

Hot-Weather Shotcreting

By Andrea Scott

The shotcrete process has a long history, with the pneumatic application of concrete going back over 100 years. It has a wide variety of applications that include new structures, tunnel and mine lining, soil, and repair. Shotcrete is a versatile and efficient method of placing concrete that can save clients a great deal of time and money. As its use in the construction industry continues to grow, new innovations are constantly expanding the realm of what can be done with this process. One thing that hasn't changed are the challenges faced with shotcrete placement of concrete in hot weather.

As shotcrete is simply pneumatically placed concrete, many of the factors that apply to the placement of quality shotcrete will be the same as those discussed in the American Concrete Institute's (ACI) document ACI 305.1-14, "Specification for Hot Weather Concreting." The ACI 305.1-14 specification defines hot weather as:

"one or a combination of the following conditions that tends to impair the quality of freshly mixed or hardened concrete by accelerating the rate of moisture loss and rate of cement hydration, or otherwise causing detrimental results: high ambient temperature, high concrete temperature, low relative humidity, and high wind speed."

Because shotcrete placement can be slower than cast-in-place and has one face of the fresh shotcrete exposed, controlling temperature takes on heightened importance. The shotcrete contractor also has to contend with moisture loss from the nozzle spray. Some of the problems when dealing with plastic concrete under extreme weather conditions may include increased rate of slump loss, concrete temperature, and water demand, as well as additional plastic shrinkage cracks and crazing. When you add in a shortened setting time, the stakes just get higher.

Working with shotcrete in the arid American Southwest during the brutal summer months can be daunting. It is not unusual for crews to experience daytime temperatures in excess of 100°F

(38°C) with humidity levels of less than 10%. This "dry heat" can add to the list of things that can negatively affect your finished product. The rapid moisture loss caused by this environment is much greater than when working in similar temperatures with high humidity. These harsh conditions are inescapable, as projects need to be completed despite the extreme working conditions. The factors that influence the quality and durability of the finished product are many, in this article they will be discussed as they pertain to the wet-mix shotcrete process. Let's start with high ambient temperatures.

Mixed concrete is unforgiving at high temperatures. A concrete mixture that has a set time of two hours at 70°F (21°C) will set up in one hour at 80°F (27°C). A good rule of thumb is that for every 10°F (5.6°C) increase, your set time will decrease by 50%. It is often recommended, but seldom practical to provide shade or cooling misters to large areas of in place work. The forms and grade where the concrete is to be placed should be moistened and kept cool to give the benefits of evaporative cooling, as well as not adding or subtracting moisture from the concrete.

Some of the steps that can be taken to lower ambient temperature can be as simple as watching the weather report and choosing a cooler day of the week for placement of shotcrete, or more commonly, by adjusting the start time of the work shift. With projects underway during the hottest weeks of the warm summer months, our crews often work at night to take advantage of the lower temperatures (Fig. 1). With temperatures falling as much as 20°F (11.1°C), the difference in production is clearly noticeable. High ambient temperature does have a profound effect on employees. In high-heat conditions, the productivity of the workers drops. By changing the start times to the coolest part of the day, you can minimize crew fatigue and increase productivity. After a certain point on the thermometer, the rate of production actually seems to be inversely proportional to the temperature. This is particularly true the first few weeks after a sudden increase in temperatures.

Nozzleman Knowledge

Supervisors should be aware that the risk of heat-related illness is most acute as the team members acclimate to the new conditions. Addressing this topic in preconstruction safety training and onsite safety talks can help to keep it at the forefront of the employee's minds. More frequent rest breaks and ensuring sufficient hydration can help to reduce the risks. In addition, the crew members should also be trained to recognize the signs of heat illness and know what to do in the event it occurs in a worker.

High concrete temperature is next on the list of conditions that can affect the quality of the finished product. The temperature of freshly mixed concrete is largely dependent on the concrete ready mix supplier, and the handling of the ingredients that go in to the concrete prior to arriving on the jobsite. An important step towards keeping mixed concrete's temperature down is by lowering the temperature of the materials used in its production. Acceptable measures to aid in this may include shading of the aggregate stockpiles or sprinkling the coarse aggregate with water for evaporative cooling. Chilled water and ice may also be used to replace a portion of the required mixture water. Concrete can also be cooled by using liquid nitrogen. Many contractors find it useful to use retarding admixtures as well, to delay hydration and subsequent rapid setting caused by high temperatures and allow more workable time.

In the Spring 2015 issue of *Shotcrete* magazine, the "Nozzleman Knowledge" article described the many factors to keep in mind when evaluating a ready mix supplier. It is important to find one that is able to service your project, and provide a mixture that has worked well in the past under similar conditions. By varying the amount of gypsum in the cement to affect the set time, the cement industry works to control the proportions of the mixture to account for local and seasonal fluctuation. Prior test results from other projects, or preconstruction testing, as well as the proportions of the concrete mixture will need to be considered when working in extreme heat. This should be addressed in preconstruction meetings and submittals. It is also helpful to note the location of the material supplier's batch plants, as well as the number of trucks that will be available on shooting days, which will make a difference in the amount of workable time and spacing between truck deliveries of the batched concrete.

Once the concrete is batched, it needs to be mixed and transported to the project location so that it can be discharged, placed, and finished as



Fig. 1: Nighttime shotcrete placement

quickly as possible. As shotcrete placement tends to be slower than cast-in-place, controlling temperature takes on heightened importance. Good preplanning by the contractor can go a long way in facilitating this by ensuring that there is proper traffic control and adequate signage for the drivers to find the pump, as well as allowing enough space for them to back up and start discharging their load. In addition, the placing crew needs to be ready, and of a sufficient size for the shotcrete work that is to be performed. Next, all forms and grade where the concrete is to be placed should be premoistened and kept cool to give the benefits of evaporative cooling. Bear in mind that on projects when applying shotcrete to hot surfaces, such as slope paving, the initial temperature of the concrete being shot may matter less. High ambient temperature and substrate temperature will quickly bring the placed concrete temperature in thinner shotcrete sections to equilibrium so that the initial concrete temperature will have little impact. In the case of slope paving of large areas, there are three things you can do in hot weather. First, continuously wet the subgrade. This is done so no free water or erosion damages the slope. Secondly, place your shotcrete promptly. If a nozzle finish is specified, apply your curing material (liquid membrane curing compound or water) as soon as possible. A hand sprayer will not suffice; you will need a power sprayer or a pressurized pneumatic tank to apply a liberal amount of cure. This prompt, liberal (twice the manufacturer's specification if using a curing compound) application will have a significant impact on the reduction on the formation of plastic shrinkage cracks. If finishing is required, an evaporation retardant will definitely reduce moisture loss. Again, after finishing, cure the work as soon as possible.

Shotcreting in hot weather can have advantages. Shotcrete contractors in warmer parts of the country seldom use accelerators, where in colder climates they are often a necessity. Also,

Nozzleman Knowledge

shotcreting vertical walls in hot weather allows for rapid vertical application because the lower lifts set quickly. Although, for overhead work, you may still find accelerators beneficial.

Low relative humidity and high wind speed also need to be addressed. Many contractors today are familiar with the graph originally published by the Portland Cement Association that can now be found in the ACI 305.1-14 (Fig. 2). This is a very useful tool. It not only tells what influences moisture loss, but it also quantifies the effects, with the rate of moisture loss being affected by the in-place concrete temperature and the humidity. Using this simple graph will give an idea of the rate of water loss. For those who want

it even easier, there are devices available that measure these variables and then calculate the results automatically. Having the materials needed for onsite evaporation control is important to protect the fresh concrete and prevent the rapid evaporation of free water when it is deemed necessary under the conditions outlined in Section 3.1.3 of the ACI 305 document. One of the methods for doing this is the application of liquid membrane curing compound. Another method is water curing, which is simply the continuous application of water. For horizontal surfaces flooding works well, if it can be done. With vertical surfaces, covering the work with clean, used carpets is another way to keep the fresh concrete moist. The big advantage of water curing is the additional benefit of evaporative cooling. In cases where compound cure or water curing are not allowable options due to the necessity of subsequent work such as staining or adhesive application, covering with tightly sealed polyethylene sheeting is another option. This membrane will keep the moisture in and mitigate the effect of moisture loss due to wind.

When all the various project and material conditions, and their potential for problems, have been taken into account and addressed, the likelihood of a durable, safe and profitable completed project increases tremendously. Ultimately, isn't that the result the owners, engineers, suppliers, specifiers, contractors, and inspectors who make up the shotcrete industry strive to provide for their clients?

References

ACI Committee 305, 2014, "Specification for Hot Weather Concreting (ACI 305.1-14)," American Concrete Institute, Farmington Hills, MI, 7 pp.

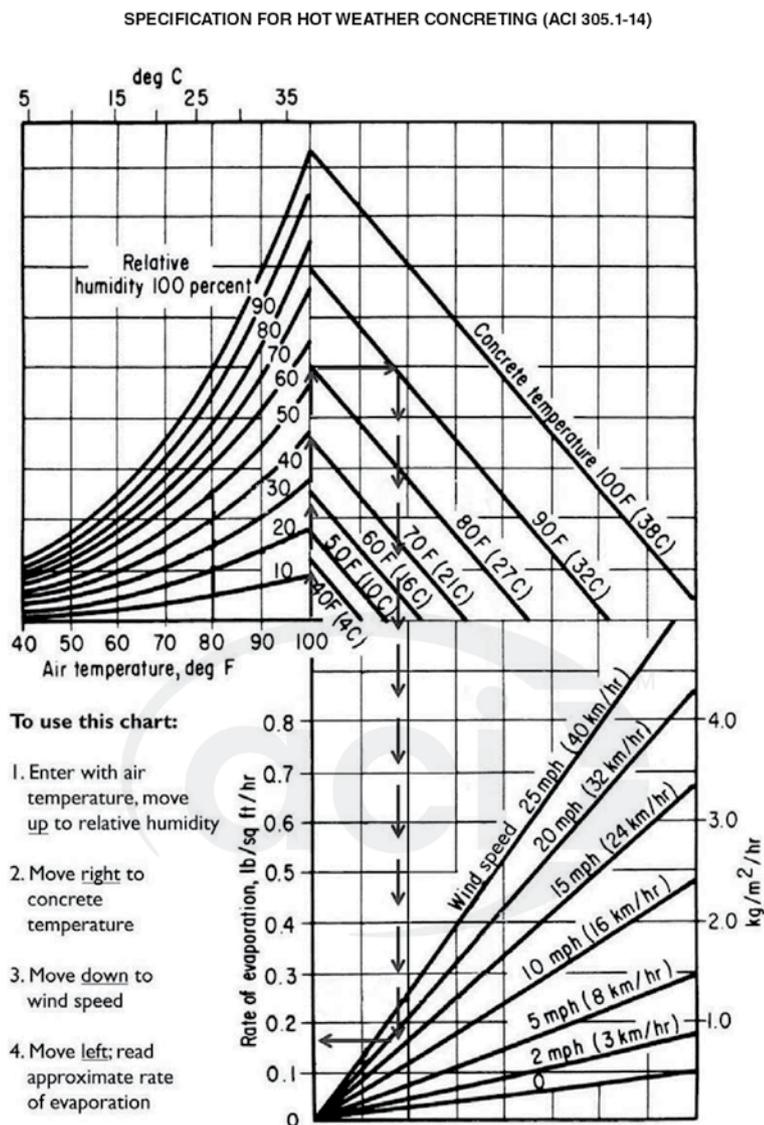


Fig. 2: Effect of concrete and air temperatures, relative humidity, and wind speed on the rate of evaporation of surface water from concrete (ACI Committee 305 [2014])



Andrea Scott is the Director of Safety and Quality Control for Hydro-Arch, Henderson, NV. She has over 20 years of experience in the construction industry with a background in special inspection of reinforced concrete, reinforced masonry, structural steel and welding and non-destructive testing. She is an active member of ASA, currently serving on the Board of Direction and as Chair of the Safety Committee. Scott is also a longtime ACI member and is the Vice President of the Las Vegas Chapter – ACI.