Monitoring of Reinforcement Corrosion in Field Exposed Concrete Blocks

Henrik Erndahl SØRENSEN
Team Manager, Concrete, MSc, PhD
Danish Technological Institute
DK-2630 Taastrup
hks@dti.dk

Ulf JÖNSSON
Construction Manager, MSc
Femern A/S
Vester Søgade 10, DK-1601 Copenhagen
ujo@femern.dk

Dorthe MATHIESEN
Centre Manager, Concrete, BEng
Danish Technological Institute
DK-2630 Taastrup
dma@dti.dk

Christian MUNCH-PETERSEN
Concrete expert, MSc
Emcon A/S
Ordrupvej 60, DK-2920 Charlottenlund
cmp@emcon.dk

Summary

Three concrete blocks instrumented with rebars, anode ladders and other sensors have been produced and exposed to sea water in Fehmarn Belt field exposure site in Roedbyhavn in Denmark. The corrosion activity on the anode ladders is continuously monitored by measurements of half-cell potentials and linear polarisation resistance. The design of the instrumented concrete blocks is presented together with the first results after 2 years marine exposure. Corrosion initiation on anodes with small concrete cover has been identified from the electrochemical measurements and verified by visual inspection. Chloride profiles have been measured for three different binders.

Keywords: Chloride profiles, Corrosion, Field exposure, Half-cell potential, Linear polarisation resistance, Marine environment, Monitoring, Reinforcement.

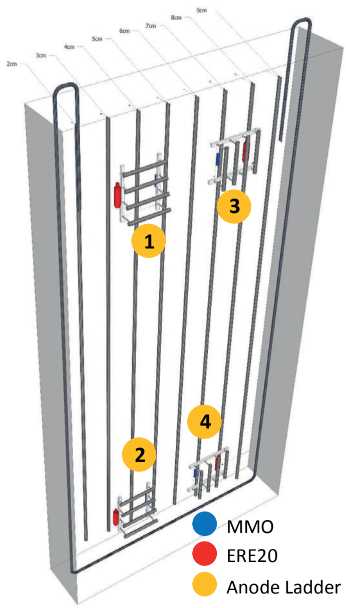

Fig. 1: Principle of the design of the concrete blocks. View from back side.

1. Introduction

During the last two decades, monitoring of corrosion initiation on reinforcement has been implemented in many large concrete structures exposed to chloride. In several cases the performance of the monitoring systems shows only a limited success. The lifetime of the monitoring systems are often too short and the evaluation of data has shown to be difficult in some situations, especially when only electrochemical potential measurements are applied. This is one of the reasons why Femern A/S has initiated field tests on corrosion monitoring of reinforcement in concrete blocks.

2. Production and exposure of concrete blocks

The design of the instrumented concrete blocks has been based on experience from former field exposure tests in Sweden and Denmark. The size of the blocks is 2x1x0,2 m (HxWxD). This size should allow long-term exposure before interaction from the opposite exposed face needs to be taken into consideration. The concrete blocks have 8 nos. of vertical Ø12x1800 mm ribbed rebars facing the front with concrete covers from 2 cm to 9 cm, refer to Fig. 1. Four anode ladders are placed on the back side. Two upper anode ladders are located in the splash zone and two lower anode ladders are in the submerged zone, when the concrete blocks are exposed to sea water. Each anode ladder has separate ERE20 reference

https://doi.org/10.2749/222137813806521414

electrodes and MMO working electrodes, refer to Fig. 1.
Three concrete blocks has been cast with an eq. w/c-ratio of 0.400 using the following three different binder compositions:

Mix A: Low alkali sulphate resistant Portland cement CEM I 42,5 N (368 kg/m^3)
Mix F: 3-powder mix with cement as in mix A, Silica fume slurry, and fly ash (352 kr/m^3)
Mix K: Slag cement CEM III/B 42,5 N (362 kg/m^3)

The concrete blocks have been placed in the field exposure site in Roedbyhavn harbour at an age of 56-59 maturity-days. The blocks are placed partly immersed in sea water with the upper 70 cm above normal water level.

All rebars and three of the four anode ladders in each of the instrumented concrete blocks are connected to a commercially available data logging system, which allows measurements of potentials, macrocell currents, and linear polarization resistance (LPR).

3. Preliminary results

In Autumn 2012, half-cell potentials (HCP) and linear polarisation resistance (LPR) have been measured continuously on the anode ladders for more than 200 days. Typical values for HCP and LPR are shown in Table 1 for passive anodes. Observations on corroding anodes show that the half-cell potential drops to values below -800 mV vs. ERE20 and the linear polarisation resistance drops to values in the range 0,1-0,4 kOhm. So far, all corroding anodes are situated in the immersed zone. Furthermore, chloride profiles have been measured after 532 days exposure and three of the outmost anodes in the immersed zone have been extracted and evaluated by visual inspection. Results are presented in the long CD-ROM version of this paper.

Table 1: Typical values for half-cell potential and linear polarisation resistance on passive anodes. HCP-values are measured against the ERE20 reference electrode (Mn/MnO$_2$).Correction to CSE reference electrode (Cu/CuSO$_4$) is done by adding 100 mV.

Exposure conditions	Immersed zone			Splash zone		
Concrete composition	**Mix A**	**Mix F**	**Mix K**	**Mix A**	**Mix F**	**Mix K**
HCP (mV vs. ERE20)	-300	-400	-600	-200	-300	-300
LPR (kOhm)	1-3	1-5	1-5	1-3	1-3	1-5

4. Discussion

Based on the preliminary results on a very limited amount of observations from this test, the combined use of HCP and LPR measurements on anode ladders might be applicable in order to evaluate corrosion initiation on reinforcement in concrete. The additional use of data from LPR measurements compared to more traditional HCP measurements facilitates the detection of corrosion initiation, even in situations where the HCP values are very low due to lack of oxygen (for instance in slag cement concretes and immersed situations).

The frequent measurements and continuous data logging enables a safe identification of the time for corrosion initiation on the anodes. If this observation is combined with measurement of chloride profiles, it will be possible to determine the on-site chloride threshold values for real structures in the field. For new structures anode ladders could be placed in advance in concrete blocks with reasonable small covers in order to determine the chloride threshold values for different field exposure situations. Since a generally accepted test method for determination of chloride threshold values does not exist yet, this could give very important input to the service life estimation of the actual structure.

5. Conclusions

The preliminary observations from measurements on anode ladders in field exposed instrumented concrete blocks in Roedbyhavn harbour show that the use of combined HCP and LPR measurement might be applicable to detect corrosion initiation in concrete structures. However, the numbers of observations are still too limited to make a final conclusion. The ongoing experiment is expected to document, how this setup can be used to determine in-situ chloride threshold values and to produce valuable input to service life modeling of chloride exposed structures.