MINISEMINAR ON EARLY VOLUME CHANGE AND REACTIONS IN PASTE-MORTAR-CONCRETE

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ABSTRACT

The background for the seminar was the currently widespread interest in the problem of cracking in high performance concretes (HPC) at early ages. Volume change due to both autogenous shrinkage and thermal dilation are driving forces creating stresses that may exceed the tensile strength. The aim of the seminar was to gather researchers actively engaged in thefield to present their techniques and results for thorough discussions.

The results presented did not show any uniform development of the autogenous deformation. The main conclusion is, therefore, that more and collaborated work is needed in order to find the truth. Another conclusion is that there is a rather low research activity on the cracking problem in the "initial phase", i.e. before and during setting. The researchers confirm, however, that cracking of HPC in this phase is a major world wide problem in e.g. floors, bridge decks and pavements.

1 INTRODUCTION

The use of low water/binder ratio concretes, mostly called high performance or high strength concretes (HPC or HSC), has revealed that this type of concrete is more vulnerable to cracking in the early age than normal concrete. Volume change due to both autogenous shrinkage and thermal dilation are driving forces creating stresses that may exceed the tensile strength. These early volume changes, measured either volumetrically or as vertical and/or horizontal components, are difficult to measure and they appear to depend on the apparatus and testing procedures employed. This is particularly true at very early ages (initial phase)

through the setting process. Furthermore, there appears to be differences in principle between the results of measurements on paste and mortar or concrete.

The aim of the seminar was to gather researchers actively engaged in the field to present their techniques and results for thorough discussions, and thereby establish good relations and a consensus for the further research in the field. The seminar, called "Early Volume Change and Reactions in Paste - Mortar - Concrete" was held 28 and 29 November 1996 at the Norwegian University of Science and Technology in Trondheim.

2 PRESENTATIONS

There were 21 invited speakers presenting theories, chemical reactions, testing on paste - mortar - concrete, and numerical simulation of the early volume change. Some of the authors referred to relevant papers, which are given in the list of references. All the presentations are listed below (related references are given in brackets):

Introduction: Erik J Sellevold, The Norwegian Institute of Science and Technology.
Sellevold described the Norwegian research project on cracking in high strength concrete at early ages. He listed a number of fundamental questions, e.g.: Measurement techniques in both the initial and thermal phase, and how do we define the transition between the two? Can autogenous shrinkage be characterised by the maturity concept? How do we separate the contribution from thermal dilation and autogenous shrinkage? What is the relationship between total chemical shrinkage ("internal"), autogenous shrinkage ("external") and the chemical reactions?

Importance of Autogenous Shrinkage: Erik J Pedersen, DTI, Denmark.
Pedersen discussed the importance of autogenous shrinkage relative to thermal effects on stress calculations. He showed examples where the calculated stress taking autogenous shrinkage into account, was higher than the measured tensile strength, but lower when not calculating with autogenous shrinkage. Thus, both thermal dilation and autogenous shrinkage must be considered.

Hydraulic Hardeniug - Energetic Approach: Peter Paulini, University Innsbruch, Austria /1/.
Paulini presented calculated volume change development of different cement types. The volume change was calculated from the energy change during hydration of the cement minerals. The results show, surprisingly, an expansion the first 10 - 12 hours of age. They were not confirmed by measurements.

Chemical Shrinkage - Pozzolanic Reactions: Harald Justnes, SINTEF Civil and Environmental Engineering, Norway /2/.
Justnes presented measured chemical shrinkage of the silica fume - lime reaction and the fly ash - lime reaction. The results indicate that the chemical shrinkage of the silica reaction and fly ash reaction is in order of a magnitude higher than the cement reaction.

Maturity Concept of Autogenous Deformation: Ole Mejlhede Jensen, DTU building Materials, Denmark.

Jensen discussed the relevance of the maturity concept of autogenous deformation. He concluded that the concept is not basically applicable since the autogenous deformation is controlled also by other temperature dependent parameters (e.g. surface tension of pore water and creep). However, he said that the concept may be adequate as a part of an engineering tool.

Autogenous Shrinkage - Volumetric Measurements: Birgit Ardoulli and Elke Hendrix, Leuven University, Belgium (diploma students at The Norwegian Institute of Science and Technology).
Ardoulli and Hendrix presented a number of results from their measurements of the total chemical (dilatometry) and autogenous shrinkage (buoyancy principle) of pastes and mortars. The results show that the two methods confirmed each other, giving the same and nearly linear shrinkage devilment in the time between casting and about setting. Furthermore, the shrinkage (related to cement weight) was not influenced by the addition of aggregates.

Autogenous Shrinkage - Linear Measure-Initial Stage: Tor Arne Hammer, SINTEF Civil and Environmental Engineering, Norway.
Hammer discussed the problem of cracking of low w/b concretes, of horizontal surfaces particularly, in the initial stage (i.e. before setting). The field experience show that cracking may occur even if proper curing agents are applied (i.e. to prevent plastic shrinkage). He expressed that the reason may be that the autogenous shrinkage is a major "driving force", and the tensile capacity of these low w/b concretes is low in a rather long period of time (due to a more rapid slump loss and retarded setting). He is building test rigs to measure the shrinkage and tensile capacity.

Autogenous Shrinkage - Stress Generation: Øyvind Bjøntegaard, The Norwegian Institute of Science and Technology (NUST) /3/.
Bjøntegaard presented the test rigs for temperature controlled measurements of autogenous deformation and stress generation in the restrained cases, at NUST/SINTEF (a tour in the laboratory was included). Furthermore, he presented results showing the development of the thermal dilation coefficient, and autogenous shrinkage at different temperatures. He concluded that the initial concrete temperature is of major importance for the development of the autogenous shrinkage, and that the maturity concept may be applied on autogenous shrinkage (as suggested by Jensen) when the initial concrete temperature is close to 20 °C.

Early Volume Change and Reactions in Paste-Mortar-Concrete: Lars Andersen, DTU Building Materials, Denmark.
Andersen presented the "balloon test" for determination of autogenous deformation of pastes and mortars (buoyancy principle), and an example of the development of a "Densit" mortar. Furthermore, he presented a "steelring test" for determination of the stress generation in restrained cases, and some results showing the stress generation of water cured and drying mortars.

Autogenous Shrinkage - Thermal Strains: Veronique Baroghel-Bouny, LCPC Paris /4/ and /5/.
Baroghel-Bouny presented the RH and autogenous shrinkage development of some high performance concretes, and a very good linear correlation between the two. Moreover, she presented the effect of w/b and silica fume content on the autogenous deformation of pastes. The results showed and increasing short term (about a week) swelling (as shown by Paulini)

with increasing w/b higher than 0.40, but an increasing shrinkage with decreasing w/b lower than 0.40. She also presented the determination of the thermal dilation coefficient and autogenous shrinkage at different temperatures. Her results were mainly in accordance with the results presented by Bjøntegaard.

Autogenous Shrinkage - Phenomenology and Theory: Adrian Radocea, Chalmers University of Technology, Sweden /6/.
Radocea discussed the relationship between early volume change and pore water pressure under differenet curing conditions and temperatures. He presented a theoretical model for the volume change.

Pore Depression - High Performance Concrete: Bertil Persson, Lund University, Sweden /7/ and /8/.
Persson presented experimental results and discussed the relation between self-desiccation and autogenous shrinkage, with focus on the influence of w/b, amount of silica fume and air content.

Restrained Shrinkage: Grazia Toma, Laval University, Sainte-Foy (Quebec).
Toma presented a research program on the topic to be started at the Laval University. She also presented the test rigs being built, to determine autogenous deformations and stress generation.

Autogenous Shrinkage - Facade Concrete: Markku Leivo, VTT Building Technology, Finland /9/ and /10/.
Leivo presented the cracking problem of precast facade elements in Finland, and a test set up at VTT used to investigate the problem. He showed examples on how the cement type and aggregate type influence the autogenous shrinkage.

Numerical Simulation - Dimensional Change: Eddie Koenders, Delft University of Technology, Netherlands /11/.
Koenders presented the "Hymostruc" numerical model for hydration of cement, and how the model is being used to simulate the autogenous shrinkage. He showed good correlation's between simulated and measured values. The model is, for the time being, valid for pure Portland cement systems only.

Measurements and modelling - Hardening Concrete: Gustav Westman and Hans Hedlund, Luleå University, Sweden /12/.
Westmann and Hedlund presented the work going on at Luleå University. They have developed an engineering tool, i.e. a "package" including needed tests and calculations to predict the crack risk of a given structure or structural member. They had performed sensitivity analyses varying the autogenous shrinkage: The autogenous shrinkage is a very important parameter, and thus also the accuracy of the numerical simulation is important.

Shrinkage and Cracking Early Ages: Yoshio Kasai, College of Industrial Technology, Nihon University, Japan /13/ and /14/.
Kasai presented the test equipment for determination of autogenous deformation, tensile strength and strain development of very young concrete (from the age of two hours). He presented a lot of results and, among others, his "famous" graphs showing the development of tensile strength and strain capacity before, during and after setting.

Ultrasonic Pulse Velocity (UPV) to Characterise Setting-Hardening: Kjell Skjeggerud and Åge Rettvin, Norcem, Norway.
Skjeggerud and Rettvin presented the test method of using UPV to characterise the structural built up before, during and after setting. They have correlated the results with results using other relevant methods (from slump to compressive strength). They concluded that the UPV method is the only one that is valid between the "zero slump-age" and the age when the mechanical properties may be tested according to standard procedures.

3 CONCLUSIONS

There is a consensus that autogenous deformation is a major parameter in the evaluation of the early crack risk. Furthermore, the maturity concept seems to able to characterise the process for a given concrete with a constant initial temperature until setting. However, the shrinkage development is very much influenced by the initial concrete temperature, and the results presented did not show any uniform development of the autogenous deformation. Different test apparatus and procedures may be one reason for the variations. More and collaborated work is, therefore, needed in order to understand the mechanisms aud describe the shrinkage development in a generalized way.

Another conclusion is that there is a rather low research activity on the cracking problem in the "initial phase", i.e. before and during setting. There is a lack of knowledge about the volume changes and development of the tensile capacity of low w/b concretes in this phase. Only Kasai presented relevant investigations. The researchers confirm, however, that cracking of HPC in this phase is a major world wide problem in e.g. floors, bridge decks and pavements.

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