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# CREEP, SHRINKAGE AND DURABILITY MECHANICS OF CONCRETE AND OTHER QUASI-BRITTLE MATERIALS

Proceedings of the Sixth International Conference

CONCREEP-6@MIT

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## PREFACE

The Proceedings comprise both the invited and contributed papers presented at the Sixth International Conference on Creep, Shrinkage and Durability Mechanics of Concrete and other Quasi-Brittle Materials (CONCREEP-6), held at the Massachusetts Institute of Technology, Cambridge, U.S.A., from August 20 to 22, 2001. The tradition of international conferences on concrete creep began with the conference chaired and organized in Munich in 1958 by Hubert Ruesch. The second conference was held also in Munich, in 1968, chaired again by Ruesch and organized by Folker H. Wittmann. The third conference followed in Leeds in 1978, chaired and organized by Adam Neville. Although these three conferences, all held under the auspices of RILEM (International Union of Testing and Research Laboratories for Materials and Structures, Paris), were not considered to constitute any conference series, the conference held in Evanston in 1986 under the sponsorship of the U.S. National Science Foundation, which was chaired and organized by Zdeněk P. Bažant, was labeled as the fourth conference in order to initiate a series anchored in a tradition. RILEM was asked to co-sponsor that conference scientifically, and the proceedings, published by John Wiley & Sons, U.K., were dedicated to the memory of Robert L'Hermite, the founder of RILEM and a leading early researcher in the field. The acronym CONCREEP was created with the fifth conference, which was held in Barcelona in 1993. It was organized by Zdeněk P. Bažant and Ignacio Carol, and its proceedings, published by F&N Spon, London, were dedicated to Adam Neville.

Pursuant to this long tradition, CONCREEP-6 at MIT presents again the latest results and implementation strategies of creep and shrinkage research at the interface of solid mechanics, materials science, experimental mechanics, computational mechanics of concrete-like materials and structural engineering. It is organized with the scientific co-sponsorship of RILEM, the American Concrete Institute, and the American Society of Civil Engineers through the Committee of Material Properties of the Engineering Mechanics Division.

The increasing need for evaluation of the durability performance of concrete structures has led recently to the development of advanced material models and numerical approaches founded on applied mechanics and computational mechanics. At the same time, the recent and rapid development of new cement-based materials with properties far exceeding conventional concrete standards has been accompanied, in materials science, with new experimental techniques that allowed novel insight into the microstructure of cement-based materials. There is now a need to bridge the gaps between materials science and advanced computational modeling and innovative concrete engineering on the multiple fronts of engineering mechanics, industrial applications, and advanced engineering education. This is the unifying theme of the 109 conference papers in the CONCREEP-6 Proceedings. The Proceedings are subdivided into four parts: I. Micromechanisms and Micromechanics of Creep and Shrinkage; II. Creep, Shrinkage and Fracture Couplings; III. Durability Mechanics of Concrete Structures; IV. From New Concrete Materials to the Design of High Performance Structures.

We would like to thank the members of the International Scientific Advisory Board (Graham Baker, Jim Beaudoin, Arnon Bentur, Neal Berke, Nenad Bičanić, Oral Buyukozturk, Ignacio Carol, Luigi Cedolin, Mario Chiorino, Olivier Cousy, Henri van Damme, Walter Dilger, Bhushan Karhaloo, Herbert Mang, Harald Mueller, Gilles Pijaudier-Cabot, Jaime Planas, Hans Reinhardt, Pierre Rossi, Jan Rots, Surendra Shah, Tada-aki Tanabe, Kaspar William, Yumping Xi) for their support and substantial efforts in the rigorous reviewing of the 145 submitted abstracts, which ensured the excellent quality of the 109 accepted papers. We are proud about a strong graduate student participation in CONCREEP-6, which was made possible through the competitive Industry Stipends of Excellence for Graduate Students, generously sponsored and awarded by the Lafarge Group and Electricité de France (EDF). We are grateful to the Industry Stipend of Excellent Award Committee (Paul Acker, Bruno Gérard, Folker H. Wittmann) for the merit-based selection of the awardees. This highlights the close link between industrial leaders in Cement and Concrete Engineering and academia, which has always been a great success of CONCREEP-conferences.

To recognize one of the founders of Materials Science of Cement and Concrete, the Sixth International Symposium on Creep, Shrinkage and Durability Mechanics of Concrete and Other Quasi-Brittle Materials will be dedicated to the legacy of Tieval C. Powers (1900 - 1997). Dr. Powers earned recognition through his researches as one of the foremost authorities on the structure and properties of Portland cement pastes and concrete. Dr. Powers was born in Palouse, Washington, and grew up in Oregon. After majoring in chemistry at Willamette University in 1925, he joined The Oregon State Highway Commission as a chemist in the materials testing laboratory. In 1930, he joined the Portland Cement Association in Chicago, where he stayed until his retirement in 1965. His unequaled understanding of the structure of Portland cement paste and concrete was an incentive and a driving force for generations of concrete scientists and engineers. As far as the topic of this conference is concerned, his ideas on the thermodynamics of volume change and hindered adsorbed water laid the foundation for the modern theory of creep and shrinkage mechanisms and its applications in constitutive modeling.

As the future of our built infrastructure is at stake, we trust that the conference papers in the CONCREEP-6 Proceedings will significantly contribute to Concrete Science and Engineering in the 21st century.

Franz-Josef Ullm — Zdeněk P. Bažant — Folker H. Wittmann  
Cambridge—Evanston—Zurich, May 2001.

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