

# THE 5TH INTERNATIONAL SYMPOSIUM ON CEMENT AND CONCRETE

OCTOBER 28 ~ NOVEMBER 1, 2002

SHANGHAI, CHINA



VOLUME 1

TONGJI UNIVERSITY PRESS, SHANGHAI, CHINA



## 图书在版编目(CIP)数据

第五届水泥与混凝土国际会议论文集/王培铭主编.  
上海:同济大学出版社,2002.10  
ISBN 7-5608-2526-5

I. 第… II. 王… III. ①水泥—国际学术会议—  
文集②混凝土—国际学术会议—文集  
IV. TQ172-②TU528-53

中国版本图书馆 CIP 数据核字(2002)第 0076583 号

## 第五届水泥与混凝土国际会议论文集

作者 王培铭 主编

责任编辑 司徒妙龄 责任校对 徐春莲 司徒妙龄 封面设计 李志云

---

出 版 同济大学出版社  
发 行 (上海四平路 1239 号 邮编 200092 电话 021-65985622)  
经 销 全国各地新华书店  
印 刷 上海市印刷七厂一分厂印刷  
开 本 889mm×1194mm 1/16  
印 张 81 插页:2 页  
字 数 2592000  
印 数 1—500  
版 次 2002 年 10 月第一版 2002 年 10 月第一次印刷  
书 号 ISBN 7-5608-2526-5/TU·474  
定 价 180.00 元

---

本书若有印装质量问题,请向本社发行部调换



**PROCEEDINGS OF**

**THE 5TH INTERNATIONAL SYMPOSIUM**

**ON CEMENT AND CONCRETE**

**OCTOBER 28~NOVEMBER 1, 2002**

**SHANGHAI, CHINA**

**MAIN SPONSOR**      **The Chinese Ceramic Society**

**SPONSOR**            **Cement Committee of the Chinese Ceramic Society**  
**China Building Materials Academy**  
**Tongji University**

**CO-SPONSOR**      Ministry of Science and Technology of China  
China National Science Foundation  
China Building Material Industry Association  
United Nations Industrial Development Organization  
American Concrete Institute  
ZKG International  
Japan Cement Association  
Japan Concrete Institute  
The American Ceramic Society  
The Ceramic Society of Japan  
Russian Chemistry Society  
The Society of Inorganic Materials, Japan  
China Yangtze Three Gorges Project Development Corp.

**EDITED BY**        Wang Pei-ming (Editor in chief)  
Chen Yi-min (Sub-editor)  
Tan Mu-hua                      Shi Mei-lun  
Gu Guo-fang                     Shen Rong-xi  
Zhang Zhen-quan                Xu Qian-wei

**TONGJI UNIVERSITY PRESS, SHANGHAI, CHINA**



## **Symposium Chairman**

Zhang Ren-wei      President of the Chinese Ceramic Society  
President of China Building Materials Industry Association

## **International Consultative Committee**

J. F. Young      Professor, PhD. , Research Center for Advanced Cement-based Materials,  
University of Illinois, USA

F. P. Glasser      Professor, Department of Chemistry, University of Aberdeen, UK

M. Daimon      Professor, Inorganic Materials Department, TOKYO Institute of Technology, Japan

Y. Ohama      Professor, PhD. , College of Engineering Nihon University, Japan

A. P. Osokin      General Director of Zao "Scientific and Technical Center", Russia

J. Stark      Professor, PhD. , F. A. Finger Institute for building Materials Science, Bauhaus  
University, Weimar, Germany

L. J. Struble      Professor, PhD. , Department of Civil and Environmental Engineering, University of  
Illinois, U. S. A

Tang Min-shu      Professor, Member of China Academy of Engineering, Director of Silicate Research  
Laboratory, Nanjing University of Technology, Jiangsu

Li Zong-jin      Associate Professor, PhD. , Hong Kong University of Science and Technology,  
Hong Kong

## **Secretary-general**

Sui Tong-bo      PhD, Director, Institute of Cement Research and New Building Materials, China  
Building Materials Academy

## **Vice Secretary-general**

Xu Qian-wei      Associate Professor, PhD. , School of Materials Science and Engineering, Tongji  
University



## Organizing Committee

### Chairman

Wu Zhao-qi      Professor, Secretary-general of the Chinese Ceramic Society, Beijing

### Vice Chairman

Yao Yan      Professor, President, China Building Materials Academy, Beijing  
Wang Pei-ming      PhD. , Professor, Dean of School of Materials Science and Engineering, Tongji University, Shanghai  
Pan Dong-hui      Professor, Vice Secretary-general of the Chinese Ceramic Society, Beijing

### Members

Gao Rui-ping      Director, Division of Inorganic Non-Metal Materials Science, National Natural Science Foundation of China, Beijing  
Cai Ke-yu      Director of International Department, the Chinese Ceramic Society, Beijing  
Wang You-yun      Honorary Board Chairman, Cement Committee of the Chinese Ceramic Society, Beijing  
Cao Yong-kang      Board Chairman, Concrete and Cement Products Committee of the Chinese Ceramic Society, Beijing  
Tao You-sheng      Board Chairman, House Building Materials Committee of the Chinese Ceramic Society, Beijing  
Jiao Yong-dao      Board Chairman, Environment Protection Committee of the Chinese Ceramic Society, Beijing  
Jin Da-biao      General Manager, China ISO Standard Sand and Co. Ltd. , Fujian  
Guo wen-san      General Manager, Anhui Conch Cement Company Limited, Anhui  
Cao Guang-jing      Vice General Manager, China Yangtze Three Gorges Project Development Corp. , Hubei  
Zhao Jian-guo      General Manager, Mengxi High Technology Materials Co. Ltd, Neimenggu  
Liu Zhi-jiang      Professor, President, Tianjin Cement Industry Design and Research Institute, Tianjin  
Xin Fa-long      General Manager, Shanghai Building Component and Products Co. Ltd. Shanghai  
Cai Ji-ming      General Manager, Shanghai Boa Tian New Building Material Co. Ltd. Shanghai  
Cai You-shan      Director, China Quality Certification Center for Cement and House Building Materials, Beijing  
Zhu Wei-zhong      Vice Director and Vice Chief Engineer, Heilongjiang Cold Region Construction Science Research Institute, Heilongjiang  
Li Guo-chang      General Manager, Tonghua Special Cement Co. Ltd. , Jilin  
Li Ye-qing      General Manager, Huaxin Cement Co. Ltd. , Hubei  
Pan De-fu      General Manager, Cement Factory of Gezhouba Co. Ltd. , Hubei  
Xu He-lin      General Manager, Badao Special Cement Factory, Hunan  
Dong Rui-bao      General Manager, Chongqing Diwei Tenghe Co. , Chongqing



## Scientific Committee

### Chairman

Yao Yan                      Professor, President, China Building Materials Academy, Beijing

### Vice Chairman

Xu Zhong-zi              Professor, Dean of Materials Science and Engineering, Nanjing University of Chemical Technology, Jiangsu

Xu Yong-mo              PhD, Director of International Cooperation Department, China Building Materials Industry Association, Beijing

Yan Pei-yu                Professor, School of Civil Engineering, Institute of Building Materials, Tsinghua University, Beijing

Hu Shu-guang            Professor, Wuhan University of Technology, Hubei

### Members

Tan Mu-hua              Professor, Deputy of Editorial Department of Journal of Building Materials, Shanghai

Xu Qian-wei              Associate Professor, School of Materials Science and Engineering, Tongji University, Shanghai

Chen Yi-min              PhD, Director of the Key-laboratory of Cement-based Materials Science, China Building Materials Academy, Beijing

Sui Tong-bo              PhD, Director, Research Institute of Cement and New Building Materials, China Building Materials Academy, Beijing

Cui Qi                      China Building Materials Academy, Beijing

Li Jin-yu                Professor, Director of the Committee of Concrete Durability, China Institute of Water Resources and Hydro-power Research, Beijing

Chen Xin                Professor, Vice-President of Jinan University, Shandong

Tang Ming                Professor, Director of Shenyang Architectural and Civil Engineering Institute, Research Institute of Building Materials, Liaoning

Zhang Qing-yu          Professor, Tianjin Cement Industry Design and Research Institute, Tianjin

Kong Xiang-zhong      Director of Grinding Department, Hefei Cement Research Institute, Anhui

Sun Shu-shan            Professor, Chief Engineer, Research Institute of Environmental Protection, Central Metallurgical Research Institute, Beijing

Zhu Wei-zhong          Vice Director, Vice Chief Engineer, Heilongjiang Cold Region Construction Science Research Institute, Heilongjiang

Miao Chang-wen        Director, Jiangsu Research Institute of Building Science

Zhu Rong-yao            Director, Suzhou Concrete and Cement Products Research Institute, Jiangsu

Hu Li-min                Manager of Quality Department, Huaxin Cement Co., Ltd., Hubei



## **PREFACE**

Sponsored by the Chinese Ceramics Society, the Fifth International Symposium on Cement and Concrete (5<sup>th</sup> ISCC), formally known as the 4<sup>th</sup> Beijing International Symposium held in 1998, is held in Seagull International Convention Center in Shanghai, P. R. China on from October 28 to November 1, 2002.

The objectives of the symposium are to review the progress in the fields of cement and concrete since the 4<sup>th</sup> Beijing International Symposium held in 1998, and to exchange the achievements of related scientific research throughout the world, thus to promote the sustainable development of cement and concrete industries in the 21<sup>st</sup> century.

Committed by the 5<sup>th</sup> ISCC Scientific Committee, we have the pleasure of taking the editing work of the symposium proceedings, which comprise 202 papers to be presented at the symposium, among which 67 papers are from foreign countries and 135 from China.

The proceedings in two volumes cover five themes, namely the technology and equipment of cement manufacture; fundamental research and experiment methods; blended and special cements; industrial wastes and by-products used in cement and concrete industry and concrete and its products.

At the moment of the publication of the proceedings we would like to express our sincere thanks to the individuals and organizations who have generously provided financial support to the symposium which makes it possible to host the symposium and publish the proceedings, and who have taken active part in reviewing of the papers.

Professor Yao Yan  
The Scientific Committee of the 5<sup>th</sup> ISCC  
Shanghai, P. R. China  
October 28, 2002



# CONTENTS

## VOLUME 1

Preface

### I. GENERAL LECTURE

Advanced Cement-based Materials .....	J. Francis Young (New Zealand)	3
Advances in Sulfoaluminate Cements .....	F. P. Glasser (Scotland)	14
New Advances in Research on Concrete Durability in China .....	Yao Yan (China)	25
Alkali-Carbonate Reaction—A Review .....	Mei Lai-bao, Deng Min and Tang Ming-shu (China)	33
Dispersion Mechanisms of Comb-type Superplasticizers Containing Grafted Polyethylene Oxides .....	Sakai Etsuo and Daimon Masaki (Japan)	42
Recent Progress in Development of Concrete-Polymer Composites in Japan .....	Yoshihiko Ohama (Japan)	49
New Approaches to Ordinary Portland Cement Hydration in the Early Hardening Stage .....	Stark J. , Möser B. and Bellmann F. (Germany)	56
The Development and Countermeasures of Technologies and Equipment of Chinese Cement Industry .....	Liu Zhi-jiang (China)	71
Using Dynamic Rheology to Probe the Microstructure of Fresh Cement Paste .....	Leslie Struble, Huagang Zhang and Chun-Tao Chen (U. S. A. )	79
Property Investigation of Cement-based Materials at Early Ages .....	Li Zong-jin and Jin Xian-yu (China)	86
Concrete Construction Techniques in the Three Gorges Project .....	Cao Guang-jing (China)	97
The Micro Ice Lens Model of Frost Attack-basics and Consequences for Testing and Application .....	Max J. Setzer (Germany)	105

### II. PROCESS TECHNOLOGIES AND EQUIPMENT

Study of Forces Applied to Spring Plates of Rotary Kiln .....	Li Jian-sen (China)	115
Analysis of Sulfur Dioxide Pollutant in Cement Industry .....	Kao Hong-tao, Ye Xu-chu, Hu Dao-he and Wang Yan-ru (China)	119
Design of Pilot Line for Cement Clinker Production by Rt-Technology .....	Abramson I. G. , Egorov G. B. and Nikiforov Yu. V. (Russia)	124
Development and Research of Pulverized Anthracite Burners Used in Cement Kiln .....	Xia Jing-xian (China)	128
Finite Element Analysis of Reducer Housing of Center Drive Type Cement Mill .....	Yan Ke-jun (China)	135
Study of the Application of Pulsed Tracking Dusting Technology .....	Chen Shao-long and Liu Zhong-cai (China)	140
LMC Low Pressure Long Bag Pulse Dust Collector, Features of Design .....	Hou Da-gang, Hu Jian-peng and Liang Xian-wen (China)	148
Principle and Application Research of Water Collecting Dust Device on New Cement Vertical Kiln .....	Xu Jin (China)	154
Computer Control Equipment Model DKQ-III for Bag Filters		



..... Jiao Yong-dao, Yu Cheng, Mao Xiao-jun, Song Li-ming, Wang Yue-pei and Fan Ya-chuan (China)	157
An Attempt to Utilize New Standard of Cement by Application of Open-cycle Grinding Technique with High Fineness and High Output	
..... Jin Cheng-sheng, Lin Zhong-yu, Fang Hai-yan and Yang Chun-bao (China)	162
Trends of Bag Dust Collector Application in Cement Industry .....	Mao Zhi-wei (China) 168
Vibration Analysis and Experimental Study of GHM Rorimill in Operation	
..... Huang Zhi-chu, Chai Yan-hong and Hou Zuo-men (China)	173
Study and Application of the New Type of HKD Filter Bag for Dryer	
..... Wang Hao-ming, Zhang Qi-jun and Sun Li-ming (China)	178
Influence of Low Frequency Vibration on Surface Voids and Segregation in Self-compacting Concrete	
..... Kazuo Ichimiya, Takehiro Yamasaki and Takashi Idemitsu (Japan)	186

## II. PORTLAND CEMENT, BLENDED CEMENT AND SPECIAL CEMENTS

Control Methods for the Early Hydration in $\text{Ca}_3\text{Al}_2\text{O}_6$ — Gypsum System with Superplasticizers	
..... Sakai Etsuo, Kang Jin-Kyu and Daimon Masaki (Japan)	195
Absorption of SP Agent and Flowing Efficiency of Paste and Mortar Made with Cement Produced in Korea and Japan	
..... Gyu-Yong, Kim, Taka-aki ohkubo, Michihiko Abe (Japan) and Moo-Han, Kim (Korea)	202
Stability of the Calcium Sulfoaluminate Hydrates	
..... Hanaa Youssef Ghorab (Egypt)	209
Study of Long Time Hydration of Ba-bearing Sulphoaluminate Cement	
..... Cheng Xin, Chang Jun, Lu Ling-chao and Liu Fu-tian (China)	216
Relationship among the Agglomeration, Microstructure of Clinker and the Performance of High Belite Cement	
..... Guo Sui-hua, Zhang Hong-tao, Lin Zhen, Zhang Wen-sheng and Chen Yi-min(China)	220
Research on Ultrafine High Performance Cement	
..... Guan Xue-mao, Hu Shu-guang, Ding Qing-jun and Li Xiao-lei(China)	227
Influence of Seed Crystal on Hydration of Cement and Strength Development of Concrete under Negative Temperature .....	Wang Zheng, Li Jia-he and Zhang Yu-zhen (China) 233
Effects of Type WH- II Concrete Super Retarder on the Hydration of Portland Cement	
..... Wang Bao-min, Wang Li-jiu, Mu Hong-ying, Ren Zheng-yue and Cao Ming-li (China)	238
Study on Resistance to Acid Rain Attack and Carbonation for High Belite Cement Modified by Nanometer $\text{SiO}_2$ .....	Chen Han-bin, Chen Jian-xiong and Wu Jian-cheng (China) 242
Research on High Early Strength Belite-rich Cement Prepared with Composite Clinkers	
..... Guo Sui-hua, Chen Yi-min, Feng Pei-zhi, Sui Tong-bo and Liu Ke-zhong (China)	247
Experimental Studies of the High Belite Sulphoaluminate Cement	
..... Lan Ming-zhang, Tang Run-rong, Chen Zhi-feng and Zhang Zhen-qi(China)	254
Strength and Pore Structure of High Belite Cement	
..... Sui Tong-bo, Wang Jing, Wen Zhai-jun, Zhang Zhong-lun, Liu Yun, Wang Xian-bin, Guo Sui-hua, Liu Ke-zhong, Huang Tai-dong, Chen Zhao-hua, Liu Yong-dong and Zhang Shui-jian (China)	261
Research of the Industrial Production of New Type Barium-bearing Sulphoaluminate Cement	
..... Wang Zhong-wei and Bi ya-juan (China)	266
Influence of Fluorite on the Burnability of Barium-containing Sulphoaluminate Cement Clinker	



... Zhang Wen-sheng, Yu Qi-jun, Zhang Hong-tao, Guo Sui-hua and Chen Yi-min (China)	271
Studies of Inhibition of ASR with LiOH at 80℃	
..... Mo Xiang-yin, Yu Chen-jie, Wang Ke-yu, Liang Li, Xu Zhong-zi and Wu Ke-ru (China)	276
Study of a Kind of Soil-Stabilizing Cement	282
..... Chen Yun-bo and Xu Pei-tao (China)	
Manufacturing and Properties of Eco-cement: a New Type Portland Cement Made from Municipal Waste Incinerator Ash	
..... Hiroshi Hirao and Shigeru Yokoyama (Japan)	288
Research on Preparation of Tricalcium Aluminate by Sol-gel Method	
..... Chen Hong-xia, Wang Pei-ming and Wu Jian-guo (China)	295
Study on State of Free-CaO in Sulphur-fixed Coal Ashes of Circulating Fluidized Bed Combustor	
..... Wang Zhi, Qian Jue-shi and Peng Zhao-hui (China)	300
Aluminosilicate Binder Synthesized at Room Temperature	
..... Li Zong-jin and Ding Zhu (China)	305
Active Mineral Additives and High Performance Concrete	
..... Pu Xin-cheng and Wang Yong-wei (China)	310
Hydration Processes of Cements Blended with Limestone Powder	
..... Xiong Xiang-jun, Klaas van Breugel and Hans S. Pietersen (The Netherlands)	317
Experimental Study on the Impact-resisting and Wear-resisting Cement	
..... Yu Fei, Sun Li-hua, Gao Jian and Li Lun (China)	325
The Development of High Sulfate Resisting Silicate Cement	
..... Ju Qing, Zhen Hai-ying and Jia Bao-sheng (China)	331
Pozzolanic Activity of Burned Coal Gangue and Its Effects on Cement Strength	
..... Zhang Chang-sen (China)	336
Super-corrosion Resistant Cement	
..... Osokin A. P. , Entin Z. B. , I. S. Pushkarev and Sivkov S. P. (Russia)	342
Influence of Raw Mix Reacting Capacity on the Qualities of High Sulphate Resistant Well Cement	
..... Osokin A. P. , Entin Z. B. and Sivkov S. P. (Russia)	346
Cementless Corrosion Resistant Binder	
..... Constantin Freidin and Shoshana Lakh (Israel)	350
Stabilization of Clay Soil Using Cement Kiln Dust	
..... Cui Su-ping (China) and Wang lan (USA)	358
Properties of Well Cement with High Specific Area	
..... Wu Xiao-rong, Sui Tong-bo and Song Chun-yan (China)	365
Studies on Performance of a New Kind of Mineral Admixture—Metakaolin	
..... Wen Zhai-jun, Sui Tong-bo, Wang Jing, Zhang Zhong-lun and Fan Lei (China)	372
The Properties of AEC Expanding Cement and Its Application in Channel Second Back-up Lining Construction	
..... Lu Jian, Dong Lan-nu, Chen Wei-wu, Liu Ke-zhong, Jiang Yu-nan, Jin Xin and Zhou Hong-sheng (China)	380
Research on Cases of the ISO14001 Environmental Management System Implemented in Cement Enterprises	
..... Xie Yu and Xiao Ying (China)	387
A Comparison of the Plant Performances of Different Synthetic Gypsums	
..... J. H. Potgieter, S. S. Potgieter, R. I. McCrindle and C. A. Strydom (South Africa)	392
A Method of Control Chemical Analysis for Determination of Four Main Compositions in Cement Raw Mix	



..... Liu Yu-bing, Zhao Ying-li, Yiu Liang-jian and Zhang Yu-chang (China)	398
Portland Cement Production Properties Dependence	
..... M. Komljenovic, Lj. Petrasinovic-stojkanovic, B. Zivanovic, D. Dasic and B. Kastic (Yugoslavia)	403
Coordination between Expansion and Strength Development of C-CSA-BFS Ternary Cementitious Materials	
..... Wang Dong-min, Jin Xin and Ouyang Shi-xi (China)	411

#### IV. FUNDAMENTAL RESEARCH AND EXPERIMENTAL TECHNIQUES

Resources Circulation and Ecomaterialization in Short-cut Fiber Reinforced Cement Composites	
..... Fukushima Toshio (Japan)	419
Microstructure of Portland Cement Pastes with Low Water-cement-ratios after Long-time Curing under Water	
..... C. Hofheinz (Germany), F. Winnefeld (Switzerland) and D. Knöfel (Germany)	425
Alkali-carbonate reactivity of limestones at Triassic age by different test methods	
..... Lan Xiang-hui, Deng Min, Xu Zhong-zi and Tang Ming-shu (China)	430
Gradient Structures in the Interfacial Transition Zone of Fresh Cementitious Material	
..... Chen Hui-su (China), Stroeven Piet (The Netherlands) and Sun Wei (China)	437
Electrochemical Research on the Hydration Mechanism and Properties of Cement Based Material with Fly Ash	
..... He Hong-zhu and Chen Zhi-yuan (China)	443
Analysis of Excessive Retarded Setting of Dam Concrete Caused by Adaptability of Cement Composition with Admixture	
..... Chen Yi-min, Li Wen-wei, Lin Zhen, Zhang Hong-tao, Zhang Wen-sheng and Guo Sui-hua (China)	447
Stress-Strain Analysis for Steel Fibre Reinforced Concrete under Flexural Load	
..... Ding Yi-ning, He Wei (China), Markus Pfeuffer (Germany), and Zhang Yu-lin (Portugal)	454
Study on the Restricted Expansion Rate of Expansion Agent Using Orthogonal Design Method	
..... Xu Zhi-quan, Yan Pei-yu and Peng Jiang (China)	462
Relationship Between Characteristics of Particle Group of Fly Ash and Rheology of Fresh Cement Pastes	
..... Guan Wen and Tan Mu-hua (China)	469
Effect of Compound Powders on Rheological Property of Fresh Concrete	
..... Shi Yun-xing (China), Isamu Matsui (Japan) and Feng Nai-qian (China)	476
Bauxite Expansive Agent and Its Mechanism of Expansion	
..... Xi Yao-zhong and Ren Shu-xia (China)	484
Study of the Influence of The Proportion of $C_3A/C_4AF$ in the Cement Clinker for Road on the Properties	
..... Zhang Hong-tao, Chen Hu-xing, Guo Sui-hua, Zhang Wen-sheng and Chen Yi-min (China)	492
AAR Suppressed By LiOH and Its Mechanism	
..... Mo Xiang-yin, Xu Zhong-zi and Wu Ke-ru (China)	499
Investigation on the Possibility of Using $SiO_2/Na_2O$ as a Criterion for Determining the Expansibility of ASR	
..... Feng Nai-qian and Feng Xiao-xin (China)	505
Strength Characteristics of New Slag Cement	
..... Zhang Shu-qing, Yang Quan-bing and Wu Xue-li (China)	510
Research on Fine Powder of Steel-making Slag Used as Mineral Admixture for Flowing Concrete	



..... Chen Yi-min, Zhang Hong-tao, Lin Zhen, Guo Sui-hua and Zhang Wen-sheng (China)	515
Effects of Alkali Content of Cement on the Actions of High-grade Water-reducing Agent	
..... Sun Zhen-ping, Jiang Zheng-wu, Wang Yu-ji and Zhang Guan-lun (China)	521
Effect of Aggregate Size on Concrete Strength under Complex Stress State	
..... Wei Xue-ying, Li Jian-chun and Yu Mao-hong (China)	528
Image Analysis of Change in Pore Structure in Hardened Cement Paste during Early Age	
..... Kiyofumi Kurumisawa and Kyoji Tanaka (Japan)	532
Study on Mass Diffusivity of Concrete under Isothermal Condition	
..... Huang Da-hai and Liu Guang-ting (China)	538
Influence Factor on Service Life and Life Expectancy of Concrete	
..... Yu Hong-fa, Sun Wei, Ma Hai-yan and Yan Liang-hui (China)	545
Internal Relative Humidity Distribution in Cement Paste Due to Moisture Diffusion and Self-Desiccation	
..... Jiang Zheng-wu, Sun Zhen-ping and Wang Xin-you (China)	552
Influence of Particle Size Distribution of Cement System on Properties of Cement and Concrete	
..... Wu Xiao-mei, Fan Yue-ming and Guo Wen-ying (China)	558
Investigation of the Formation and the Transformation of Ettringite	
..... Peng Jia-hui (China)	565
Two-variable Strength Formula of Fly Ash Concrete	
..... Yang Qian-rong, Wu Xue-li and Zhang Ling-yi (China)	571
Non-destructive Monitoring System of Setting and Hardening of Cementitious Materials Based on the Dielectric and Ultrasonic Properties	
..... Ye Guang (The Netherlands), Antonio Princigallo (Italy), K. Van Breugel and A. L. A. Fraaij (The Netherlands)	577
Analysis of High Strain Rate Dynamic Tests on Concrete	
..... Han Zhao (France)	583
An Indirect Tension Test for Concrete	
..... Andrew Boyd (USA) and Sidney Mindess (Canada)	590
Discussion and Analysis on the types of Concrete Durability	
..... Li Zhi-guo (China)	595
Research on Durability Design of Modern Prestressed Concrete Structure	
..... Zhang De-feng and Lu Zhi-tao (China)	603
Quantitative Design on Frost-Resistance of the Concrete	
..... Li Jin-yu, Pen Xiao-ping, Deng Zheng-gang, Cao Jian-guo, Guan Yu-shi, Lin Li, Tian Jun-Tao, Li Fang, Wang Ai-qin, Wang Zhi-gang, Peng Tao, Cai Mei-zhu and Zhang Xiu-mei (China)	609
Effect of High Strength Additive on Reduction of Environmental Burden	
..... Kenji Yamamoto, Minoru Morioka, Yoshiharu Watanabe, Etsuo Sakai and Masaki Daimon (Japan)	618
Exploring the Cracks of Structures under Water by Ultrasonic Method	
..... Luo Qi-xian, Song Ren-xin, Fu Xiang and Wang Wu-ping (China)	624
Leaching Properties of Cement-based Solidified Zinc Sludge by Sequential Chemical Extraction	
..... Zhang Ya-mei, Sun Wei and Li Xiang-dong (China)	629
Study on the Rapid Test of Detecting Alkali Reactivity of Aggregates Used in Beijing	
..... Hao Ting-yu, Feng Nai-qian and Hui Yin-ling (China)	634
The Realization of Fly Ash Concrete Expert System	
..... Yang Qian-rong, Zhang Ling-yi and Wu Xue-li (China)	639



Quantitative Analysis on the Degradation Characteristics of High Strength Concrete Subjected to Freezing and Thawing Cycles	
..... Sun Wei, Guan Yu-gang and Miao Chang-wen (China)	645
Application of the Rebound Method and the Ultrasonic-rebound Method in the High-strength Concrete Non-destructive Test—Research and Formulate the Strength Test Curve in Kunming	
..... Lü Long, Zhao Bao-sheng, Liu Yong and Li Xin-cheng (China)	651
An Accelerated Method to Predict the Service Life of Concrete Constuctions Under Carbonation	
..... Zhou Jun-liang, Liu Nong and Xu Guan-shao(China)	657
A Study of the Dispersing Effects of Polycarboxylate-based Dispersant on Fine Particles	
..... Akira Ohta and Tomomi Sugiyama (Japan)	664
An New Annotation on the Dynamic Data of $\text{CaCO}_3$ Decomposition Reaction by TGA Test	
..... Chen Han-min (China)	671
Calculation of Load Doorsill Value of Creep of Cement Mortar under Static Load and Normal Temperature	
..... Huang Peng-fei, Bao Yi-wang and Yao Yan (China)	678
Character Research of Cement for Joints	
..... Guo Jun-cai, Xiang Xin, Zhang Qiu-ying, Guo Qi-qiang (China)	684



## **I . GENERAL LECTURE**







## ADVANCED CEMENT-BASED MATERIALS

J. Francis Young

(Professor Emeritus, University of Illinois  
474 Matahui Road, R. D. 2 Katikati, 3063 New Zealand)

**ABSTRACT** This paper discusses the changes in chemistry and microstructure that are the basis of advanced cement-based materials. The paper considers both processing required to achieve high performance with particular reference to systems densified by particle packing at the micron level, as well as the interrelationships between microstructure and properties. Modification of the cement-based matrix by fibers or polymers is also discussed.

**Key words** DSP cement; fiber-reinforcement; MDF cement

### 1 INTRODUCTION

Over the past twenty years concrete materials scientists and engineers have been steadily pushing the limits to the strength of cement-based materials. It is now possible to produce composites with compressive strengths exceeding 400 MPa, and tensile strengths greater than 200 MPa. However, it is now recognized that the issues of ductility and durability are more important than strength *per se*, so that it is important to understand how performance is linked to the chemical and physical make-up of the material. This paper attempts to summarize the current knowledge regarding the performance of advanced cement-based materials. Three distinct approaches have attracted considerable research effort in recent years. They are:

- (1) Dense, particle packed systems (e. g. DSP cements) that preserve castability while using very low water contents<sup>[1]</sup>;
- (2) High volume, fiber-reinforced composites to provide a high degree of ductility and strength<sup>[2]</sup>;

(3) Reactive cement-polymer composites (e. g. MDF cements) which harness the complementary properties of polymeric materials<sup>[3]</sup>.

The first system will be discussed in more detail since these systems are being used commercially and illustrate most of the important principles underlying the control of high performance in concretes.

### 2 FORMULATION OF DSP

#### 2.1 Processing

It is a challenge to produce castable cement-based composites with low water contents because of the negative impact on workability. High cement contents are required to maintain adequate workability, and with the use of superplasticizers concretes can be successfully produced and placed with a w/cm as low as 0.35. To achieve lower values requires the use of mineral admixtures in conjunction with superplasticizers (as summarized in Table 1). Fly ashes with suitable spherical morphology can improve workability and lower the w/cm values to 0.3 in favorable cases, but to



achieve lower water contents requires the use of silica fume because its sub-micron particle size allows it to pack between the cement grains. In this way spaces between cement grains that would normally have to be occupied by water are partially filled with other solid particles. This is the basis of castable DSP (Densified with Small Particles) systems which can have  $w/cm$  as low as 0.16<sup>[4, 5]</sup>. Only a 6 wt. % replacement of cement by silica fume can be effective<sup>[6]</sup>; larger replacements give quickly diminishing improvements, but can be used to control the phase composition of the hydrated paste matrix.

DSP systems require careful attention to processing in order to realize the full benefits of particle packing. Strengths can be more than doubled without changing the formulation simply by changing processing strategies (Table 2). High doses of superplasticizer are required, typically 2wt. % ~3 wt. % for the sulfonated naphthalene formulations, to successfully disperse both cement and silica fume, although the newer polycarboxylate admixtures are more effective. Separate mixing of the paste components under high shear seems to be the most efficacious form of processing. It is also necessary to avoid using densified fumes. These have been mechanically agglomerated (Fig. 1) and cannot be fully dispersed chemically, or by conventional mixing. Incomplete dispersion can lead to performance problems under certain circumstances<sup>[7]</sup>. Further densification by pressure dewatering is required to reduce  $w/cm$  ratios below 0.15. In this way,  $w/cm < 0.10$  and compressive strengths exceeding 400 MPa can be attained<sup>[5]</sup>.

**Table 1 Characteristics of Concretes**

	Regular	High Strength	V. High Strength	DSP
Compr. Str. (MPa)	<50	50~100	100~150	150
$w/cm$	>0.45	0.45~0.30	0.30~0.25	<0.25
Admixtures	NR*	WRA/SP*	SP	SP
Chemical mineral	NR	Fly ash	SF*	SF
Permeability (m/s)	<10 <sup>-12</sup>	10 <sup>-13</sup>	10 <sup>-14</sup>	<10 <sup>-15</sup>

\* NR = not required;

\* WRA = conventional water-reducing admixture;

SP = superplasticizer; SF = silica fume.

**Table 2 Processing Strategies to increase compressive strength ( $w/cm = 0.2$ )**

Conventional mixing	
with SP*	100 MPa
with SP + SF	125 MPa
SP + SF + de-airing	175 MPa
Pre-blending of solids + de-airing	
SP only	170 MPa
SP + SF; no reaction of SF	~240 MPa
SP + SF reacted at 25°C	310 MPa
as above. dried at 200°C	350 MPa

\* SP = superplasticizer;

SF = silica fume.

## 2.2 Particle packing

Effective particle packing depends on the relative size of particles and the number of different sizes<sup>[8]</sup>. Ternary systems can give denser packings than binary systems (see Table 3) and the relative particle size should not be greater than 10 : 1 for each size classification. Therefore in binary systems, if the mean cement particle size is 15  $\mu m$ , then the particle size of the smaller packing phase should not exceed 1.5  $\mu m$ . In principle calcined clays, such as metakaolin, should be able to achieve dense packings; but these materials are not as effective because of their platy morphology. The spherical morphology of silica fume particles, and the high relative size ratio (100 : 1), makes it the optimum choice. However, although smaller sizes do not give theoretically denser packings, they make it easier to approach the theoretical values more closely in practice. Nevertheless, long mixing times (> 10 min) are needed to give good packing.

## 2.3 Hydration chemistry

While particle packing is a purely physical phenomenon, silica fume is also a highly reactive pozzolan and modifies the hydration of the cement. Initially silica fume accelerates the hydration of alite and thus partially offsets the set retardation caused by the high dosage of superplasticizer. Later silica fume reacts pozzolanically with both calcium hydroxide and high-lime C-S-H gel formed by the hydration of alite and belite to give a low-lime C-S-H gel with the approximate composition  $CSH_x$ . The actual composition of C-