# A Phase-Field-Based Chemo-Mechanical Model for Corrosion-Induced Cracking in Reinforced Concrete

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We propose a new model for the corrosion-induced cracking of reinforced concrete [1]. This complex chemo-mechanical phenomenon is of a great practical importance because it results in the spalling/delamination of concrete cover, and corrosion-induced damage is responsible for 70-90 % of prematurely deteriorated reinforced concrete structures.

The state-of-the-art knowledge of the underlying chemo-mechanical processes has been incorporated in three interconnected sub-models – (i) a reactive transport model for: (i.A) the transport of aggressive corrosion-activating species (such as chlorides) to the steel surface and (i.B) the transport and precipitation of iron ions released from the steel surface in the concrete porosity, (ii) model for the corrosion-induced pressure resulting from the concurrent constrained accumulation of: (ii.A) the rust layer in the vicinity of corroding steel rebar and (ii.B) the rust in the concrete pore space, (iii) a phase-field fracture model calibrated to accurately describe the quasi-brittle fracture of concrete. In addition, a damage-dependent diffusivity tensor has been employed to capture the enhanced transport of chlorides to the steel surface and the local reduction of the rate of accumulation of rust due to the enhanced transport of iron ions through cracks away from the steel surface.

The proposed model was numerically solved with the finite element method in COMSOL Multiphysics software. Several two-dimensional and three-dimensional numerical case studies were investigated including impressed current tests carried out experimentally in laboratory conditions. The comparison of experimental and numerical results revealed that the model can simultaneously capture the steel mass loss and the evolution of surface crack width for different concrete cover depths and applied corrosion currents. Also, for the samples with multiple rebars, the model accurately predicted the spalling or delamination patterns depending on the rebar spacing.

The results also indicated that corrosion-induced fracture could proceed with a partial saturation of the concrete pore space with rust. The rust was found to be largely in the vicinity of the rebar but also spread up to millimetres away from the steel surface, reducing the precipitation-induced pressure and delaying cracking. In regions with locally growing cracks, dissolved iron species were preferentially transported deeper into the cracks and precipitated there or in areas away from the steel rebar. Also, the enhanced transport of chlorides through cracks was found to importantly affect the resulting steel mass loss and the surface crack width. Parametric study revealed the profound influence of the porosity of concrete and the mechanical properties of rust, specifically Young's modulus and Poisson's ratio, on the resulting surface crack width, highlighting the need for appropriate characterisation studies of rust.

## References

[1] E. Korec, M. Jirásek, H. S. Wong, E. Martínez-Pañeda, A phase-field-based chemo-mechanical model for corrosion-induced cracking in reinforced concrete, under submission (2023).