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## Editorial

Dear reader,

After a busy summer period, in this edition of Concrete News we have chosen to present three very different tasks that illustrates the wide range of tasks the Concrete Department performs.

This edition describes a case with brownish precipitation on a natural stone coated fountain, which turns out to be dead alga. We also describe a case which showed huge variations in corrosion attacks on wire ties, and not least a 3-year research project, which is in the final phase, and which deals with the effect of concrete inhibitors on reinforcement corrosion.

Furthermore, we present two brand new types of equipment, a new single-person operated radar system and "MIRA", ultrasonic tomography equipment.

We anticipate releasing the next issue of Concrete News at the beginning of summer 2012.

Enjoy your reading.

Brían Kofoed

## Building of a new fountain - it is not always that straightforward

Can you imagine anything worse than having spent time and large sums of money on an impressive fountain of beautiful Italian stone cladding meant to be the delight of passers-by, only to find out that brown stripes stream down it after a few weeks? This was the exact case with a new fountain that we were requested to inspect.

### New fountain with precipitations

The fountain was built of concrete clad by tiles on all visible surfaces. The applied Italian travertine was of the type Travertino Classico. Precipitations had now been found both through and over the travertine. The precipitations had started immediately after water filling and developed into first whitish and later brownish precipitations after about three weeks.

The builder now wanted to know if it was possible to detect scale and origin of the precipitations as well as to find the cause and place the responsibility. Further, we were asked to suggest repairing of the damages and to describe necessary initiatives and risk of no action as well as danger of the suggested solutions.

### Examination

Precipitations were found on by and large all tiles; typically locally around cracks and areas with increased porosity. The precipitations were typically whitish, but locally they appeared with a brownish colour. Also, increased growth of alga was seen on and along these precipitations, which had a granular character and could easily be scraped off.

We used electron microscopy (SEM/EDX) to analyse the composition of the precipitations and it helped investigation of the problem.

### Softened water shifted the equilibrium

In connection with the inspection, we were informed that the fountain was fed with softened water to prevent depositing in the pipes. By use of softened water, the equilibrium between dissolved calcium in the water and the travertine was shifted; the unfortunate result of this being dissolution of the travertine surface.

### The cause was dead alga

Observation of spalling on the surfaces showed that this kind of rock holds plenty of possible, coherent, horizontal duct systems that may lead water from the upper tub and out to the surface. We judged that the precipitations were caused by moisture penetrating through porosities in the bottom tiles and, from there, through the mortar and out to the side of the concrete construction.

As many types of alga thrive well around pH 8, growth of alga is fast in places with fine grained, porous calcareous spar. When these alga die, a dye is liberated, resulting in brown and reddish discoloration.

### What can be done to reduce the damage?

Based on the elucidation, we recommended the following preventive measures:

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- Fastest possible gentle cleaning of efflorescence and retreatment of the surface
- Fastest possible sealing of the upper tub, via a membrane below the bottom tiles to ensure that no moisture penetrates through the mortar layer separating the concrete construction from the travertine.

When these measures have been taken, it is expected that the undesirable precipitations stop, and that the surface on the travertine remains clear of new deposits.



White and brown precipitations on an entirely new fountain.

### Building of a new fountain

Before a new fountain is built, it is important to know what material gives the intended look. If you choose natural stone, you should be aware that stone is an inhomogeneous material and has usually no impermeable surface - like glass, for instance.

Moreover, physical and chemical exposure from weather, water and possible chemicals should be clarified.

It may therefore be wise to consult a specialist in this field.

#### Further information

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## Is your facing wall in danger of collapse? Corrosion of wire ties is a hidden risk

Until as late as the mid-80s, the building industry has almost exclusively used wire ties (wall anchor) of hot-dip galvanized steel for anchoring of facing brickwalls. Depending on moisture influence, mortar and age of the wire tie, the ties may have more or less advanced corrosion attacks and in some cases, the ties are so corroded that the facing wall is at risk of collapse; for instance in connection with heavy wind.



Housing association Fjordblink. Almost intact tie can be seen. Photo courtesy of Grontmij A/S in Aalborg.

### Materials for wire ties

Over the years, the wire ties in Denmark have been made of different materials; the most common being hot-dip galvanized steel, stainless steel and tin-bronze. Rarely, also wire ties of brass have been used. Wire ties of hot-dip galvanized steel or brass may corrode relatively fast in case of high moisture impact, or if an accelerator has been added to the mortar. Thus, there is a risk of collapse of old facing walls equipped with these ties.

### Corrosion rate

The corrosion rate of the ties may vary much according to their different placing in the wall and is highest where water may penetrate into the brickwork. Experience has shown that the wind mostly blows

from the west, and the north side gets no sun. Therefore corrosion rate is often highest in north and west-facing walls.

A typical example of this variation of corrosion attack can be seen in examinations performed for Grontmij A/S in Aalborg for the housing association Fjordblink Dept. 13 in Aalborg. See photos. The housing estate was built around 1966, and both corroded and almost intact hot-dip galvanized ties were found in the same block. Therefore it was decided to renovate this housing estate.

As the corrosion rate may be very high and unpredictable, requirements have been made for use of corrosion-resistant ties.

Corrosion-resistant wire ties are made of tin-bronze or of stainless steel which has sufficient resistance in brickwork. Very limited, superficial corrosion may still occur but it is negligible considering impact on strength, and the tie lifetime will be very long.

### Where is the largest risk of serious damage?

Corrosion problems may occur in a 1-store building, but as a collapse would have limited consequences, thorough ex-

amination is usually not needed.

Old buildings with solid brickwork or facing walls with bricks have no ties, and therefore there is no need of thorough examination.

Since 1969, the Danish "Code of practice for the structural use of masonry", DS 414, has specified use of corrosion-resistant wire ties for buildings with three or more stores and, normally, thorough examination is unnecessary.

By 1984, the DS 414 standard required application of corrosion-resistant wire ties in all outer walls, and in buildings from the period after 1984, thorough examination should not be needed either, assuming that the rules have been observed.



Housing association Fjordblink. Galvanized tie is almost corroded through. Photo courtesy of Grontmij A/S in Aalborg.

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### How do you map the risk of failure?

If a building may be at risk of collapse considering age and height, a thorough examination should be performed. It might be a 3-store building from 1975. First and foremost, you should check if the number of wire ties is correct. This is often possible by use of nondestructive measuring methods, like CoverMeter. Then, when the ties have been localised, a suitable number of ties should be taken out for analysis to determine whether they are corrosion-resistant. If the ties are corrosion-resistant (of stainless steel or tin-bronze), there is no risk of collapse, and further examination is superfluous. If the ties are made of hot-dip galvanized steel or brass, a closer examination must be made by cutting and

taking out ties for examination. The ties should be removed as gently as possible and their condition should be assessed after removal of mortar, etc. In case the condition is poor, it may be necessary to retrofit new wire ties.



Example of wire tie of hot-dip galvanized steel after about 30 years. Very deep corrosion attacks at bend and in straight piece.

### Further information

Further information about corrosion of wire ties and instruction on examination and retrofitting can be obtained by addressing the writer, or by reading SBI-anvisning 211 from 2005: "Corroded wire ties in brickwork. Examination of risk of collapse and instruction on retrofitting of new wire ties" [translated title] or BYG\_ERFA blad 04 12 31: "Wire ties in brickwork – avoid risk of collapse" [translated title].

#### Further information

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## Can inhibitors decelerate ongoing corrosion in reinforcement?

Concrete structures are known to deteriorate over time and repairing them is expensive and often difficult. Therefore testing with application of inhibitors on concrete structures shall show whether this can reduce corrosion in the reinforcement and thus maintain the concrete for a longer period of time.

The protection of the embedded reinforcement given by the concrete's high pH value may degrade, and this may cause serious damage to our concrete structures. It costs the society billions of kroner every year despite the fact that we have become much better at designing, performing and maintaining our concrete structures such as bridges, high buildings, swimming pools, etc.

Corrosion attacks embedded reinforcement in concrete structures for various reasons but, primarily, for two main reasons in Denmark: Either because the concrete is neutralised by carbon dioxide in the air (carbonisation), or because chlorides penetrate into the concrete, for instance from thawing salt. A combination of these impacts is also possible. This article will address the issue of damage repairing caused by carbonisation.

### Spalling in coating

Normally, carbonisation damage is found as spalling of concrete above the reinforcement, often with a corroded piece of iron at the bottom of the concrete wound. Frequently, the first sign is a sharp-edged, detached piece of concrete in the surface, later developing into downright spalling of small or large pieces of concrete. This kind of damage

is therefore often seen in places where the coating of the reinforcement is thinner than in other places in the structure, but it may also occur where the concrete has local defects such as casting faults or incorrectly encased spacers. The carbonisation rate is often visible and is relatively slow compared to that of chloride-damaged concrete. However, falling pieces of concrete may cause serious personal injury as this kind of damage may occur outdoors on all buildings, especially when the moisture is between 70-85 % RH.

Traditionally performed repair work removing all neutralised concrete is often durable if the repair work follows the instruction in EN/DS 1504. However, conditions may favour untraditional repairing if traditional repair work will disfigure the building aesthetically or functionally. This might be the case for indented bar facades, coloured concrete, or where access is difficult. A colourless inhibitor may advantageously be used for this exact application.

### Inhibitor for protection against corrosion in reinforcement

Inhibitors have been used in e.g. the machinery industry for many decades but, in Denmark, they were only put in use

for concrete repair work by the end of the 90's.

The definition of an inhibitor is a substance which retards a given process and thus reduces corrosion rate. Many investigations have been performed in order to elucidate the effect of the various inhibitors.

This has, for instance, led to the fact that the suppliers now develop third generation inhibitors.

There are many types of both inorganic and organic inhibitors. For concrete, organic inhibitors are often used because of their strong affinity to the reinforcement and their capability of diffusing through the concrete. Further, they are believed to form a protective film thus decelerating the corrosion flow.

### "Case"

Through the last ten years, many tests with concrete inhibitors have been initiated in Denmark with diverging results. Partly because of this, The Danish Building Defects Fund decided to support a project with the consultant ORBICON A/S for the housing association 3B back in 2008. In contrast to many other projects, this project includes both field and laboratory examinations.

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### Field examinations

The building of Lønstrupgård in Vanløse was finished in 1972. It consists of two-storey blocks built of concrete elements with indented bar and a coloured concrete facade – also denoted “the Ishøj profile”. After approximately fifteen years, the facade elements were examined due to initiating deterioration such as spalling.

The damaged reinforcement was primarily observed in deep grooves in the indented bar facade or behind the facade toe. The damage was caused by carbonisation of the concrete in areas with very thin coating. To perform traditional repair work of this facade would be very costly. Therefore, an alternative solution was chosen, namely an organic, silane-based corrosion inhibitor. But as this product was new to the Danish market, it was decided to initiate tests with the purpose of confirming or disconfirming the product’s corrosion decelerating effect. However, some large, partial laminations were repaired traditionally. Subsequently, the facade was colour-washed with coloured cement mortar so that the building got a homogenous appearance.

Experience has shown that these outdoor tests would present measuring technical challenges, partly because measuring should be performed under different weather conditions, and partly due to the choice of and requirements for mea-

suring principle as very small changes had to be registered. The Concrete group at FORCE Technology recommended electrochemical measuring techniques, making it possible to measure the development of the reinforcement’s potential and also the corrosion rate in the existing reinforcement in the facade. Three areas were chosen, each with four measuring areas that were treated only with inhibitor, with inhibitor with colour washing and, finally, also an untreated reference surface.

This test has now lasted for two and a half years, entering the final phase of the project. Slight indications show that both a mixture of inhibitor with colour wash and an inhibitor alone will contribute to reduce the corrosion rate - compared to a reference surface with no application.

At present, it is not possible to prove whether using inhibitor alone is more effective than using inhibitor with colour wash. The last field measuring in the autumn is expected to provide a precise answer before a final evaluation will be made.

### Reference measuring in the laboratory

Field measuring is supplemented by laboratory examinations of fifteen samples exposed to carbonisation under accelerated conditions. The samples have been divided into three groups; inhibitor treat-



Measuring of corrosion rate with and without applied inhibitors

ment, treatment with inhibitor with colour washing and untreated reference surfaces. Measuring of laboratory samples is performed by using the same electrochemical techniques as in the field examinations; however the LPR technique, a well-known method of measuring the corrosion rate, is also used.

At the time of writing, a clear distinction between the treated and untreated surfaces is observed; a more precise evaluation of the corrosion-decelerating properties of inhibitors will be made by the end of the project which is finalised by the end of 2011.

#### Further information

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## New equipment provides better and faster results

FORCE Technology now has new radar and ultrasonic equipment at their disposal which provides even better results for the benefit of the customers.

### Radar systems

We have acquired more radar systems in order to better comply with the requirements of our customers. The objects are a “1.6 GHz Structure Scan Mini” and a “2 GHz palm antenna”. Now the data analysis computer has become an integrated part of the antenna and the survey cart. Thus the equipment is easily manned by one operator only. As the 2 GHz antenna is smaller, we are now able to scan structures closer to the edges, into corners and in narrow places that we were not

able to before. Furthermore, the 2 GHz antenna provides us with better data solution qualities, which is an obvious advantage if the reinforcement in the structure is closely spaced.

### MIRA – Ultrasonic tomography

We also acquired ultrasonic equipment – MIRA that generates and provides a 3D picture of defects inside the concrete structure, such as the lacking grout in cable ducts, delamination, honey combs and voids. During measuring, signals are

gathered, analysed and presented in a 2D picture. By use of further data treatment, several 2D pictures may later be stitched into a 3D picture. Presentation of the measurements in coloured 2D and 3D pictures also provide an advantage compared to previous equipments’ grey scale 2D pictures.

#### Further information

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