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What Makes Concrete Pumpable?

As design and construction teams place higher demands on concrete, pumping complex concrete mixes becomes ever more challenging.

BY DEBORAH R. HUSO || **AS CONCRETE MIXES** become more complex in order to address ever-increasing needs for strength and durability and to meet environmental sustainability standards, concrete pumpers often face challenges when it comes to moving concrete through pump lines with the efficiency demanded by accelerated construction schedules.

"We pump at such high pressures today," says Gary Brown, director of concrete pumping for R.L. McCoy Inc., an Indianapolis, Ind.–based concrete pumping company. "It places stress on the equipment." And that stress can cause equipment to fail.

Brown says that since the 1990s, concrete producers have increasingly reduced water and cement (paste) content in favor of chemicals designed to increase performance. "When you add chemicals, you take out cement," he says. "I'd like to see concrete pumping at a reasonable pressure again—for safety. Chemicals aren't the only answer to making good concrete."

BASF senior scientist and engineer Van Bui adds, "The first step is that the concrete mixture, including cement content and dosage of chemical admixtures, should be well proportioned and designed to achieve not only the required performance in the hardened state, but also satisfactory fresh properties such as workability, workability retention, pumpability, and placeability."

How do construction teams make sure concrete mixtures meet the performance requirements of architects and engineers while also being efficient and safe to pump? Brown says the key is getting your pumping contractor involved early. "We know the materials, what we can tolerate, and what chemicals might be needed with a given mix," he says. "If I can't pump it, they can't sell it, and we want everyone to be successful."

Factors that Impact Pumpability

A wide array of factors can impact concrete pumpability, Bui notes, such as the dimension, shape, gradation, and volume of aggregates. Supplementary materials like fly ash, silica fume, slag, and limestone also influence the rheology of the mix and therefore its pumpability.

"The two main ingredients that make concrete pump are water and cement," Brown says, and while admixtures can increase pumpability, that will only happen if the supplier doesn't take out too much water and cement. "If you replace too much of that water and cement with a chemical, it may give the same slump, but it takes out pumpability. That doesn't mean the product won't pump, but the pumping will be slower, meaning a pumper may get 40 yards an hour instead of 90."

Steve Lloyd, CEO of Lloyd Concrete Services Inc., in Rustburg, Va., agrees that water is critical to pumpability. "A lot of people now want to do a chemical mix to replace the water," he says. "The concrete pump knows if the mix doesn't have enough water, and it won't pump without water."

Rocky mixes can collect on the hopper grate and bridge in the hopper or agitator area.
PHOTO: ADOBE STOCK / SOMMERSBY

"A good mix that pumps well will empty from the truck in 5 minutes," says Steve Lloyd. "That means quick turnaround and more money for everybody." PHOTO: LLOYD CONCRETE SERVICES

Tommy Rutura, president of New York–based Ruttura & Sons, says a good water-cement ratio is critical. Ruttura, who pumped for the construction of the World Trade Center, says, "If you're pumping high-strength concrete with a water-cement ratio of 0.28, that's not efficient; we were only able to get about 20 yards an hour." It can also put a lot of pressure on the hose clamps. Ruttura says the ideal is to "have at least 270 pounds of water per cubic yard, although we can pump it with down to about 230 pounds with a well-blended aggregate."

"When we put out a proposal, we say the mix has to be pumpable," Lloyd says. "All mixes aren't the same. You have different types of aggregate in different parts of the country." The type of concrete also plays a role. Ruttura says normal-strength concrete between 3,000 psi and 6,000 psi pumps easily, but at higher strengths, the water-cement ratios become too low to pump at high volume.

Very-high-strength vibrated and self-consolidating concretes with very low water-cementitious materials ratios can create high pressure in the pump due to high viscosity and high thixotropy (ability of the concrete to flow), according to Bui. But the opposite is also true—self-consolidating concrete with poor mix designs, too-high slump flow, and insufficient cohesion can result in segregation and blocking, which also causes high pressure in the pump.

"Our industry fails to [remember that] the slump cone was designed in 1917, and was designed to test water added to a mix and maintain water consistency," Brown says. "We still use the slump cone as a measuring device but we may only be measuring chemical slump. The only thing that tells you how wet the concrete really is, is the water-cement ratio. The only true test is, will it go through the pump on the jobsite?"

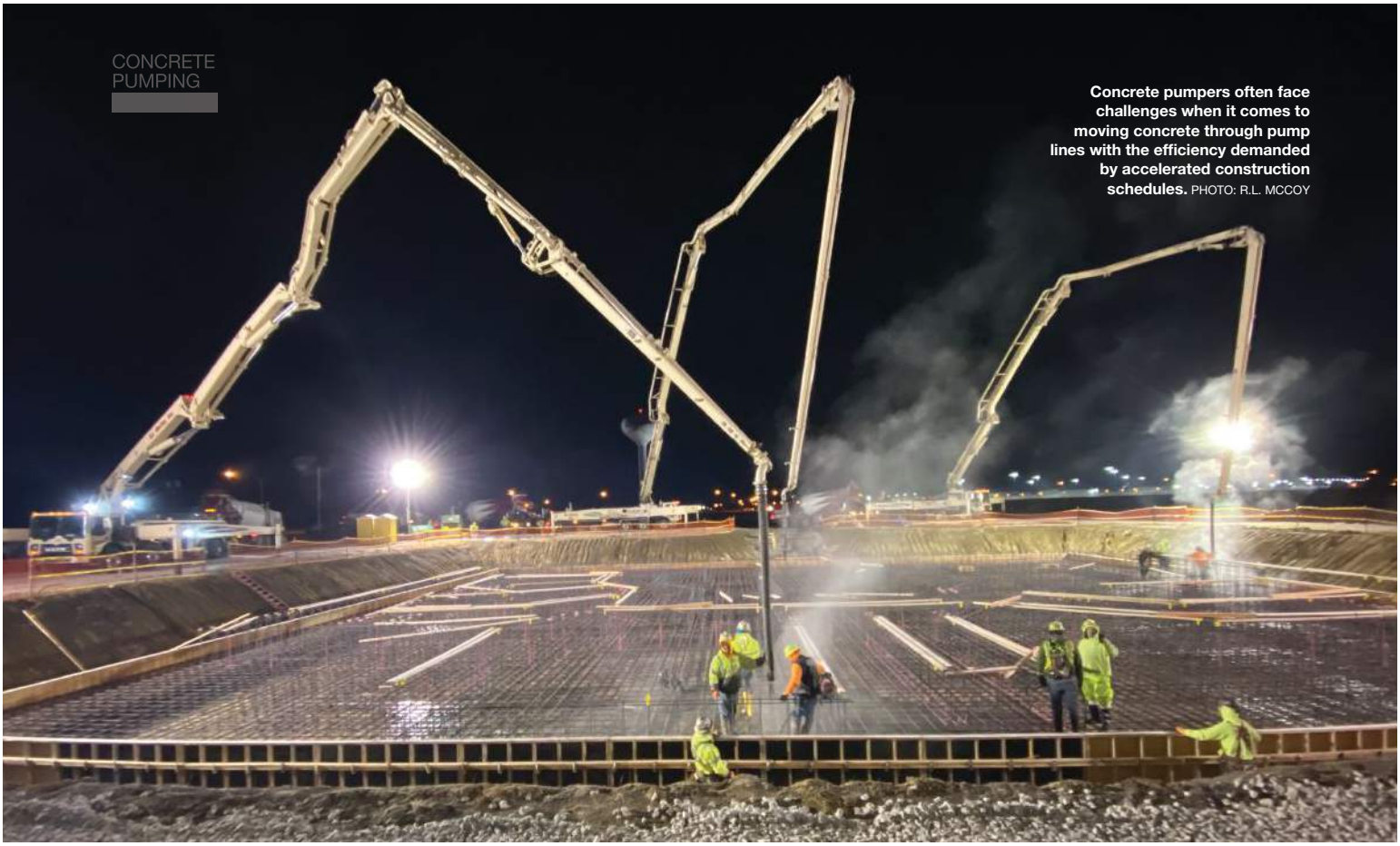
Brown says that if pumpers keep an eye on the pressure gauge or operator box, they'll see that the pressure changes when the mix changes. "If the pressure is consistent start to finish, you've got good-quality concrete."

Pumping Fibers

When it comes to fiber-reinforced concrete, synthetic and steel fibers typically don't decrease pumpability, but they can impact how fast one can pump. And, as Lloyd points out, macro-synthetic fiber can collect on the hopper grate. "It's important to modify your standard grate to a round and smooth grate," he says.

Brown says his company recently completed a job where they had to pump concrete with 50 pounds of steel fiber per cubic yard, the highest dosage they'd ever pumped. "We were able to pump it without issues; we just couldn't pump it as fast," he says, because the material tended to bridge in the hopper and so wouldn't load the cylinders completely full. Brown indicates the same can happen with synthetic fiber.

A wide array of factors can impact concrete pumpability such as the dimension, shape, gradation, and volume of aggregates and fibers. PHOTO: PUTZMEISTER



Concrete pumpers often face challenges when it comes to moving concrete through pump lines with the efficiency demanded by accelerated construction schedules. PHOTO: R.L. MCCOY

Lightweight Concrete

When it comes to lightweight concrete, Clint Chapman, west region marketing manager for Arcosa Lightweight in Boulder, Colo., says air entrainment can help with pumping, making the concrete more flowable and keeping the mix from segregating. He notes that water content is often higher in lightweight concrete than in standard-weight concrete and that sufficient aggregate moisture is critical in successfully pumping lightweight concrete. The critical factor is to make sure the lightweight aggregate is saturated surface-dry as it goes in so that it will not absorb water from the mix, especially under the pressure of pumping.

"The concrete pump knows if the mix doesn't have enough water," says Steve Lloyd, "and it won't pump without water." PHOTO: LLOYD CONCRETE SERVICES

"You can lose a lot of slump when you pump [lightweight concrete]," Lloyd says. Because lightweight that is not saturated absorbs water so quickly, Lloyd advises putting the lightweight aggregate in a pit and soaking it before mixing. "Water sprinkling is not enough," he cautions. "You will lose slump."

Arcosa's Chapman disagrees that water sprinkling is not enough and notes that wetting aggregate with sprinklers "is done with great success every day throughout the country. As long as the aggregate is pretreated with moisture sufficiently before pumping, slump loss will be minimized."

Chapman also recommends a good-quality fly ash to help with pumpability of lightweight concrete. But with fly ash supplies sometimes tight due to the gradual elimination of coal-fired power plants, concrete producers will use slag in its place (which also helps contractors meet sustainability requirements by reducing cement). But R.L. McCoy's Brown points out that because slag is angular, it's far less pump-friendly than fly ash. "That means adding more chemicals to get back to pumpability," he says. Also, since concrete mixtures with slag pump more slowly, pumping contractors often have to use additional pumps to meet pumping volume requirements.

Chapman says that with lightweight concrete, pump configuration is often the most likely issue to create pumpability problems. "Boom angles can help or hurt," he notes. "You want as flat a boom angle as possible." As far as line diameter goes, Chapman recommends a minimum of 5 inches throughout the system with as much steel line as possible.

Impacts of Aggregate

Aggregate size can also impact pumpability, of course, though most pumps can handle up to 2-inch aggregate. As long as pumpers have a 5-inch system, says Brown, they shouldn't run into issues.

ACI 304.2R, Guide to Placing Concrete by Pumping Methods, recommends

Well-designed mixes pump easily, are finishable, and meet all of the hardened specifications.
PHOTO: SCHWING

the maximum size of angular coarse aggregate should be no more than one-third the smallest inside diameter of the pipeline. In the case of well-rounded aggregate, that diameter can go as high as two-fifths, since more-rounded aggregate goes through pump lines with fewer issues, as does natural gravel and natural sands because they're spherical in shape.

Since mortar separates aggregate particles and rougher textures need more separation to achieve maximum pumpability and finishability, pumpers should pay attention to mortar volume fraction—the percentage of concrete volume including everything except the coarse aggregate. That should stand at about 50% for most mixes using clean, rounded gravel. For crushed stone mixes, that figure should be closer to 60%. When mortar volume fractions get much higher than these numbers, it can lead to pump clogging.

Pumping Aids

Bui notes that some chemical admixtures aid pumpability by improving workability, reducing segregation, and increasing the lubricating effect between the concrete mixture and pipe surface. Without enough water in the mix, though, pumping speeds will slow; on the other hand, too much water or high-range water reducer (HRWR) can cause the mix to segregate. In mixes like that where there's the danger of coarse aggregate segregation, Brown says a viscosity-modifying admixture (VMA) stabilizes aggregates, especially with self-consolidating concrete.

To indirectly improve the pumpability of high-strength concrete, Bui recommends using a medium-range water-reducing admixture and/or a superplasticizer (HRWR), which increase workability and reduce the water-cementitious materials ratio. High workability, satisfactory workability retention, and enough cohesion in the mix improves pumpability, although close attention must be paid to good mix designs in which the paste is sufficient.

Lloyd says he sometimes uses Slick-Pak, a polymer-based concrete pump primer, but after priming the pump, he doesn't use anything else because

he doesn't want pump aids showing up in the slab where it can retard the concrete set.

Get Ahead of the Job

Pumping contractors unanimously agree that the key to ensuring that concrete mixes are pumpable (and pumpable at the required rates) is getting involved in the process early, but concrete pumpers aren't always included. Also, the more that architects and engineers look for cost savings and increased strength in their mixtures, the more likely pumpers are to face problems.

"Properly designed concrete is always going to pump," Brown says. "Get ahead of the job. Talk to the ready-mix supplier and the contractor about the mix early on, so that once you're on the job you won't be standing there looking at each other when you're not getting the production you want out of the pump." Brown cautions contractors to work with their pumpers before they bid a job because if chemicals are needed and add to the per yard price, someone is going to have to pay for that.

"Before we go to jobs, we have in-person meetings," Lloyd says. "If the concrete doesn't pump, it's going back to the plant." Lloyd says he cannot emphasize enough the dangers of a "borderline mix."

Bui recommends doing trials and mock-ups in advance of a pumping job to determine suitable pumping equipment, accessories, and procedures and emphasizes the need to "enhance communication and collaboration among specifiers, contractors, concrete producers, and admixture suppliers within a project."

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Troubleshooting Pumping Issues

BASF's Van Bui offers some tips for addressing potential concrete pumping challenges:

- Observe concrete flow in the hopper to see if there are blocking issues, segregation, or viscosity problems.
- Stay alert for dramatic changes in concrete materials and properties.
- Check for proper priming procedures before pumping.
- Adjust pressure and/or pumping speed.
- Change to a pump with a larger pipeline diameter.
- Evaluate the need to modify the mix design.
- Communicate with specifiers, concrete producers, and admixture suppliers before as well as during pumping.

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