SPRAYED CONCRETE AND ITS APPLICATION

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Shotcrete and Gunite – The easy way to concrete

History
In 1910, a double chambered cement gun, based on a design developed by Carl Akeley, was introduced to the construction industry. The sand-cement product of this device was given the proprietary name Gunite. In the ensuing years, trademarks such as Guncrete, Pneucrete, Blastcrete, Blocrete, Jetcrete, and the terms pneumatically applied mortar and concrete, were introduced to describe similar processes. The early 1930’s saw the generic term “shotcrete” introduced by the American Railway Engineering Association to describe the Gunite process. In 1951, the American Concrete Institute adopted the term shotcrete to describe the dry-mix process. It is now also applied to the wet-mix process and has gained universal acceptance in the United States.

The 1950’s saw the introduction of dry-mix guns, which applied mixtures containing coarse aggregate, wet-mix shotcrete equipment, and the rotary gun, a continuous feed device. These innovations enhanced the utility, flexibility, and general effectiveness of the process.

What is Shotcrete?
Shotcrete or sprayed concrete is defined as traditional concrete placed pneumatically placed concrete utilising kinetic energy from the spraying process to provide a dense homogeneous compacted concrete. Additives are often incorporated in the concrete mix to reduce the water cement ratio, improve density and bond and for specialist applications increase setting times.

What is Gunite?
Gunite is defined as pneumatically placed concrete utilising kinetic energy from the spraying process to provide a dense homogeneous compacted concrete. The aggregate size does not exceed 5mm. The aggregate and cement is mixed and conveyed dry, the mix water is added at the placement nozzle. Additives are often incorporated in the concrete mix to improve density and bond and for specialist applications improve setting times.

Materials used in the Shotcrete process are generally the same as those used for conventional concrete, Portland cement, lightweight aggregate, water and admixtures. Shotcrete projects also call for the same types of reinforcement specified for conventional concrete, including deformed bars, welded wire, mesh, fabric and prestressing steel.

Shotcrete can be applied to surfaces using a wet or dry mix method. The wet-mix concrete method consists of cement and aggregate premixed with water at a ready mixed concrete plant or an agitating concrete truck before the concrete pump pushes the mixture through the hose. Additional compressed air is added at the spray nozzle to increase the velocity of the mixture to the work face. In the dry-mix process compressed air propels a premixed blend of cement and damp aggregate through the hose to the nozzle. At the nozzle, water is added from a separate hose and completely mixed with the dry mixture, just as both streams are being projected onto the prepared surface.

Shotcreting processes
Shotcreting is usually classified according to the process used, wet-mix or dry-mix, and the type of aggregated used, coarse or fine.

Dry-mix process – This process consists of the following steps:

1. A cementitious binder and aggregate are thoroughly mixed.
2. The cement-aggregate mixture is fed into a special mechanical feeder or gun called the delivery equipment.
3. The mixture is usually introduced into the delivery hose by a metering device such as a feedwheel, rotor, or feed bow. Some equipment users air pressure alone (orifice feed) to deliver the material into the hoses.
4. The material is carried by compressed air through the delivery hose to a nozzle body. The nozzle body is fitted inside with a water ring, through which water is introduced under pressure and intimately mixed with the other ingredients.

5. The material is jetted from the nozzle at high velocity onto the surface to be shotcreted.

**Wet-mix process** – This process consists of the following steps:

1. All of the ingredients, including mixing water, but usually excluding accelerator, are thoroughly mixed

2. The mortar or concrete is introduced into the chamber of the delivery equipment.

3. The mixture is metered into the delivery hose and moved by displacement or conveyed by compressed air to a nozzle.

4. Accelerator is usually added at the nozzle.

5. Additional air is injected at the nozzle to increase velocity and improve the gunning pattern.

6. The mortar or concrete is jetted from the nozzle at high velocity onto the surface to be shotcreted.

**Comparison of the process:**

Shotcrete suitable for normal construction requirements can be produced by either process. However, differences in capital and maintenance cost of equipment, operational features, suitability of available aggregate, and placement characteristics may make one or the other more attractive for a particular application. Differences in operational features and other properties which may merit consideration are given in Table 1.

Coarse aggregate shotcrete uses a lower cement factor, with a corresponding reduced admixture requirement, and for some applications offers certain economic advantages. However, for both dry and wet-mix processes, coarse aggregate shotcrete has higher rebound, is more difficult to finish, and cannot be used for thin layers.

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**Table 1: Comparison of Dry and Wet-Mix Processes**

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<thead>
<tr>
<th>Dry-mix process</th>
<th>Wet-mix process</th>
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<tbody>
<tr>
<td>1. Instantaneous control over mixing water and consistency of mix at the nozzle to meet variable field conditions.</td>
<td>1. Mixing water is controlled at the delivery equipment and can be accurately measured.</td>
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<tr>
<td>2. Better suited for placing mixes containing lightweight aggregates, refractory materials and shotcrete requiring early strength properties.</td>
<td>2. Better assurance that the mixing water is thoroughly mixed with other ingredients.</td>
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<td>3. Capable of being transported longer distances.</td>
<td>3. Less dusting and cement loss accompanies the gunning operation.</td>
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<td>4. Start and stop placement characteristics are better with minimal waster and greater placement flexibility.</td>
<td>4. Normally has lower rebound resulting is less material waste.</td>
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<td>5. Capable of higher strengths.</td>
<td>5. Capable of greater production.</td>
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Generally the Shotcrete gun nozzle is held at a right angle approximately 0.6mm – 1.8mm from the surface. Shotcrete can be built up to the required thickness in a single application, but for some vertical and overhead applications and for some F5 finishes Shotcrete must be applied in 25mm – 50mm thick layers. Once Shotcrete is sprayed it can be screeded and then finished to a variety of methods off the nozzle broom, rough trowel, and smooth steel trowel finish. Shotcrete concrete should have 7 days curing period.

**Fibrous shotcrete**

The use of short fibres of steel or other materials in conventional and refractory shotcrete has been gaining favour during the past few years. The fibres can provide improved flexural and shear strength, toughness, and impact resistance. For refractory shotcrete, fibres increase resistance to thermal shock, temperature cycling damage, and crack development. Some specific future uses where fibrous shotcrete can be cost effective are slope protection ground support in tunnels and mines, concrete repair, swimming pools, thin shell configurations and refractory applications such as boilers, furnaces, coke ovens, and petrochemical linings.

Although most uses of steel fibre reinforcement has been in dry-mix shotcrete, the material is also applicable to wet-mix shotcrete application. Special care, and sometimes special equipment, may be required in adding fibres to the shotcrete mix to prevent clumping or kinking of the fibres, and to assure that they are properly proportioned. The use of fibres in shotcrete is a relatively new development, and much has still to be learned about the optimum size and shape of the fibres, methods of addition to both wet and dry-mix shotcretes, and other factors.
Since its invention in 1910 the Shotcrete process has been sprayed successfully in a wide variety of building and civil projects including residential buildings throughout the world. Shotcrete can be applied to horizontal or vertical surfaces this is especially suited for curved or thin concrete structures plus shallow repairs. Other applications include swimming pools, grain silos, fire proofing structural steel, building basements, bridges, tunnels, dams, concrete tanks, earth retention systems, land fill quarries and retaining walls. Shotcrete is used to strengthen existing building exterior and interior walls. Shotcrete is also used to duplicate natural rock formations to swimming pools and sea walls. One of the most recent project completed by Shotcrete was the Sealion and Penguin exhibit at the Auckland Zoo. Shotcrete concrete was used at the Auckland Zoo’s exhibit to recreate a New Zealand Coastline. This was achieved by spraying concrete onto steel netting in the rock shape that was required, then spraying a second layer so that the concrete could be carved and crafted like real rocks which are then spray painted the same colour as rock formations.

Shotcrete (NZ) Ltd is contracted to Downer Construction at the new Britomart Railway Station in Auckland to Shotcrete spray 12 concrete volcanoes, which are the main feature of the Railway Station roof. These volcanoes are Shotcrete sprayed onto a Steel mould. When the concrete has reached the design strength the volcanoes are jack lifted into position and bolted to the main roof beams 11 metres from the floor. The steel mould is then lowered back down to the floor and the whole method is repeated.

Shotcrete is specified to strengthen the existing exterior brick walls of the Old Central Post Office in Auckland to a structurally designed Shotcrete sprayed back up walls to the whole building.

Shotcrete was used to build plant room structural walls to 277 shopping mall in Newmarket. These walls were 10 metres long by five meters high and 250mm thick with double steel cage and finished to a U2 finish. Shotcrete boxed one side only and sprayed against this boxing. It was considered to costly and labour intensive to pour these walls institute.

North Shore City Council’s main Sewage Pipe around the coastline has been under mind by seawater. Shotcrete was contracted to design a structural wall over the existing pipes to stop the pipes moving. Shotcrete’s design had to include rock formations to match the same as the existing coastal rock formations. There is about three kilometres to spray.

Gunite sprayed concrete has been specified by civil engineers to stop erosion to motorways and waterways, also excavation behind buildings where the subsoil is unstable.

Shotcrete is also used in the construction of residential swimming pool construction, where any shape or design can be sprayed to suit the client. Shotcrete (NZ) Ltd would average about 50 pools per year.

In conclusion Shotcrete sprayed concrete can be used in any field of construction, sprayed concrete has a very substantial reduced construction period which inturn will save the client time and money.