

The importance of cement grout in micro piling.

Sten-Åke Pettersson
Atlas Copco Craelius AB

Atlas Copco Craelius in Micropiling

Atlas Copco Craelius has since long been involved in drilled foundations in various roles.

- Already 1935 was a patented method; the so-called Dahren piling used for underpinning job in confined areas.
- Atlas Copco Craelius is the oldest and biggest commercial manufacturer of grouting equipment in the world. - Craelius has produced grouting equipment since 1921
- The OD and ODEX –drilling systems were introduced by Atlas Copco more than 35 years ago.
- Many different types of drill rigs have been in use since long.

Today are the news: Boodex, DEPS, Plastic Casing, Mustang drill rigs. Logac, Pumpac and Unigrouts.

The grout specification

Grouting is an often-neglected part of the micropiling work.

- A) The specification states sometimes that the grout should be: "a neat cement grout with a w: c ratio of 0,45 "
- B) The type of cement is rarely specified. At best it is stated that it should be " a standard cement".
- C) And no one specifies how the grout mixing operation shall be done

A) W:c Ratio

The quality of the grout i.e.: compressive and tensile strength, setting time, shrinkage, shear strength, freeze or thaw resistance, etc., is primarily set by the w: c ratio.

We know that the lower w: c ratio the grout has, the better quality will the grout have.

For a cementgrout is a w: c ratio of 0,28 normally the proportion that is needed for hydrate the cement completely. All water beyond that is merely for transport purposes.

For bolting purposes it is said that the grout has to have a consistence similar to whipped cream. Meaning, you shall be able to hold the grout in your open palm and turn the hand upside down without dropping the grout.

There are different specification and w: c ratios for this grout, some specifies the w: c ratio to be 0,28, some says 0,30-0,32 and even above 0,34 is said to be the correct values.

In order to have a sufficient fluidity of the grout to be used in small diameter drillholes shall the grout have a w: c ratio of at least 0,4

Grout exposed to saline water or grout in a ground where the water from time to time will be contaminated with salts shall have a w: c ratio under 0,40.

There is also a borderline at approx. 0,45 when it comes to frost in combination with salts.

Thaw resistant grout shall have a w: c ratio of 0,50 or lower.

For grout, which shall be resistant against water, penetration shall the w: c ratio is under 0,60.

For a "stable" grout, with less than 5 % sedimentation after 2 hours curing time, we know that the grout must have a w: c ratio below 0,67.

Today when using the GIN-method for grouting is a w: c ratio of 0,7 the standard ratio.

Considering the above we now have the following w: c ratio for different qualities and applications.

Indicatively they can be as below for OPC (Ordinary Portland Cement):

<u>W:c-Ratio</u>	<u>Quality</u>
0,28	The perfect water content, but the grout is immobile.
0,32	Grout for bolting
0,40	High strength grout
0,45	Grout for micropiling
0,50	Thaw resistant
0,60	Resistant against water penetration
0,67->	"Unstable" grout
0,70	GIN-grout

B) Types of cement

Today there are many different kinds of cement.

There are the two main types: Portland cement and Slag cement.

Then those two types are grinded in various sizes and then these are mixed together in various blends and with natural or artificial pozzolans as replacer for parts of the cement.

When using some pozzolans will the "self healing" effect of cracked or fissured grout is much lower. This since the pozzolan consumes the free $\text{Ca}(\text{OH})_2$, which is the remedy to the self healing cement.

C) The grout mixing operation

There are two main types of mixers in connection with grouting -related work.

We, as other serious producers of grouting equipment, have put in a lot of effort in trying to make high standard grout mixing equipment. But paddle mixers or versions of paddlemixers i.e. continuous mixers from the concrete industry are still the most common mixers at micropile sites.

Both types must be handled according to the need for the final result

1) Paddle mixers

With a paddle mixer or a continuous mixer of traditional type is it easy to get any w: c-ratio. It is possible to get the desired 0,28, but it is difficult to tell how well it is mixed.

Theoretically is it possible to go down to a w: c ratio of 0,0, this happens when you just stir the pure cement.

This is impossible in a colloidal type mixer, since the cement will get stuck in the confined impeller housing.

In reality is it probably not possible to achieve a real w: c ratio of below 0,50-0,55 with a paddle mixer.

A paddle mixer will not mechanically break up the cement and the resulting grout is not stable.

2) Colloidal type mixers

The other type of mixer is the colloidal type of mixers.

Shear forces are produced at one, two or even three different places with this mixer.

Close tolerances in the mixer housing also breaks up the cement and the resulting grout will be stable. W: c ratios down to 0,32 can be produced with standard equipment

We are presently doing work with grouts for special applications / purposes.

In this case we are well below the w: c ratio of 0,32. Here we can see that there is a clear difference for the various w: c ratios below 0,33

There are some remarks that have to be made when using a colloidal mixer for micropile works.

The energy that is needed for a thoroughly mixed grout creates heat in the mixture. This heat can produce cracks in the hardening and curing grout due to temperature difference to the ground.

This will primarily be done when using too small batches in order to, not to have to dispose off unused grout.

Sometimes it also happens, that the personal just keep the mixer running when attending to other matters.

Depending on batch-sizes and mixer the increase in temperature can vary between 1 and 5 degrees Celcius per minute.

The heat generated by the hydration of the cement is approx. 400 kJ/kg depending on the type of cement.

Agitators

Another risk for creating cracks is when using old and hardening grout.

This happens when using too big agitators or agitators that are not able to keep the grout "open" until everything is used. These types of agitators are used in connection with both types of mixers.

Micropile sites

In dry and perfect ground it does not matter too much if the grout is not very well mixed, because the cement will eventually harden, when water or moisture enters the poorly mixed grout.

But there is also a risk that the ground can "suck out" the water in the grout and in such cases it is better to prewater the ground before. This is often naturally done when using flushwater during drilling.

But under site conditions with bad or very wet ground and this is the "normal" ground where micro piles are needed. Here must the hardening of the grout start before any leakage passways have been established, neither in to the steel reinforcement nor between the grout and the ground, Here we want the grout to act and react more or less immediately.

Bolts and bolting experiences

From a report regarding 40 years old bolts, which have been drilled out and examined, I would like to quote. :
". Despite the great age, the steel bolts were intact in all cores but one, where a small corrosive attack on the surface of the bolt was observed.... " and "...The inspection of the cores, from the overcoring, revealed bad adhesive capacity, which was later verified by the laboratory tests. The chemical analyses showed that Ca-leaching had occurred in the grout close to the rock while calcite was found close to the bolt steel. These observed chemical processes in the grout surrounding the rock bolts, which remind of the effects of the shotcrete in the tunnel, cause a decreasing adhesive capacity. In the long run the consequences of these processes are very serious for the long-term function of the reinforcement."

From another report started by Atlas Copco Rock Drills with the intention to develop a classification system for corrosivity of rock bolts. They have come to the following conclusions: *the field inspections show that the presence of water is crucial for bolt corrosion. A rock bolt can remain free from rust in a dry environment during a long period, while in a wet environment it can rust very rapidly. In very aggressive environments the grouting cement can also rust.* Especially when the grout is soft (I.e. with low w: c ratio) where the cement can be dissolved into a powderous material.

Conclusions

It is probably not a very bold assumption to suppose that the micropiles are intended to be in use for more than 40 years.

40 years is normally the peak of the quality for a standard concrete under good conditions and after that time will the deterioration of the concrete start.

Under severe conditions will the deterioration start very early and also accelerate considerably.

In wet ground and with a bad grouting work will the deterioration start even before the grout starts to harden or cure.

Probably will the grout be the critical part of the micropile during its "life" -time.

The awareness of the importance of cement grout in micro piling must be stressed for the future.

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