Nuna Innovations Inc.

Why not Shotcrete?

requires specialist labor

The quality of shotcrete depends largely on the skill of the application crew. The shotcrete crew may consist of four to eight individuals, depending on the size of the operation and the type and setup of equipment. A typical crew may include the foreman, nozzleman, delivery equipment operator, and nozzleman's helpers. Additional personnel such as a delivery equipment operator helper and operator for haulage of materials may also be necessary.

Shotcrete nozzlmen are paid, on average $40 CAD per hour whereas general laborers capable of installing Concrete Canvas are typically paid half that amount.

requires special equipment

There are two basic types of shotcrete delivery equipment known as guns: dry-mix guns and wet-mix guns. Although either type may be used for most shotcrete work, each has its limitations. It is important to select equipment, which is capable of placing the job mixture and maintaining an adequate production rate.

Batching and mixing equipment. Most shotcrete is batched and mixed in the field using portable mixing equipment or delivered in mixer trucks from a local ready-mixed concrete plant. Wet concrete has a 90 minute window from the time it is batched at the plant until it placed. Temperature of the material and the air temperature can increase or decrease the set times of the concrete.

Air compressor. A properly operating air compressor of ample capacity is essential to a satisfactory shotcreting operation. The compressor should maintain a supply of clean, dry, oil-free air adequate for maintaining sufficient nozzle velocity for all parts of the work while simultaneously operating all air-driven equipment and a blowpipe for cleaning away rebound.

Water supply for dry-mix equipment. Water supply booster pumps should be capable of supplying at least a 10-gallon/minute flow at 60 psi at the nozzle for standard nozzles. The water pressure must be constant and must be 15 to 30 psi or more greater than the operating air pressure.

rebound

Rebound is aggregate and cement paste that bounce off the surface during the application of shotcrete because of collision with the hard surface, the reinforcement, or the aggregate particles themselves. The amount of rebound varies with the position of the work, air pressure, cement content, water content, maximum size and grading of aggregate, amount of reinforcement, and thickness of layer. There is always the possibility of debris and rebound affecting the site. Rebound for conventional dry-mix shotcrete, in the best of conditions, can be expected to be at least 20 percent of the total material passed through the nozzle. Wet-mix shotcrete rebounds somewhat less than dry-mix shotcrete.

limited access to the site

The time from the batching of shotcrete to final placement should not exceed 45 minutes during warm weather, when ambient temperatures exceed 80 °F. When ambient temperatures are below 80 °F, the time may be extended to a maximum time of 90 minutes. These requirements apply to both wet-mix and dry-mix shotcrete. These time limits may need to be shortened to accommodate additions of polymers, silica fume, or other additives.

Dependent on the location of a concrete plant, an onsite plant may also need to be established on site. Shotcrete applications will also require site access and space enough for a gunite rig and air compressor, which is about the equivalent of 2 pick-up trucks.

There must also be a nearby water connection that can be accessed.

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project cost

Concrete Canvas case studies frequently report that clients chose CC due to it being a more cost effective solution than shotcrete, however, this is heavily dependent on site access and location of concrete plants.

hidden costs

Unreinforced shotcrete, like unreinforced conventional concrete, is a brittle material that experiences cracking and displacement when subjected to tensile stresses or strains. The addition of fibers to the shotcrete mixture adds ductility to the material as well as energy absorption capacity and impact resistance. The composite material is capable of sustaining postcrack loadings and often displays increased ultimate strength, particularly tensile strength. Fibers used in shotcrete are available in three general forms: steel fibers, glass fibers, and other synthetic fibers These additives are an added cost.

CC is proven to have a high level of abrasion resistance during testing, (DIN 52108).

risk of damage

Because shotcrete rebound, overspray, and dust can damage adjacent surfaces, protection for these surfaces may be needed. Means of protection include plastic or cloth covers, masking materials, temporary coatings, or plywood or other wood. If protection is not feasible, then adjacent surfaces should be cleaned before contaminants harden.

Spraying around sensitive pipes, obstacles, equipment, or site features pose significant risk of damage. Protective and cleaning activities required increase man hours and project costs.

to contain the dust and flying rebound. Shotcreting should not be undertaken unscreened alongside moving traffic.

safety issues

Caustic dust from the additives can cause skin and lung problems, and represents a real health hazard to construction workers.

A great deal of dust can be created by the shotcreting process. For this reason, no delicate machinery should be left uncovered in the vicinity, and other trades should be moved away from the working area. Provision should be made

longer installation time

Dry-mix shotcrete is often applied at a rate of 1 or 2 cubic yards per hour compared to wet-mix shotcrete applied at a rate of up to 7 or 8 cubic yards per hour.

Typically, preconstruction testing and evaluation must precede the actual work by more than 30 days to allow time for nozzleman certification at the start and ending with strength testing at 28 days. This protracted start-up period may add significant costs to a small repair contract and may delay the start of actual construction.

The work area must be maintained “wet” with fresh shotcrete so that initial set does not occur until after shooting of the area is completed. Therefore, the work area size is dependent upon sun exposure, ambient temperature, wind velocity, admixtures in the shotcrete, accessibility of the work surface, equipment being used, and the nozzleman’s ability. When a layer of shotcrete is to be covered by a succeeding layer, it should first be allowed to develop its initial set. Then all loose material and rebound should be removed by brooming, scraping, or other means. Surface deposits which take a final set should be removed by sandblasting and the surface cleaned with an air-water jet.

Shotcrete needs to be protected from rain until it obtains its final set, usually 4 or 5 hours. Following final set, it should be wet cured for at least 4 days, preferably 7 days if possible

Concrete Cloth installations have been observed at 5-10 times faster than shotcrete in the same application.

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susceptible to damage from freeze-thaw cycles

The durability of shotcrete in freeze-thaw cycles depends on correct air-entraining in the shotcrete mixture. The American Concrete Institute's "Recommended Practice for Shotcreting" (ACI 506-66: revised 1983) cautions that it is not feasible to entrain air in dry-mix shotcrete. However, air-entraining admixtures may be used in many wet-mix applications. According to ACI 506, data on the effect of entrained air in shotcrete are limited, but air entrainment would be expected to increase resistance to freezing and thawing damage and to make some mixes more workable.

environmental issues

Due to its porous nature, large quantities of groundwater seep through causing caustic alkalines to be leached out of the concrete. These are washed into aquifers and rivers, where they constitute a serious polluant. Leaching causes problems for tunnel owners as well, because hardened leachate rapidly blocks the tunnel's drainage systems.

dependent on weather

Shotcrete cannot normally be applied during periods of rain, snow, or high wind.

It is impossible to produce good shotcrete in windy conditions. Strong winds will separate the material between the nozzle and the point of deposit, reducing strength. If there is any likelihood of even moderate winds occurring, provision must be made to screen the nozzle. If proper shields cannot be erected to reduce the effects of the wind, the shotcreting must be discontinued. Winds and draughts also promote drying shrinkage cracking by rapidly cooling the fresh shotcrete and are as harmful as direct sunlight in this respect .

Rain may wash out the cement leaving a sandy surface, or it may saturate the shotcrete and cause sloughing or sagging. Fresh shotcrete must be protected against rain in exposed sites. Shotcrete, having a low water/cement ratio, is very absorptive of water when fresh. Heavy rain falling on fresh shotcrete, if it does not cause it to slip or run, will at least reduce its final strength.

Generally, concrete mixtures should be maintained at temperatures above 50 °F (10 °C) and below 100 °F (38 °C). Ambient temperatures should be maintained in a similar range. Low temperatures will significantly increase set times.

Regarding surface temperatures, concrete should never be placed on a frozen substrate. Practical experience in Canadian mines has lead to a suggested minimum temperature of 40 °F (4 °C) for the rock receiving the shotcrete. Without special measures, cold temperatures will cause the shotcrete to set more slowly and result in slower strength development. Remember that in thin sections, the shotcrete will lose its heat more quickly in cold conditions.

performance of product is unpredictable

Properties of shotcrete vary dramatically depending on water-cement ratio, aggregate quality, size, and type, admixtures used, type of cement used, and construction practices. The durability and performance are also highly dependant on the experience and quality of work of the installation crew. Pre-construction shotcrete panels are frequently required to test the ability of the crew, the equipment, and the shotcrete mixture to produce shotcrete that meets specifications (Swihart and Rutenbeck, 2001).

Hydrostatic pressures, settlement and expansion or shrinkage of the subgrade readily damages thin shotcrete linings. Furthermore, the inherent difficulty in controlling the thickness of the shotcrete application may result in a lining with areas where the thickness is less than specified, creating weak areas.

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difficult to waterproof

Shotcrete is commonly applied to a blind-wall form with no access to apply a membrane. Membranes that are hung on the form and shot against risk damage and/or torn seams. Membrane installation also adds time and money.

Tie-backs, rakers, and other penetrations are notoriously difficult to waterproof. They require special details, which are time-consuming and often leak. It is difficult to reliably waterproof around pipes and other penetrations. Leaks are common with shotcrete structures waterproofed by membranes.

There are many costs associated with membrane waterproofing that go unquantified:

Delays Rain damage may delay membrane install or require a re-install. Overtime charges may result from crystalline waterproofing agent leading to longer set time.
Tying membranes into existing structural elements or lagging can be more complicated than expected and drive up labor costs.

Preparation costs Surface prep of concrete to accept membranes costs money. Missed costs often appear for membrane inspections. Required equipment or labor to meet warranty requirements is expensive.

Repair costs Membranes may damaged by another trade. Damage to a membrane may go undiscovered until late in a project, when repairs get much more expensive.

Spray coating shotcrete with waterproofing is labor intensive and hence expensive.

Admixtures exist that can decrease the cost of waterproofing by 40% but there is still a significant additional cost to provide a waterproof shotcrete solution as this in not a built-in characteristic of this product. Further, this solution leads to a longer set time which delays work.

higher maintenance costs

Shotcrete requires periodical cleaning of the concrete of materials that may lead to deterioration. Materials and debris must be removed from the surface and not allowed to penetrate the pore structure of the concrete. An appropriate surface sealer must also be applied and maintained.

road closures

If the installation site is near a roadway, road closures may be necessary due to the placement of necessary equipment.

additional limitations

• Due to the difficulty of placing shotcrete around waterstops, use of waterstops in shotcrete applications should be avoided.

• Can not have flowing water for 24 hours after placement of shotcrete

• Smallest diameter pipe that can be lined is 42” diameter pipe, for safety

• Can not be placed under water

• Concrete Cloth reaches 5,000 psi compressive strength within 24 hours. Early strength of shotcrete can be very high, reaching 1,000 psi in 5 hours. Shotcrete typically reaches a strength of 3,000 psi in 24 hours or less, and a 28-day strength of 5,000 psi or greater. Ad-mixtures, such as silica fume, can increase the strength to as much as 8,000 psi but, as noted, shotcrete takes much longer to reach this strength than Concrete Cloth.

• Often experiences failure due to limitations preventing proper curing