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Ground Anchorages and Anchored Structures in Service

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Simple equations expressing the nett uplift force to the basement area and the head of water have proved useful in assessing the demand to the ATMs. The authors recognised the fact that during its service life the grout column around the steel tendon cracks and requires an 'unperforated' corrugated UPVC duct installed along the full length of the steel tendon and extending into the base slab to ensure continuity of protection. Programmes of long-term monitoring using strain gauge instrumented ATMs demonstrated the rapid increase in water pressure that can occur once the dewatering system was decommissioned at the end of the construction phase. Such data serve to improve understanding of the behaviour of deep basements structures subjected to uplift forces and allow the optimal design of structural elements.

Ten years ago the ICE conference entitled *Ground anchorages and anchored structures* covered a broad spectrum of subjects focusing on the design, construction and testing of ground anchorage systems. Ten years later, emphasis at this conference has been placed on the performance of ground anchorage systems in service. The papers presented in this session have provided invaluable insights into the service behaviour of different types of anchorages and anchored structures. The ground anchorage systems presented have been subjected to a variety of loading conditions ranging from the static loading imposed by ground pressures to dynamic loads generated by earthquakes. In addition, some papers have directly addressed issues related to the service environment, providing useful insights into the type of degradation that can occur over time under certain conditions. All these factors are important since ultimately it is the service behaviour of anchorages that provides the most accurate indication of performance under working conditions.

Jan Maertens, *Jan Maertens BVBA*

As a member of the working group on ground anchors for the European Standard EN1537 and as convenor of the working group on micro piles, I have been discussing corrosion protection for a very long time, so I want to take the opportunity to give my personal point of view. When high strength steel is used I fully agree that protective sheaths are necessary and when the risk level is very high I fully agree that double sheaths should be used always, even if it is not easy to install them in all conditions. I do not agree that for ground anchors made with low strength steel, it is always necessary to have protective sheaths. In my opinion, there are a lot of cases where sacrificial steel is much better than corrosion protection and in my personal practice I mostly propose to spend the money that is normally used for corrosion protection to use it to enlarge the thickness and use the sacrificial thickness. I am well aware of the fact when speaking about corrosion protection it is always a discussion between believers and non- believers and even with conferences, we will not solve this problem. I am sorry for that but I think this is the reality. When looking also to corrosion protection we have to keep in mind that when cast in situ piles are used as tension elements for pier walls and also to secure against uplift, it is still a common practice in a lot of countries. There is also the contact between cast in situ concrete piles and the foundation slab, everybody knows there is a layer of quite bad concrete but no one speaks about crack widths of 0.2 mm. There is a big gap between the design of corrosion protection for concrete elements and corrosion protection for micro piles and ground anchors.

Instead of continuing to discuss yes or no, a good approach could be that when anchors are installed with a sacrificial thickness, some additional anchors should be installed, as has been done in the beginning for reinforced earth constructions. There have also been reinforced elements that have been installed and then examined after 5 and 10 years. I think if we want to learn a lot, the proposal should be to install sacrificial anchors and to extract them after 5 and 10 years and then to look to the corrosion and to the capacity of the anchors.

Stuart Littlejohn, *University of Bradford*
I agree with many things that you have said. I am suspicious however when people advocate the use of sacrificial coatings such as galvanisation. How do you then ensure bond if you are allowing for a sacrificial loss. It is all very well in the free length but not necessarily where you are relying on bond between the grout and the tendon. If you are saying we can except sacrificial loss just where you want to mobilise bond that is an issue. I do however support your view at the very end that there is a lack of factual evidence, regarding the performance of anchorages with different types of designed corrosion protection, where the aggressivity of the ground and the ground water are also quantified. Those of us who are geotechnical engineers here will know how little we spend in ground investigations on measuring the aggressivity. We focus on geotechnical properties but not aggressivity and so seldom do you have that quantified. I found in our keynote presentation that we could only find three case histories in the world where the failure descriptions were allied to environmental considerations. This is an important issue and more case histories are required where all the relevant data are quantified, if we are going to resolve these matters.

Jan Maertens, *Jan Maertens BVBA*
I think in highly aggressive soil, corrosion protection is necessary but there are a lot of cases where everybody knows the aggressiveness is very low and it is my personal point of view that corrosion protection is not necessary. On the problem of the bonding of the bond length I believe if you have corrosion of the steel in the bond length the roughness will be larger and I cannot believe that there will be a rupture between the steel and the grout.

Tony Barley, *Single Bore Multiple Anchor Ltd*
I think there is a further consideration associated with loss of steel in a sacrificial steel situation. What happens to the increase in volume, the rust volume, of the corroded material which is typically 6 – 7 times the volume of the original steel. It must completely change the stress field in the cementitious grout and if it is expanding them surely it will aggravate the cracking in the grout.

Gareth John, *CAPCIS Ltd*
When steel corrodes you normally get expansion of anything from 4 – 16 times the volume. This is what you classically see in corrosion of steel in concrete and associated spalling, but that is only when you have full aeration of the condition. If you have an anaerobic condition or limited oxygen that could happen when you have anchorages that are deep in the ground, you will not get the expansive oxide film; at best, you might get