Shrinkage model for concrete made of limestone-rich cements

An approach from cement paste to concrete

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“The sea will be the sea, whatever the drop's philosophy”

Attar of Nishapur
(1145-1221)

PREFACE

The present thesis is the major outcome of my five-year activity at Institut für Massivau of the Technische Universität Darmstadt as a scientific assistant.

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Darmstadt, May 2017 Moien Rezvani

Abstract

Concrete is the most widely used contemporary building material. Production of concrete accompanies with undesirable environmental impacts and a tremendous CO_2 emission. Reduction of the Portland cement clinker and replacement with limestone in limestone-rich cements is detected as one of the most efficient approaches to reduce the environmental impacts through concrete manufacture. Concrete made of cement with 50 wt.-% limestone and a reduced water-cement-ratio could exhibit sufficient fresh and hardened properties and a significant CO_2 cut-off. However, long-term creep and shrinkage of concretes made of such limestone-cements with high limestone contents was observed to be significantly dependent on the content and the type of limestone.

Within this thesis, drying shrinkage, autogenous shrinkage and carbonation shrinkage behaviour of hardened cement paste and concrete made of limestone-rich cements with limestone contents up to 70 wt.-% were analysed. Based on the conducted experiments, thermodynamic laws and mechanics of the porous materials, a multi-scale model is proposed to predict the drying shrinkage of hardened cement paste and concrete made of cements with high limestone contents. Prominently, this model considers the influence of the content and chemical-mineralogical properties of limestone on the shrinkage deformation. In addition, the applicability of the current code DIN EN 1992-1-1 for predicting the shrinkage of concretes made of limestone-rich cements was evaluated. Based on conducted evaluation and the experimental findings, a recommendation for adaption of DIN EN 1992-1-1 for concretes made of limestone-rich cements is proposed as a function of the content and the chemical-mineralogical properties of limestone.

Zusammenfassung

Die Zementindustrie (Klinkerherstellung) verantwortet weltweit ca. 5 % der vom Menschen verursachten Kohlendioxidemissionen. Die Reduzierung des Klinkergehalts in Zement und Beton durch Anwendung von kalksteinreichen Zementen kann daher zu einer Absenkung des Treibhauspotentials beitragen. Es wurde bereits festgestellt, dass der Beton aus Zement mit 50 M.-% Kalkstein und einem reduzierten Wasser-Zement-Wert von 0,35, neben einer deutlichen CO_2-Einsparung, ausreichende Frisch- und Festbetoneigenschaften aufweist. Des Weiteren wurde beobachtet, dass das Kriech- und Schwindverhalten der Betone mit hohen Kalksteingehalten signifikant von der chemisch-mineralogischen Zusammensetzung des Kalksteins beeinflusst wird.

Im Rahmen der vorliegenden Arbeit wurde zunächst das Schwindverhalten von Zementstein und Beton aus kalksteinreichen Zementen umfangreich experimentell untersucht. Dabei wurden das Trocknungsschwinden, das autogene Schwinden und das Karbonatisierungsschwinden von Zementstein und Beton mit unterschiedlichen Kalksteingehalten und Kalksteintypen genauer betrachtet. Auf Basis der durchgeführten Experimente sowie der thermodynamischen und mechanischen Gesetze wurde ein analytisches Modell zum Trocknungsschwinden in Abhängigkeit des Gehalts und der chemisch-mineralogischen Eigenschaften des Kalksteins entwickelt. Die Eignung der aktuellen DIN EN 1992-1-1 für kalksteinreiche Betone wurde zudem geprüft und es wurde einen Vorschlag zur Anpassung der DIN EN 1992-1-1 unter Berücksichtigung des Kalksteingehalts und dessen chemisch-mineralogischer Zusammensetzung präsentiert.

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