INVESTIGATIONS OF CONCRETE BOREHOLES FOR BONDED ANCHORS

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SUMMARY

The use of chemical bonded anchors has increased over the last years due to diminished costs, time and simply of installation. The present paper considers the modelling of chemical bonded anchors. It consists of two parts: the first part describes the common types of chemical anchor - systems. The second part concerns the influence of environmental conditions on the behaviour, especially the effect of borehole – roughness.

Keywords: anchors, bond stress, resin, roughness

1. INTRODUCTION

Fastening systems to concrete are divided into two typical types of anchors. Cast-in-place anchors and post installed systems. Because of reducing the average-time of construction and flexibility in planning, post installed anchors increases in it´s importance. Post installed anchors are divided in a wide range of different systems. The most common used anchors are expansion anchors, undercut anchors and bonded anchors. Mechanical and cast-in-place anchors transfer load from the head of the anchor into concrete. In contrast, bonded anchors transfer load from the steel rod through an adhesive layer into the concrete along its bonded interface.

2. CHEMICAL BONDED ANCHORS

The chemical bonded anchor consists of a structural adhesive and a threaded control rod or a reinforcing bar which are inserted in a drilled hole. The adhesive is acting as a bonding agent between the anchor and the concrete. Figure 1 (taken from Cook, Kunz, Fuchs, Konz ,1998), shows the different types of adhesive anchors and their adhesives. The hole diameter is about 20% larger than the diameter of the threaded control rod or the reinforcing bar. Typically the hole is drilled by an universal hammer drilling and boring machine. For special cases it could be necessary to use a diamond drilling machine (Strauss, Unterweger, Bergmeister,1998). Usually, the effective anchorage depth is about 10 times larger than the diameter of the threaded control rod or a reinforcing bar.

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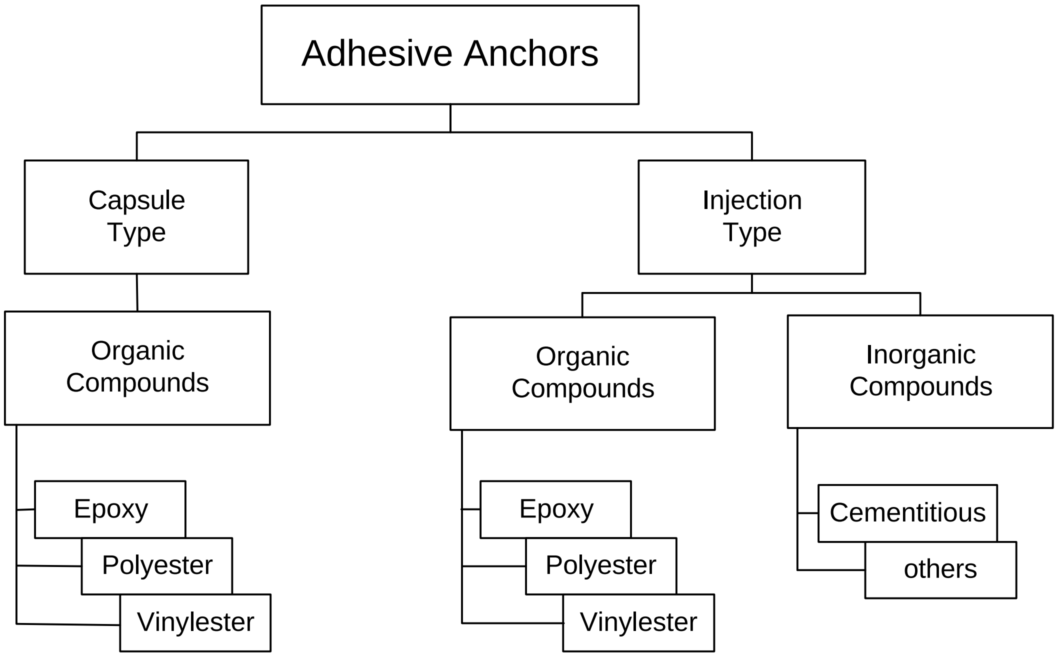

Figure 1: types of adhesive anchors, taken from Cook, Kunz, Fuchs, Konz ,1998

2.1 Adhesive anchor systems

- **Capsule anchor system**

It consists of a resin capsule. The resin capsule is containing synthetic resin, hardener and quarz aggregates. The capsule is inserted into a cleaned drilled hole and is mixed directly by the rotation and hammer effects of the threaded control anchor rod or reinforcing bar.

- **Injection system**

A common injection anchor system consists of a plastic cartridge, filled with pre-measured amounts of resin and hardener. The components are mixed during installation process by a special mixing nozzle. The resin is injected into a cleaned drilled hole first, then the threaded control anchor rod or reinforcing bar is pushed into the hole by hand.

2.2 Influencing parameters on the behavior of bonded anchors

- *Concrete strength*: The effect of concrete strength on the capacity of bonded anchors is negligible for most products. (Cook,Kunz,Fuchs,Konz,1998)

- *Borehole cleaning*: For capsular systems, boring flour, which adheres, on the wall of the borehole is abraded by the quartz aggregates during the hammering - rotational installation process of the anchor. The decrease may be up to 20 %.
  For injection systems the behavior in uncleaned holes is depended on the adhesive and the load reduces up to 50 % (Eligehausen, Mészáros (1996)).

- *Roughness of borehole*: the effect of borehole roughness is an important factor and will be discussed in the next chapter.

3. ROUGHNESS OF CONCRETE BOREHOLES

The present experimental work is one part of many different experimental investigations with the aim to make predictions of the pull-out of bonded anchors (Strauss 1998). For this reason, it was necessary to relate the types of drilling and the resulting geometry of the borehole. The used drilling machines were a universal diamond drilling machine and a universal hammer milling, drilling and boring machine. At each experiment the investigated parameters were: drilling capacity, drilling time, geometrical survey, subsequently the determination of the volume of all boreholes and the resulting surface roughness.

3.1 Roughness parameters

3.1.1 Roughness average R_a

In Great Britain and USA it is often called *AA* or *CLA* and denoted in Micro-Inches. The roughness average R_a (Sorg 1995), can be seen as a sort of universal value, because it is known and used world-wide. His force of expression for runaway-detection is quite finite. The creation of the mean value has narrow influence to characteristic value.
R_a is equivalent to the magnitude of a rectangle with the length l_m and the high R_a. In the following figure 2 theoretical progression of the profile and afterwards the calculating equation for the roughness average will be described.

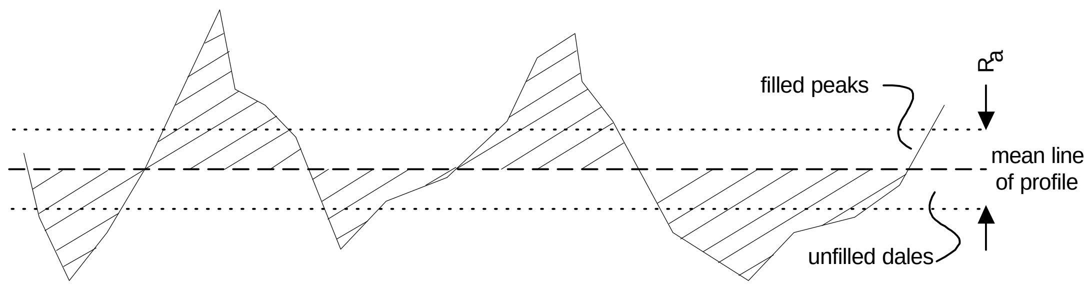

Figure 2: theoretical progression of R_a

$$R_a = \frac{1}{l}\int_0^l \left|y(c)\right| dx \qquad [1]$$

Equation [1] shows that with the help of the sum of areas of completely filled peaks and the sum of areas of unfilled valleys, the rectangle R_a will be created.

3.1.3 Depth-of-Profile-Value P_t

The Depth-of-Profile-Value P_t is the largest distance from the highest peak of the profile to the deepest valleys of the profile within the datum stretch. Therefore, it should be the distance of two parallel boundary lines, which enclose the apprehended profile as closely as possible within the datum line. This characteristic value will be calculated from the unfiltered P-Profile. It should be noticed that the Depth-of-Profile-Value P_t is very sensitive against the influence of runaways. One single runaway can influence the results to the extend of several magnitudes.

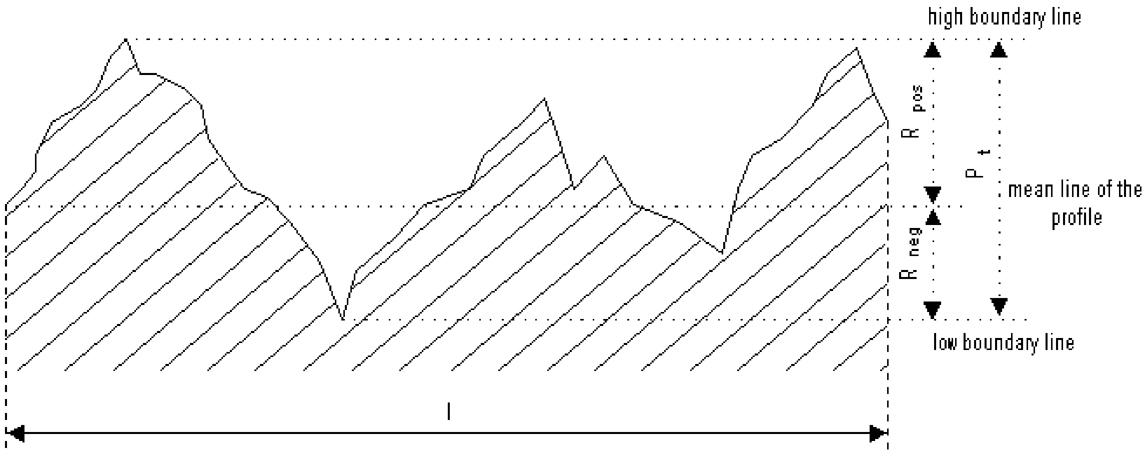

Figure 3: theoretical P_t – Profile

The Depth-of-Profile-Value P_t is always detected perpendicular to the mean line of the profile. It is calculated out of the aberrations up and down from mean line of profile (see Equation [2]).

$$P_t = \left| R_{pos} + R_{neg} \right| \quad [2]$$

3.1.2 Roughness of Surface

In order to be able to measure roughness, there are many different measuring-apparatus available. The spectrum of roughness measuring apparatus reach from the simple mechanical minimeter type instrument to highly complicated optical measuring apparatus. In this case, an optical measuring apparatus has been engaged. It was developed as a prototype by OMEGA and is situated in the “Austrian Research and Testing Centre Arsenal“. It consist of a laser measuring device, which works by using strip projection method, and a connected personal computer. With the help of the software FRINGE, the PC is able to control laser device and to analyse and evaluate gained data. The principal of the strip projection method is outlined in figure 4. A strip pattern is projected onto the face of an object by using a strip projector. Due to unevenness of the object surface, strips of projection pattern are diverted by dependence of high-differences of unevenness. The resulting shadow pattern on the surface is recorded by a CCD-camera and is analysed and evaluated. Resulting information of highness-difference are pictured on the monitor as a colour-coded picture. In this 3D-picture it is possible to make profile cuts and to process them separately. The picture made by camera is recorded with a resolution of 8 bit (= 256 different colours). The pictured colour is equal to that degree of greyness, which was recorded by a camera when using a black and white graph. Profiles of highness addict through special calculation from the information of recorded pictures. The profile of highness is recorded with a resolution of 16 bit (= 65536 different colours). The pictured colour corresponds to the height as scaled. So it is possible to measure objects with large range of height as well.

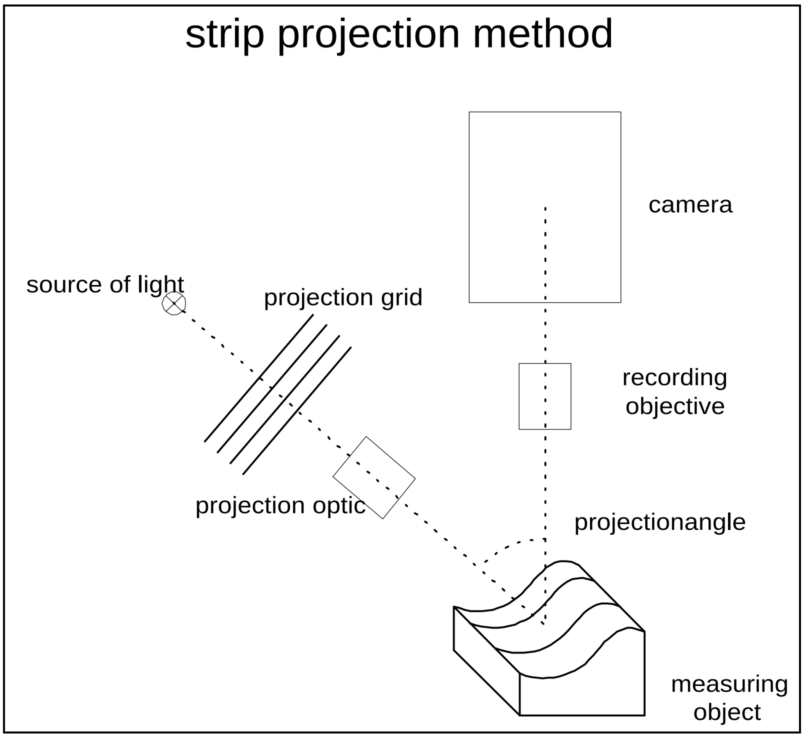

Figure 4: strip projection method

Nevertheless, it was not possible to put the concrete cubes under the measuring-apparatus as a whole, because there is only space for objects with a maximum thickness of 4 cm. Another problem was that the autofocus of the CCD-camera is just able to evaluate differences of height up to 4 cm. Even at qualities B25 and B55 concrete aggregates did not sliver, but broke out of compound.

The solution for this problem was to saw concrete cubes into small discs, with the help of a water-cooled diamond circular saw. Unfortunately, existing drilling flour in holes made by hammer drilling was baked onto the borehole wall and so roughness was smoothed. To consider this effect, each hole was cleaned thoroughly and measured again. Comparison of results shows explicit change of roughness resulting in baked drilling flour (see figure 5).

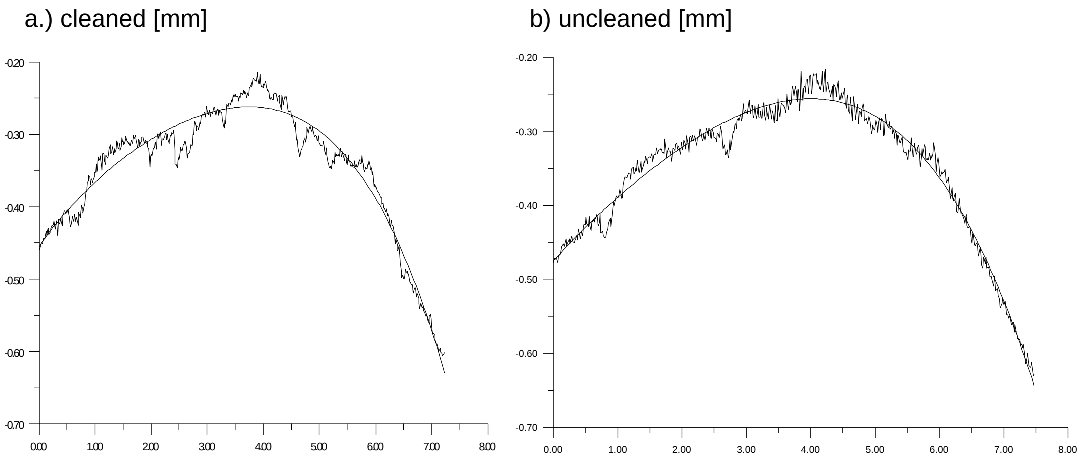

Figure 5: comparison of hammer drilling made borehole

As we can see in figure 5 (Strauss, Unterweger, Bergmeister 1998), the mean line of the borehole is formed like a parabola-bend and outreaches just to a depth of 7.5 cm. The reason of the parabola-bend is, that is was impossible to measure parallel to the edge of the borehole. The measured object appears as a coloured picture on the screen and so broad edges were not constituted. Figure 6 shows the problem.

The reason for the short measured stretch of 7.5 cm results in a limited effective range of the measuring apparatus. So the whole measured stretch has to be splitted into two pieces with a range of overlap 3 cm.

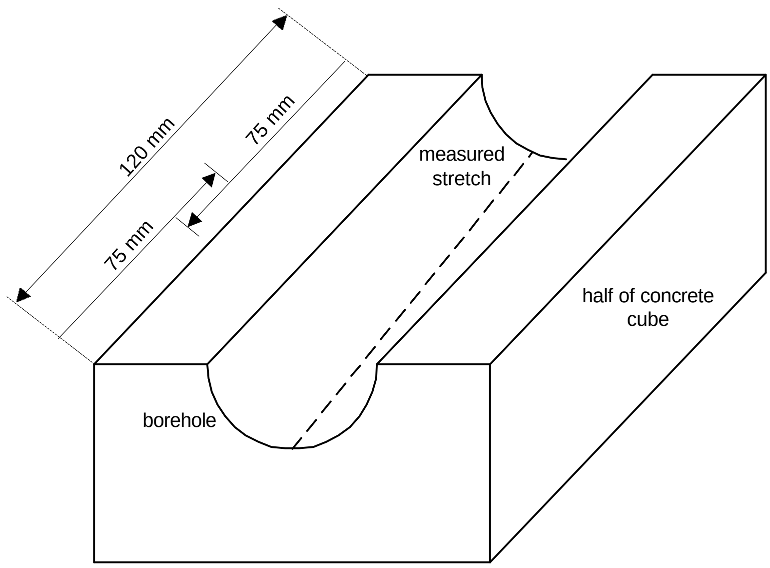

Figure 6: measured stretch

Caused by nonexisting justification of measured stretch, roughness parameters which were computed directly from measuring apparatus, could not be employed. Therefore, by help of measured x-y coordinates of points and the “least-squares method“, it was possible to calculate a mean line of profile and furthermore desired roughness parameters R_a and P_t.

4. CONCLUSION

Out of these roughness studies the following predication can be made:

- By using a diamond-drilling machine roughness average and the mean profile depth of the borehole is up to 50% less than in boreholes which are made by using a hammer-drilling machine.

- If a borehole is only to be blown out, a little quantity of boring flour will remain on the wall of the borehole. Thus, highness of peaks and valleys of the surface will be heavily interacted. This boring flour creates a kind of gliding film which produces a very uneven surface. The measured roughness decreases for about 10-20%, since the boring flour smoothes the peaks and valleys. In the following figure 7 (Strauss, 1998) the roughness parameters P_t and R_a, are shown. For bonded anchors, especially for injection systems, the boring flour do not act positively to the behavior. Under load the boring flour slides on the concrete surfaces and reduces drastically the behavior.

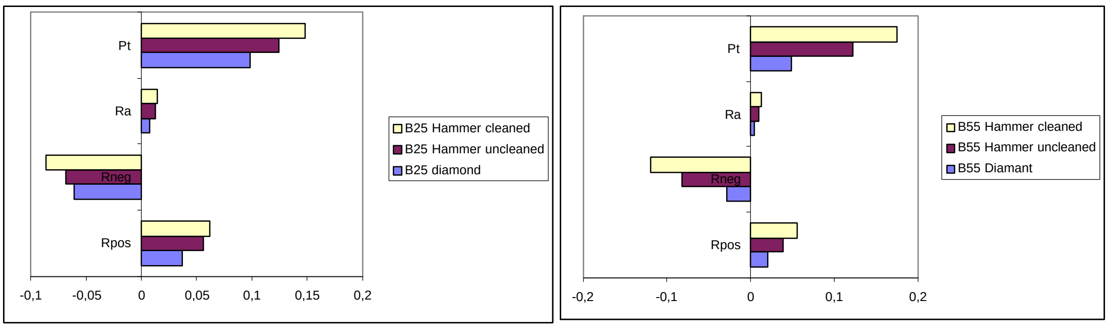

Figure 7: Rougness parameters of boreholes

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