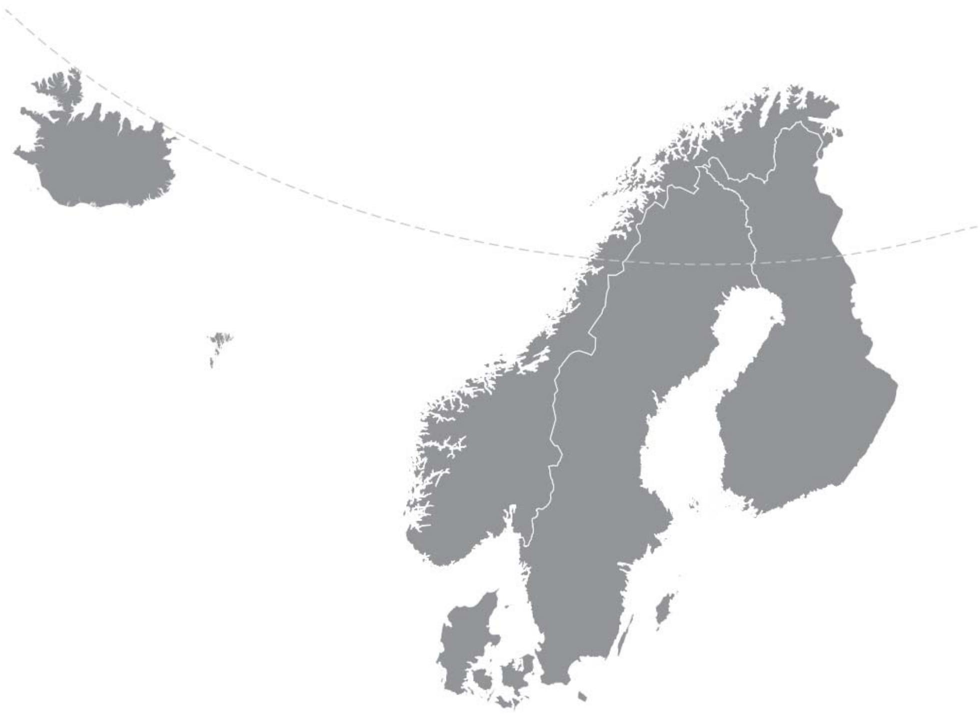
Design and construction of sustainable concrete structures: causes, calculation and consequences of cracks

WORKSHOP PROCEEDINGS FROM A NORDIC WORKSHOP

Oslo Norway, October 16th-17th, 2019



Nordic Concrete Federation

Durability aspects of cracks in concrete: field observations.

Mette Geiker
M.Sc., PhD, Professor
Norwegian University of Science and Technology (NTNU), Department of Structural Engineering, N-7491 Trondheim, Norway
e-mail: mette.geiker@ntnu.no

Tobias Danner
M.Sc., PhD, Researcher
SINTEF Community, Norway
e-mail: tobias.danner@sintef.no

Karla Hornbostel
M.Sc., Ph.D., Senior engineer
Norwegian Public Roads Administration (NPRA), Trondheim, Norway
e-mail: karla.hornbostel@vegvesen.no

Alexander Michel
M.Sc., PhD, Assistant Professor
Department of Civil Engineering, Technical University of Denmark (DTU), Denmark
e-mail: almic@byg.dtu.dk

ABSTRACT

The research presented in this paper briefly summarises findings from a project on impact of cracks on reinforcement corrosion within the Norwegian Public Roads Administration's R&D program "Ferry-free coastal route E39". A main part of the project was the collection of long-term field data on the influence of cracks on chloride ingress and reinforcement corrosion.

Key words: Concrete, cracking, ingress, reinforcement corrosion, self-healing.

1. INTRODUCTION

Based on, among others, [1-4] we concluded in [5] that there is a need for detailed long-term data and understanding of mechanisms governing corrosion propagation of steel reinforcement embedded in cracked concrete. In the literature, there is consensus on the promoting influence of concrete cracking on the initiation of reinforcement corrosion. However, corrosion propagation in cracked concrete is not yet fully understood. Contradicting conclusions are reached based on short- and long-term observations. Short-term investigations (up to a few years) indicate that corrosion rates are enhanced by cracks and mainly depend on cover depth and concrete quality rather than on crack width. The few undertaken long-term studies indicate that small cracks have limited influence on corrosion propagation. However, we do at present not have sufficient background for such a general statement.

2. FIELD OBSERVATIONS

2.1 Ingress and self-healing

The impact of cracks on chloride ingress was found to depend on, among others, crack width, exposure (road vs marine) and surface orientation [6]. Many of the observations may be explained by the self-healing ability. Extended self-healing was observed in marine exposure, especially in the splash and submerged zones [7]. The mechanism of self-healing was independent of the binders investigated [7]. Results from a long-term field test combining fatigue and cathodic protection (CP) suggest a potential beneficial impact of temporary CP, limiting chloride ingress and facilitating self-healing [8].

2.1 Reinforcement corrosion

The impact of cracks on corrosion was found to vary [6, 8, 9]. Among others, we observed a strong impact of other potential defects on corrosion development. In 25 years old marine exposed elements, severe corrosion was observed in connection with plastic spacers, whereas none or negligible corrosion was observed in the vicinity of cracks [9]. Numerical simulations support the hypothesis that the corrosion at the "weakest link" (here the severely exposed plastic spacers) protects the steel in other areas including cracks.

Results of more than 5 years of continuous *in situ* monitoring of a cracked concrete element exposed to splash and submerged conditions in Rødby Havn Denmark [10], showed unexpected behaviour: (i) Corrosion potentials indicating active corrosion were only observed after almost two years of exposure. This is in strong contrast to many laboratory investigations that have reported corrosion initiation in cracked concrete within days. (ii) Cycles of corrosion potentials indicating depassivation and repassivation were observed with a duration of several years. The varying state of corrosion underlines the importance of monitoring to understand the mechanisms of corrosion initiation and propagation and ultimately the service life of structures.

3. SUMMARY AND ACKNOWLEDGEMENTS

In summary, depending on possible self-healing and corrosion initiation at other weak areas, cracks may or may not lead to corrosion.

We should like to acknowledge funding from the NPRA R&D program "Ferry-free coastal route E39" and the DaCS project. Access to data from Femern Belt field exposure station, and contributions by Andres Belda Revert and Ulla Hjorth Jakobsen are also appreciated.

5. REFERENCES

[1] The Concrete Society: "Relevance of cracking in concrete to reinforcement corrosion", Technical Report 44 (2015)
[2] Pease, B.: "Influence of concrete cracking on ingress and reinforcement corrosion", PhD Thesis, Department of Civil Engineering, Technical University of Denmark (2010)
[3] Angst, U.M.: "Påvirker riss i betongen korrosjon på armeringen?" Fagdag Varige Konstruksjoner. Oslo, Norway (2016)
[4] Käthler, A. C. B., Angst, U. M., Wagner, M., Larsen, C. K. & Elsener, B.: "Effect of cracks on chloride induced corrosion of steel in concrete - a review", NPRA reports. NPRA, Oslo, Norway (2017)
[5] Hornbostel, K. & Geiker, M.: "Influence of cracking on reinforcement corrosion", In: Engen, M. & Tan, R. (eds.) Crack width calculations methods for large concrete structures; Nordic Mini-Seminar. Nordic Concrete Federation, Oslo, Norway (2017)
[6] Danner, T. & Geiker, M. R.; "Long-term Influence of Concrete Surface and Crack Orientation on Self-healing and Ingress in Cracks – Field Observations", Nordic Concrete Research, 58, 1-16. (2018)
[7] Danner, T., Jakobsen, U.H. & Geiker, M. R.: "Mineralogical Sequence of Self-Healing Products in Cracked Marine Concrete", Minerals, 9, 284 (2019)
[8] Danner, T., Strømme, Ø., Hornbostel, K., Geiker, M.: "Self-healing and chloride ingress in cracked, cathodically protected concrete exposed to marine environment for 33 years", Submitted (2019)
[9] Geiker, M, Danner, T, Michel, A. Revert, A.B., Hornbostel, K.: "25 years field exposure of pre-cracked concrete beams; combined impact of spacers and cracks on reinforcement corrosion", In preparation.
[10] Michel, A., Sørensen, H.E., Geiker, M.R.: "5 years of in situ reinforcement corrosion monitoring in the splash and submerged zone of a cracked concrete element", In preparation.