INFLUENCE OF MINERAL ADDITIONS AND CHEMICAL ADMIXTURES IN SCC ON MICROCRACKING AND DURABILITY: OVERVIEW OF A BELGIAN RESEARCH PROJECT

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Abstract

Since the ultimate porosity, and consequently the durability, of concrete is not only determined by the microstructural built-up, but also by the formation of (micro)cracks in the cement matrix caused by the differential shrinkage of the composing phases in the concrete matrix, a study of the microstructural built-up and the formation of (micro)cracks during hardening and curing is inevitable when dealing with durability of cementitious materials.

For this reason, the influence of mineral additions and chemical admixtures in SCC on microcracking and durability are studied in the Belgian research project G.0311.06, sponsored by the Research Programme of the Research Foundation - Flanders (FWO).

The research project is a cooperation between the Reyntjens Laboratory (K.U.Leuven), the Magnel Laboratory for Concrete Research (Ghent University) and the Royal Military Academy Brussels.

The main objectives of the ongoing research project are: (1) determination of the influence of the different parameters on the formation of microcracks; (2) determination of the influence of these parameters on the microstructural built-up and (3) formulation of porosity and flow models which simulate the durability behaviour of SCC. An overview of the research project is presented.

1. INTRODUCTION AND AIM

In a previous FWO research project (n° G.0018.02, hereafter called: project “transport”), the transport properties of potentially aggressive media in SCC and the relation with durability were investigated. [1] This research produced positive results [2-5] but also pointed at some pertinent anomalies:

- Frost resistance tests in combination with de-icing salts revealed a higher loss of mass due to the imposed frost-thaw-cycles for SCC in comparison with the traditionally
vibrated concrete (TC). On the other hand, the ultrasonic measurements indicated that TC suffered more under the imposed frost-thaw-cycles in comparison with SCC.

- Results from the permeability tests with O2-gas showed a smaller gas penetration for SCC in comparison with TC. However, a deeper carbonation front (i.e. the penetrated zone in the concrete by CO2-gas) was found for SCC in comparison with TC.

It must be noticed that the above anomalies were only observed when limestone powder was used as mineral addition for the SCC mixtures. In the case fly ash was used as addition, the above observations did not occur. In addition, the contradictory character between the ‘basic’ tests (concerning liquid and gas penetration) and the final degradation tests was more pronounced as the limestone/(limestone+cement) ratio increased.

Cause of this is the non-negligible influence of the applied (mineral) addition on the microstructure and, consequently, on the porosity and the ultimate durability behaviour of SCC. For this reason, a study of the microstructural built-up and the formation of (micro) cracks during hardening and curing is necessary since the ultimate porosity, and consequently the durability, of the concrete is not only determined by the microstructural built-up, but also by the formation of (micro)cracks in the cement matrix caused by the differential shrinkage of the composing phases in the concrete matrix. [6]

The influencing key parameters are: the type of (mineral) addition, the type of cement (C3A-content), the applied dosage of chemical admixture/superplasticizer, the water/cement ratio and the cement/powder ratio (powder = addition + cement). For the parameters “mineral addition” and “chemical admixture”, this microstructural approach just started recently [7,8] but the use of (Environmental) Scanning Electron Microscopy ((E)SEM) offers good prospects for this approach. [9]

Moreover, it is necessary that the research on durability of SCC is not restricted to the determination of the liquid and gas permeability. Additional aspects must be investigated, because the microstructural built-up also determines to a large extent the porosity and durability. It is still remarkable to notice that very little fundamental data have been published concerning durability of SCC in the field of the subject of this research project. This knowledge is, however, of extreme importance for a good and durable construction practice. This research project has the ambition to catch up, in the niche of the mineral additions and chemical admixtures.

It has to be noticed that from the start the rheological preconditions of SCC (namely high plastic viscosity and low dynamic yield value) will be taken into consideration or, in other words, the rheological properties of the ultimate SCC mixture determine the limits of the above mentioned parameters which will be studied in this project.

2. OBJECTIVES

The proposed research project has the following main objectives:

- determination of the influence of the different parameters on the formation of micro-cracks, based on an experimental and theoretical study of the shrinkage behaviour, measured on concrete and mortar;

- determination of the influence of these parameters on the microstructural built-up, based on light and electron microscopy (SEM and ESEM); and

- formulation of porosity and flow models which simulate the durability behaviour of SCC by means of the fundamental flow parameters, based on the results obtained in
previous objectives and in combination with an experimental study of the durability aspects concerning the observed anomalies.

3. DESIGN AND METHODOLOGY

First, as mentioned above, the limits of the parameters, which will be studied in this project, are defined so that the ultimate mixtures comply with the rheological principles of SCC. For this purpose, the coaxial cylinder rheometer ConTec Visco5 will be used.

Subsequently, a better understanding of the evolution of the microstructural built-up, (micro)cracking and porosity will be obtained by studying the microstructure of the mix compositions by means of light and electron microscopy. The porosity will also be studied by mercury intrusion porosimetry (MIP), Brunauer-Emmett-Teller (BET) method and ultrasonic measurements.

The development of microcracks in the matrix depends on the interactions between, on the one hand, chemical shrinkage and, on the other hand, strength and stiffness built-up. Through non-contact ultrasonic measurements [10,11], an attempt will be made to study the evolution of the stiffness built-up through liquid, plastic and hardened paste.

The autogenous shrinkage deformations of both concrete and mortar will be investigated to get a better understanding of the influence of the parameters on the microstructural built-up. Simultaneously, also the drying shrinkage deformations (at standard conditions, 20°C and 60% R.H.) will be measured. It has to be noticed that the (volumetric) shrinkage measurements can be started immediately after manufacturing, what makes it possible to study the microcrack formation during the microstructural built-up.

Flow models from the project “transport” will be validated by the findings concerning the microstructural built-up and porosity, obtained in this project. Extra ‘basic’ tests for the new compositions will be performed when needed. The conformity of these (possibly adapted) flow models with the models which characterise ultimate durability behaviour will be evaluated. For this purpose, the carbonation, sulphate attack, frost and shrinkage behaviour will be investigated. This “limited” durability study is legitimated as follows: the study of the carbonation and frost behaviour are directly linked to the observed anomalies and are, in this way, the starting point for this project. The necessity of the study of the shrinkage behaviour is explained above and the sulphate attack behaviour is added because the formed gypsum crystals are very recognizable when using the (electron) microscope, resulting in a very clear microscopic image of the degradation, what simplifies the microscopic studies.

During porosity and degradation measurements the specimens will be evaluated by means of ultrasonic techniques which lead to an accurate follow up of the porosity and mechanical properties throughout the experiments.

The above mentioned objectives are outlined more in detail in different work packages (wp).

3.1 WP1: Determination of the rheological parameters of SCC

In this work package, the rheological parameters of the different SCC compositions will be determined experimentally with the coaxial cylinder rheometer ConTec Visco5. The influence of the different parameters (type of mineral addition, dosage of chemical admixture, type of cement, water/cement ratio and cement/powder ratio) will be formulated mathematically. Based on the results, the limits for the different parameters will be defined. The results of this work package can be found elsewhere in these proceedings. [12,13]
3.2 WP2: Microstructural built-up

TASK 2-1: Microscopic study of the microstructural built-up
The microstructural built-up of the selected concrete/ matrix compositions will be studied by light (thin sections) and electron microscopy. The microscopic study will also be applied for the evaluation of the degradation mechanisms (see task 4-2). In this way, a fundamental microscopic understanding of the different compositions, both before and after degradation, will be obtained. Simultaneously, the evolution of the structural built-up and stiffness will be followed up by ultrasonic measuring techniques.

TASK 2-2: Determination of the porosity: MIP, BET and ultrasonic measurements
In this task, the porosity will be measured by mercury intrusion porosimetry (MIP). Besides, the specific surface of the pore structure will be determined by the BET method. The measurements will be combined with ultrasonic measurements where the porosity will be determined based on the differences of sonic speed in completely saturated and dry specimens.

3.3 WP3: Autogenous and drying shrinkage behaviour
In this work package, the autogenous and drying shrinkage behaviour of mortar and concrete will be determined to obtain a better understanding of the influence of the different parameters on (micro)cracking. The drying shrinkage will be studied at standard conditions (20°C and 60% R.H.).

3.4 WP4: Relation between micromechanics and durability of SCC

TASK 4-1: Theoretical description of the microstructure and validation of the traditional flow models
The aim of this task is to combine the results of WP2 and WP3, through a fundamental theoretical study, to one (or more) micromechanical flow model(s). At the same time, the results of the ‘basic’ tests concerning the liquid and gas penetration from the project “transport” will be used and the derived flow models will be validated by the above mentioned micromechanical flow model(s). Extra ‘basic’ tests for the new compositions will be performed when needed.

TASK 4-2: Experimental determination of the ultimate durability behaviour
As mentioned before, the ultimate durability behaviour of the selected concrete compositions will be studied by the degradation mechanisms carbonation, sulphate attack and frost resistance. The evolution of the mechanical properties will be followed up by ultrasonic measurements before, during and after the different degradation mechanisms. The shrinkage behaviour was already studied in task 2-1.

TASK 4-3: Durability behaviour of SCC
Based on the results obtained in task 4-1 and 4-2, the aim is to harmonize the micromechanical flow model with the ultimate durability behaviour of SCC.

4. CONCLUSIONS
A Belgian research project on the influence of mineral additions and chemical admixtures in SCC on microcracking and durability is outlined. The whole project consists of a combination of:
– an experimental and theoretical study of the shrinkage behaviour (measured on concrete and mortar) in order to determine the influence of the different parameters on the formation of microcracks,

– light and electron microscopy (SEM and ESEM) in order to determine the influence of these parameters on the microstructural built-up, and

– an experimental study of relevant durability aspects.

This combination must lead to the formulation of one (or more) micromechanical flow model(s) which can simulate the ultimate durability behaviour of SCC.

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REFERENCES


