



Proceedings
PRO 94

HPFRCC-7

Proceedings of the 7th
RILEM Workshop on High Performance
Fiber Reinforced Cement Composites

Edited by H. W. Reinhardt
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and H. Garrecht

HPFRCC-7
7th RILEM Workshop on
High Performance Fiber Reinforced
Cement Composites

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Contents

Dedication	XV
Preface	XIX
Workshop	XXI
Acknowledgements	XXV
Prolog	1
1 International workshop series on High Performance Fiber Reinforced Cement Composites (HPFRCC): History and Evolution <i>A.E. Naaman, H.W. Reinhardt</i>	3
Part 1: Production of HPFRCC and TRC	11
2 Improving the first crack behaviour of textile reinforced concrete <i>W. Brameshuber, M. Hinzen</i>	13
3 A compound for the production of high and ultra-high performance concrete <i>P. Hadl, H. Kim, N.-V. Tue</i>	21
4 Increased efficiency of column strengthening with TRC by addition of short fibres in the fine-grained concrete matrix <i>R. Ortlepp</i>	29
5 Mix design and basic properties of a new UHPFRC featuring portland-limestone cement <i>B. Shao, P. Gauvreau</i>	37
6 Effect of mineral admixtures on the properties of a sustainable ultra-high performance concrete (UHPC) <i>R. Yu, P. Spiesz, H.J.H. Brouwers</i>	45
7 Sustainable development of an ultra-high performance fibre reinforced concrete (UHPFRC): towards an efficient utilization of fibres <i>R. Yu, P. Spiesz, H.J.H. Brouwers</i>	53
8 Modifying carbon roving-cement matrix bond by inorganic coating <i>A. Peled, V. Mechtcherine, D. Nicke, S. Hempel</i>	61
Part 2: Properties of HPFRCC and UHPC	69
9 Autogeneous self healing of high performance fibre reinforced cementitious composites <i>L. Ferrara, M. Geminiani, R. Gorleza, V. Krelani, M. Roig-Flores, G. Sanchez-Arevalo, P. Serna Ros</i>	71
10 Performance characteristics of HPDSP concrete: an overview <i>S.K. Swar, S.K. Sharma, H.K. Sharma</i>	79
11 Development of a high-performance fiber-reinforced cement composite for large scale processing <i>L.F. Maya Duque, A.M. Nuñez López</i>	87
12 The effect of fiber content and aggregate type on the performance of UHPC <i>G. Agranati, A. Katz</i>	95
13 Tensile characterization of sustainable ultra-high performance fibre reinforced concrete containing GGBS <i>J. Xia, R. Tao, Y. Ma</i>	103

14	Probabilistic micromechanical model of engineered cementitious composites (ECC) <i>J. Li, E.-H. Yang</i>	111
15	Influence of steel fiber content on fracture energy of HPFRCC <i>P. Zhang, W. Ma, F.H. Wittmann, W. Wang, T. Zhao</i>	119
Part 3: Testing methods		127
16	Assessment of constitutive model for ultra-high performance fiber reinforced cement composites using the Barcelona test <i>A. Blanco, S.H.P. Cavalaro, E. Galeote, A. Aguado</i>	129
14	Determination of fibre orientation factor in high and ultra-high-performance fibre-reinforced self-compacting concrete <i>B.L. Karihaloo, S. Kulasegaram</i>	137
18	Rough concrete surfaces for strengthening and retrofitting – 3D Model of roughening process for description of concrete surface geometry <i>R. Ortlepp</i>	145
19	On the application of dispersed fibres as reinforcement for concrete shields against radiation <i>A.M. Brandt, D. Józwiak-Niedźwiedzka</i>	153
20	Concrete with superabsorbent polymer fiber <i>A. Assmann, H.W. Reinhardt</i>	161
21	Water penetration into HPFRCC under imposed strain <i>P. Zhang, F.H. Wittmann, P. Wang, T. Zhao</i>	169
22	Size effect on the flexural performance of ultra high performance fiber reinforced concrete (UHPFRC) <i>S.A. Paschalis, A.P. Lampropoulos</i>	177
23	Comparison between inverse analysis procedure results and experimental measurements obtained from UHPFRC four-point bending tests <i>J.Á. López, P. Serna, J. Navarro-Gregori, H. Coll</i>	185
24	Mechanical properties of a highly flowable ultra-high-performance fiber-reinforced concrete mixture considering large-size effects <i>P. Aghdasi, G. Palacios, A.E. Heid, S.-H. Chao</i>	193
25	On the chemo-mechanical behavior of basalt textile reinforced refractory concrete under high temperatures <i>D.A.S. Rambo, F.A. Silva, R.D. Toledo, O.F.M. Gomes</i>	201
26	Quantification of tensile response of UHP-FRC <i>L.F. Maya Duque, B.A. Graybeal</i>	209
27	Ultra high performance fiber reinforced concrete under impact loading <i>D.-Y. Yoo, N. Banthia, Y.-S. Yoon</i>	217
Part 4: Durability and sustainability		225
28	Durability performance of strain hardening fiber reinforced concrete <i>Y. Shao, L. Jiang, Z. He</i>	227
29	Self-healing capacity of a strain-hardening cement-based composite (SHCC) with bacteria <i>M.G. Sierra Beltran, H.M. Jonkers, E. Schlangen</i>	235
30	Influence of imposed compressive stress and subsequent self-healing on capillary absorption and chloride penetration into UHPFRCC <i>P. Wang, X. Yao, F.H. Wittmann, P. Zhang, T. Zhao</i>	243
31	Influence of an imposed tensile stress and subsequent self-healing on capillary absorption and chloride penetration into HPFRCC <i>F.H. Wittmann, X. Yao, P. Wang, P. Zhang, T. Zhao</i>	251

32	Development of engineered cementitious composites with local material ingredients <i>H. Ma, S. Qian, V.C Li</i>	259
33	Mineral building material stock of buildings and infrastructures in Germany and flows as indicators for recycling potentials <i>R. Ortlepp, G. Schiller</i>	267
34	Fiber-reinforced high-performance concretes exposed to high temperature: materials behavior and structural implications <i>F. Lo Monte, P.G. Gambarova, Z. Xu, Y. Li</i>	275
Part 5: Special loading conditions (impact, cyclic and seismic)		283
35	Study on deformation of a reinforced concrete bridge pier constructed using high-strength reinforcing bars and high performance material <i>K. Kosa</i>	285
36	Behaviour of high strength strain-hardening cement-based composites (HS-SHCC) subjected to impact loading <i>I. Curosu, V. Mechtcherine</i>	293
37	Tensile behavior and durability of high performance fiber reinforced concrete <i>S. Pyo, S.H. Cheong</i>	301
38	Micromechanics-based study on fatigue failure of engineered cementitious composites <i>J. Qiu, E.-H. Yang</i>	309
39	Impact behaviour of high performance glass fibre reinforced cement composite laminates <i>J. Wastiels, J. Van Ackeren, D. Van Nuffel, W. Van Paepegem</i>	317
40	Penetration and explosion of ultra-high performance fiber reinforced cement composite subjected to impact <i>L. Jianzhong, Z. Yaoyong, W. Huifang</i>	325
41	Behaviour of strain-hardening cement-based composites (SHCC) subject to cyclic loading <i>S. Müller, V. Mechtcherine, M. Zydek</i>	333
Part 6: Bending and shear		341
42	Experimental studies to determine the flexural and cracking performance of hybrid steel-mesh and polyolefin-fiber reinforced cementitious composites <i>P.B. Sakthivel, A. Ravichandran, N. Alagumurthi</i>	343
43	Hybrid steel fiber reinforced concrete panels in shear: experimental investigation <i>S.G. Chasioti, F.J. Vecchio</i>	351
44	Interfacial bond tailoring for crack width reduction in high strength-high ductility concrete (HSHDC) <i>R. Ranade, V.C. Li</i>	359
45	Effect of deformation history on steel-reinforced HPFRCC flexural member behavior <i>T.E. Frank, M.D. Lepech, S.L. Billington</i>	367
46	Investigation of the size effect in shear of steel fiber reinforced concrete (SFRC) slender beams <i>M. Zarrinpour, J.-S. Cho, S.-H. Chao</i>	375
47	Bending behavior of precast bridge slabs in UHPFRC under static and cyclic loadings <i>J.-P. Charron, F. Lachance, B. Massicotte</i>	383
48	Stability of reinforcing bars in steel fiber reinforced concrete flexural members <i>L. Monfardini, R.D. Lequesne, F. Minelli, G.J. Parra Montesinos, J.A. Pincheira</i>	391
Part 7: Structural applications		399

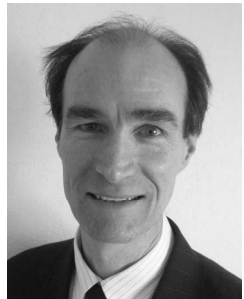
49	Performance of full-scale ultra-high performance fiber-reinforced concrete (UHP-FRC) column subjected to extreme earthquake-type loading <i>G. Palacios, S.-H. Chao, A. Nojavan, A. Schultz</i>	401
50	Seismic performance of full-scale high-performance fiber-reinforced (HPFRC) special moment frame slab-beam-column subassemblage using joints as the major energy dissipation source <i>Y.-J. Choi, S.-H. Chao</i>	409
51	Tension stiffening effect of reinforced high-performance fiber-reinforced cementitious composites <i>W. Nguyen, G.G. Jen, W. Trono, D.M. Moreno, S.L. Billington, C.P. Ostertag</i>	417
52	Finite element analysis of test configurations for identification of interface parameters in layered FRCC systems <i>T. Sajdlová, P. Kabele</i>	425
53	UHP-FRC connections: delivering innovation and enhancing performance <i>B.A. Graybeal</i>	433
54	Demountable construction for sustainable buildings <i>S. Ortlepp, R. Masou, R. Ortlepp</i>	441
55	Cable stayed footbridge made of UHPC <i>J.L. Vitek, M. Kalný, R. Coufal</i>	449
56	Impact of reinforcement ratio on deformation capacity of reinforced high-performance fiber-reinforced cementitious composites <i>M.J. Bandelt, S.L. Billington</i>	457
57	Jacketing of existing piers: evaluation of the risk of cracking due to hydration heat when different types of application techniques are used <i>F. Macobatti, C. Zanotti, A. Meda, G. Plizzari</i>	465
58	Cast-on site UHPFRC for improvement of existing structures – achievements over the last 10 years in practice and research <i>E. Denarié, E. Brühwiler</i>	473
59	Modeling the load-deformation response of FRC structural members <i>I. Paegle, G. Fischer</i>	481
60	HPFRCC beams in innovative elevated slabs: experimental characterization and modeling <i>M.C. Rampini, G. Zani, M. Colombo, M. di Prisco</i>	489
61	Influence of HPFRCC on corrosion initiation and corrosion propagation <i>G.G. Jen, W.L. Nguyen, C.P. Ostertag</i>	497
Author index		505
Subject index		507

Dedication

The Seventh International RILEM Conference on High Performance Fiber Reinforced Cement Composites (HPFRCC7) and its proceedings are dedicated to three outstanding members of our international community who have made significant and lasting contributions to broaden the safe application of fiber reinforced cement and concrete composites through fundamental understanding, testing, analysis, modeling and design.

John E. Bolander

John E. Bolander (born July 1, 1958) is a professor within the Department of Civil and Environmental Engineering at the University of California, Davis. He received his Ph.D. degree in civil engineering from the University of Michigan, Ann Arbor, in 1989. He belonged to the faculty of engineering at Kyushu University, Japan, for five years prior to arriving at UC Davis in 1994. He received the Outstanding Faculty Teaching Award from the College of Engineering in 2006.



Bolander has served as the Chief Editor of the international journal Cement and Concrete Composites for the period of 2006-2012. He received fellowship awards for computational mechanics research from the Japan Society for the Promotion of Science in 1997 and 2008. Bolander's research and teaching interests involve the effective use of high-performance materials within the civil infrastructure, with emphasis on the life-cycle performance of concrete materials and structures. Over the past two decades, he has been a pioneering developer of discrete methods for the modeling fiber reinforced cement composites.

Professor John E. Bolander is being honored for his outstanding contributions to the development of modeling tools for fiber reinforced cement composites, which have provided new insights into fibre-matrix interaction and its effect on composite behavior.

Wolfgang Brameshuber

Professor Wolfgang Brameshuber was born on August 2, 1956 in Mannheim, Germany. From 1975 – 1981, he studied civil engineering at the University of Technology Karlsruhe. Following first-part finals, more detailed study of structural engineering followed, specialising in concrete structures. In February 1988, he received his degree of doctor of engineering at the faculty of Civil Engineering of University of Karlsruhe.



After that he worked at BUNG consultant in Heidelberg, Germany, for three years. He was building materials consultant for planning and execution of building projects and was responsible for supervision of construction work and the development of the department for building maintenance. From 1991 until end of 1998 he was head of the central laboratory for building materials and building maintenance at Bilfinger Berger AG in Mannheim. Since January 1999 he has been the chair of Institute of Building Materials Science at RWTH Aachen University with a period as dean of the Faculty of Civil Engineering for 2 years.

Professor Brameshuber has been part of many expert groups e.g. RILEM (Réunion Internationale des Laboratoires et Experts des Matériaux, Systèmes de Constructions et Ouvrages) where he is the delegate for Germany and member of the Bureau, CEN (Comité Européen de la Normalisation), DIBt (Expert Groups of German Institute of Building Technology), DIN NABau (German Institute for Standardization), DBV (German Society for Concrete and Construction Technology) and the German Federal Associations of Ready-mix Concrete. In 2001 he received the STUVA Award (Award of the Research Association for Underground Transportation Facilities).

His research priorities are special concretes including high-performance concrete, self-compacting concrete and textile reinforced concrete (TRC), environmental impact of building materials, constitutive models for concrete, modelling of damage processes in concrete (micro-level structural model), durability of concrete (additives, frost, sulfate), carrying capacity and durability of masonry. He was one of the leading researchers in the Sonderforschungsbereich 532 (Special research initiative of DFG). Wolfgang Brameshuber is an international consultant for concrete technology and holds two technical patents.

He has authored or co-authored more than 300 publications and delivered more than 200 presentations worldwide.

Professor Brameshuber is being honored for his numerous contributions to the development of textile reinforced concrete and hybrid HPFRCC with textiles and fibres, especially the composition and rheology of these special concretes, as well as the introduction of TRC in practice.

Pierre Rossi

Dr. Pierre Rossi was born in Paris, France, in 1956. He started his scientific education by receiving a physics master's degree from the University of Picardie Jules Verne, France, in 1980. He then obtained a second master's degree in Mechanics of Materials from the University of Technology of Compiègne, France, in 1982. In 1986, he completed his PhD degree on the application of linear fracture mechanics to concrete, reinforced concrete and fibre reinforced concrete structures at the École Nationale des Ponts et Chaussées (ENPC). In 1990, he completed his habilitation degree (HDR) allowing him to conduct research and pursue a career as a university professor.



In 1983, he joined the Laboratoire Central des Ponts et Chaussées (LCPC – today known as IFSTTAR) in Paris as a scientist. His current research interests include the analysis of cracking in concrete structures subjected to quasi-static and dynamic loadings, nonlinear finite element modelling, normal and ultra-high performance fibre reinforced concrete, and the time-dependant behaviour of concrete. He is the author or co-author of more than 80 scientific studies published in international journals, and one book on concrete reinforced with steel fibers (1998, Presses de L'Ecole Nationale des Ponts et Chaussees). He is also holder of three patents, and has been the main instigator and chairman of the BEFIB and SSCS international conferences. He has been active in numerous international scientific, technical and standardization committees, in addition to being a reviewer for several international journals. He is also a member of the editorial board of the Fib International journal, Structural Concrete. Finally, he was the technical director of a French national project on industrial applications of steel fibre reinforced concrete between 1996 and 2000.

Dr. Pierre Rossi was awarded the international Robert L'Hermite medal from the RILEM in 1996, the French Civil Engineering Association medal from the Association française de génie civil (AFGC) in 2001, and the Chevalier National de l'Ordre du Mérite medal from the government of France in 2005 for his contributions to civil engineering research.

Dr. Rossi is being honored for his long-lasting contributions to the development of HPFRCC by experiments, material models and numerical computations. He has published pioneering ideas to the understanding of creep and shrinkage of concrete.

Preface

HPFRCC7 will be the seventh workshop in a series dealing with High Performance Fiber Reinforced Cement Composites (HPFRCC). The six prior workshops have led to a definition of HPFRCC that mostly suggests a technical challenge. That is, composites that exhibit a strain hardening tensile stress-strain response accompanied by multiple cracking (and relatively large energy absorption capacity). Besides this mechanics related definition there are other features which make a cement composite “high performing” like workability, durability and robustness. Researchers have tried to reduce fiber content to a necessary minimum. By reducing fiber content, they are simplifying the production process, helping make standard mixing procedures acceptable, and opening the way to large-scale practical applications.

The first international workshop on High Performance Fiber Reinforced Cement Composites took place in June 1991 in Mainz, Germany, under the auspices of RILEM and ACI. It was funded in part by the US National Science Foundation (NSF) and the Deutsche Forschungsgemeinschaft (the German NSF). Other co-sponsors included the center for Advanced Cement Based Materials (ACBM), the University of Michigan, and the University of Stuttgart. The second workshop took place in Ann Arbor, Michigan, in June 1995, the third in Mainz Germany, in June 1999, the fourth in Ann Arbor, Michigan, in June 2003, and the fifth in Mainz, Germany, in July 2007, the sixth in Ann Arbor, Michigan, in June 2011, all supported by the same sponsors. In each case hard-cover proceedings were published as a special RILEM publication. While the first workshop in 1991 included mostly US and German participants, subsequent workshops were opened to top researchers in the field from other countries. The last workshop in Ann Arbor 2011 assembled researchers from 20 countries. The proceedings included 66 papers grouped in 7 different sections.

Since the first workshop in 1991, continuous developments have taken place in new materials, processing, standardization, and improved products for building and other structures. Also, enhanced theory and modeling techniques for HPFRCC now allow a better description of their behavior and reinforcing mechanisms. While in the first workshop HPFRCC implied relatively high fiber volume fractions (over 4%), today HPFRCC can be designed with as little as 1% fiber volume content. While the root definition of HPFRCC is simplest (that is, fiber cement composites with strain hardening and multiple cracking behavior in tension) to clearly differentiate them from other cement composites, this is not the only description of desirable performance. Durability, fire resistance, impact resistance, diffusion resistance, imperviousness, and constructability at reasonable cost are other important attributes that need to be further investigated.

In each workshop, a broad range of technical issues, ranging from microstructure characterization to design recommendations, are typically covered; however, some selected themes are emphasized. In this seventh workshop, the organizers identified the following themes for which research information is needed:

- Production of TRC and HPFRCC
- Composite properties in the fresh and hardened states
- Testing methods
- Structural elements: design, detailing, bending, shear, tension stiffening
- Impact, cyclic and seismic loading
- Structural applications
- Durability and sustainability.

Papers addressing these themes are grouped in seven separate sections of the proceedings.

The organizers hope that this new volume will help foster the continuous development and increasing utilization of HPFRCC in both stand-alone and structural applications.

H.W. Reinhardt
G.J. Parra-Montesinos
H. Garrecht

HPFRCC7 – Workshop

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The organizers would like to thank all members of the Scientific and International Committees for enthusiastically supporting the organization of this seventh workshop, and all the authors who have contributed with the valuable papers that make these proceedings. Special thanks are due to Ms. Simone Stumpp for preparing with great care and efficiency the camera-ready material for printing. Once more, H.W. Reinhardt and A.E. Naaman would like to express their deep gratitude to the Alexander von Humboldt Foundation for giving them the opportunity to initiate, in 1990, a long-term continually productive cooperation.

H.W. Reinhardt
G.J. Parra-Montesinos
H. Garrecht

PROLOG

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