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Freeze-Thaw Deicing Salt Attack on Concrete: Towards Engineering Modelling

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1 Introduction

Adapting structures to climate change and the associated extreme weather events is a central challenge to current and future civil engineering. Therefore, the construction industry needs to be able to ensure that buildings will be resistant to environmental stresses throughout their intended service life now and in the future. Engineering models can account for changing environmental conditions such as increasing CO_2 concentrations and can estimate the adaptions required in the execution of construction work. Furthermore, optimal material choice, concrete curing time and maintenance strategies can be derived from such models.

The aim of the present contribution is to demonstrate, by means of practical experiments, how the strong variations in strength of this form of attack in field conditions can be taken into account by a new factor approach.

2 Materials and Methods

Two concrete mixes (C1 and C2) with two different types of cement were cast and the specimens exposed to five different conditions with or without intermittent dry periods in either CO_2-free atmosphere, natural or accelerated carbonation conditions. C1 contained Ordinary Portland Cement (OPC) while C2 was a slag cement (GGBFS) containing 75 % ground granulated blast furnace slag cement. Fig. 1 summarizes the experimental program.

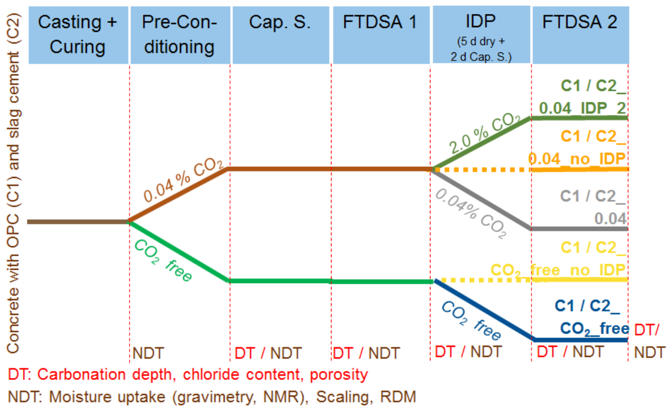

Figure 1. Overview of experimental program (FTDSA: Freeze-thaw deicing salt attack, Cap. S.: Capillary Suction; IDP: intermittent dry period, DT: destructive testing).

3 Results and Conclusions

Fig. 2 shows the scaling rate as well as the carbonation depth for the different exposure conditions. Even though the carbonation depth was very low (max. 0.4 mm for the IDP with 2 % CO_2), the effect of carbonation is significant. The uncarbonated concrete C2 possessed the lowest scaling rate and the carbonated specimen C2 the highest whereas, in contrast, carbonation led reduced the scaling of concrete C1.

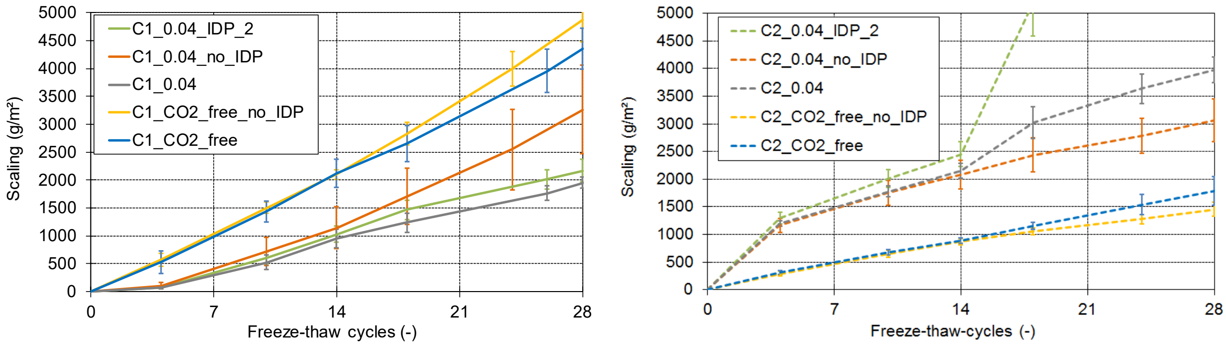

Figure 2. Scaling of C1 (left) and C2 (right). 0.04_drying at 20°C, 65 % RH and ambient air (0.04 5 CO_2); IDP_2: stored after 14 freeze-thaw cycles for 5 days at 2 % CO_2 and 2 d capillary suction before further freeze-thaw exposure; no_IDP: continuous exposure to freeze-thaw cycles, CO2_free: storage at 20°C, 65 % RH in argon (CO_2-free atmosphere).

Damage evolution strongly depends on the climatic conditions. Therefore, the scaling rate $s_r(t)$ can be described by including the initial scaling rate of the carbonated and a later scaling rate both determined in a lab performance test. The initial scaling rate $s_{r,ini}$ accounts for the effect of carbonation while the later scaling rate $s_{r,prog}$ represents the scaling rate of the uncarbonated material under damage-relevant environment. Damage-relevant are situations when sufficient moisture, rather low chloride content and a minimum temperature below - 5°C occur simultaneously. This is included in the environment factor f_e, which depends on the number of damage-relevant freeze-thaw-cycles as well as on the outer salt concentration and the minimum temperature. As the resistance of the concrete is affected by curing, the curing factor f_c is also introduced, Equation 1.

$$s_r(t) = (s_{r,ini} + t \cdot s_{r,prog}) \cdot f_c \cdot f_e \cdot f_a \quad (1)$$

This approach allows a weighting of the different scaling rates. Taking into account the actual performance of the material as well as the actual expected intensity of attack would enable more economic and eco-efficient design of concrete structures.

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