AN EUROPEAN ACCELERATOR MANUFACTURER'S VIEWS

by Walter Bauder*

In the wide field of concrete works the technique of sprayed concrete has found its own independent place. The spraying technique itself, originated in the USA in 1907 and patented under the name "Gunite" in 1910 by Allentown Pneumatic Gun Company refers to a cement-aggregate mixture with a maximum aggregate size of about 6-7 mm. Up until the end of World War 2, "Gunite" dominated the market.

New equipment to handle larger sizes of aggregate encouraged tunnel contractors in the Alpine countries and in Scandinavia to use this technique extensively for tunnel support. The Austrians, the leaders and promoters of this technique created a new term in tunneling construction, called NATM (New Austrian Tunnelling Method).

Spraying large size aggregate (16-20 mm) became an integral part of the NATM and is known as shotcreting. Shotcrete applied to the tunnel surface in thicknesses from 5 to 25 cm and on occasion even more, needs to have a good accelerator enabling the shotcrete to adhere, especially when sprayed overhead and onto moist surfaces.

Which are the most common accelerators used in Europe?

Almost one hundred percent of accelerators available on the market are those based on carbonates, aluminates and silicates. We can divide them roughly into 3 groups:

1. Carbonate and aluminate based accelerators or a combination of both, supplied in powder form.
2. Aluminate based accelerators, supplied as liquids.
3. Silicates (or so-called waterglass), only available as liquids.

* MEYNADIER MACHINES
DYM AG, Machine factory, 8404 Winterthur/Switzerland
How do these accelerators work and what is their effect on the concrete with regard to strength development?

Despite their extensive use all over the world, one does not know yet exactly what happens. For a better understanding of the influence of accelerators we must know what basically happens, when water is added to cement as for instance ordinary Portland cement.

Ordinary Portland cement consists of several mineral components. If water is added, it starts to dissolve these minerals and produces a solution which crystallizes as soon as the point of saturation is reached, like in a salt pond.

By this crystallization a little quantity of water is absorbed by the crystals, so that the concentration of the solution diminishes, enabling it to dissolve more again from the surface of cement particles. This hydration process continues slowly. The crystals grow together and interlock. The cement paste stiffens, strength development has started.

Some of these minerals or clinker constituents are responsible for the initial strength — and others for the final strength of concrete.

Now all accelerators enumerated favor the solubility of those cement constituents, which develop the final strength of concrete. This is not of advantage in view of a good ultimate strength, because a considerable amount of the potential energy contained in the cement is being absorbed for initial setting and is no more available to develop full final strength.

The loss of final compressive strength is in the order of 10-40 percent, depending on the rate of dosage which may vary in the range of 2-12 percent of the cement weight.

When assessing the strength development, distinction must be made between the early and the final strength. Depending on the requirements which are determined by the type of structure, the construction method and the cement-aggregate mixture used, greater weight will be attributed either to the early or the final strength.
The following diagrams illustrate characteristic strength development of shotcrete accelerated with liquid admixtures.

a) **Liquid Silicate**

The results of a large series of shotcrete tests performed with varying admixture/water ratios are recorded in the following two diagrams. Diagram 1 shows the early stage during the first 6 hours, and diagram 2, the period of the first year.

**Diagram 1**
In the early stage, with increasing admixture concentration almost flush set is achieved. This admixture is therefore suitable even for pre-sealing work as well as for applying thick layers. The curve "With admixture" in diagram 2 represents the average values of all concentrations used. The loss of final strength is moderate.

b) Liquid Aluminate

Identical tests were made with liquid aluminate. The results are given in diagrams 3 and 4. The initial setting proceeds slower, whereas the final strength is practically unaffected in comparison with plain shotcrete. In addition the tests have shown, that the cohesion is increased, and therefore thick layers can be applied too, in one pass.
Compared with powderous accelerators, liquid accelerators offer remarkable advantages.

The early strengths which can be achieved with silicates are considerably higher and the final strength tends to be higher too.

The early strengths achieved with liquid aluminates during the first two or three hours are about equal to those obtained with powderous accelerators. Later, the aluminate accelerator proves to be superior; after approximately 90 days, the same strengths as shown by the control mix are reached and maintained as ultimate strengths.

Insofar as these strengths exceed site specifications, a more economical solution can be found by reducing the cement content.

It is obvious, that an accurate dosage of accelerator is most important especially when using aluminates, which are only working within narrow limits of dilution ratios.

For a long time the manufacturers of shotcrete equipment did not realize the necessity to provide the contractor with dosage equipment. Only about ten years ago, some manufacturers started to look at this real problem.

In the meantime, good accurately working dosage equipment for powderous and liquid accelerators are available.

The majority of accelerators used in Europe are still powderous one's. However there is a definite trend to liquid accelerators. The reason is not only the product itself, but the combination with a dosage pump.

Some of the features are:
- controlled and regular dosaging
- free adjustment of the setting and hardening times to the prevailing conditions
- possibility of employing extremely rapid setting times
- economical feeding of the admixture - no work to be done by hand
- quick-setter-free dry blend, therefore:
- reduced danger of clogging of the conveying machine and the hoses
- less danger of fouling of the machines
- better intermixing of the spraying material with gauging water and admixture
- less dust formation
- no more irritation of the eyes and mucous membrane caused by the admixture, because the admixture-water mix is low concentrated
- considerably higher final strengths, therefore:
- possibility of reducing the cement dosage
- substantial reduction of the rebound
- extremely high early strength

REFERENCES

MEYNADIER Zurich
Research Report Nr. A250 & A332

Shotcrete tests were made with a MEYCO-PICCOLA shotcrete machine.

Shotcrete mix has been sprayed onto concrete test panels of 1 x 1 meter in size.

Shotcrete mix according DIN-Norm 18551, max. aggregate size 16 mm.
Cement content 400 kp/m³.

Ambient temperature was 10°C.

Strengths up to 6 hours were measured with KAINDL-MEYCO pullout tester; after 1 day and later by drilling cores of 50 mm diameter.