

Alkali-Aggregate Reaction

8th International Conference



EDITED BY

K. Okada, S. Nishibayashi and M. Kawamura

Copyright © 1989 by 8th ICAAR Local Organizing Committee
All rights reserved. No part of this book may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or other-wise, without the prior written permission of the publisher, 8th ICAAR Local Organizing Committee, The Society of Materials Science, Japan, 1-101 Yoshida Izumidono-cho Sakyo-ku, Kyoto 606, Japan.

Preface

In Japan, only few examples concerning deterioration of concrete structures due to alkali-aggregate reactions had been reported until 1975. However, cracking in concrete piers of Hanshin Expressway in Osaka was found to be caused by alkali-silica reaction in 1985.

Since then, nation-wide investigations for concrete structures have revealed that relatively large number of concrete structures are damaged by alkali-silica reaction almost all over Japan.

Even if preventive measures implemented in these several years in Japan will act effectively, occurrence of deterioration in concrete due to alkali-silica reaction is afraid of continuing over coming several decades.

In this situation, it is a great pleasure for us to organize the 8th International Conference on Alkali-Aggregate Reaction in Japan.

Since the detection of the phenomenon of alkali-aggregate reaction in concrete by T.E. Stanton in 1940, researches on the mechanism of the reactions, methods of examinations on the basis of petrography, evaluation of alkali reactivity of aggregates and the effects of mineral admixtures on the reactions have been actively pursued.

As the results, technology for preventing concrete from deteriorating due to alkali-aggregate reaction appears to have reached a considerable level. Particularly, understanding of various complicated phenomena with respect to the alkali-silica reaction has been deepened in recent years as a reflection of the development of studies from the aspect of pore solution chemistry, although several problems remain unsolved.


On the other hand, a large number of presentations with respect to assessment and repair of concrete structures affected by alkali-aggregate reaction have begun to be reported since the last Conference in Canada. In this Proceedings, we have also received the largest number of papers related to Assessment and Repair of Damaged Concrete Structures, which is classified into Session 6.

Rapid increase in the number of papers on structural phenomenon and repair in recent years reflects a strong demand for establishment of evaluation technique of safety of damaged concrete structures and development of technology for their repair to maintain their design life.

Contributions and discussions from various aspect in the Conference are certainly beneficial to professionals in the field of concrete industries. The Conference is also expected to stimulate research activities on alkali-aggregate reactions in various countries in future.

The support given by all members of the International Organizing Committee, the Local Organizing Committee, the Executive Committee and all others who have contributed to the planning and execution of the Conference is cordially appreciated.

I would like to express deep acknowledgements to all the Conference sponsors whose support was indispensable for the Local Organizing Committee to achieve great success in running of this Conference.

A handwritten signature in cursive script that reads "Kiyoshi Okada". The signature is written in black ink and is positioned above the printed name.

Kiyoshi Okada

Chairman, 8th ICAAR Local Organizing Committee
Professor Emeritus of Kyoto University

Organization

International Organizing Committee

M. Berra	Italy	S. Diamond	USA
P.E. Grattan-Bellew	Canada	G.M. Idorn	Denmark
K. Kishitani	Japan	U. Ludwig	FRG
B. Mather	USA	R.E. Oberholster	RSA
K. Okada	Japan	A.B. Poole	UK
M. Regourd-Moranville	France	A. Shayan	Australia
D.A. St John	New Zealand	N. Tenoutasse	Belgium

Local Organizing Committee

K. Okada (Chairman)		H. Muguruma (Vice-Chairman)	
M. Fujii	Y. Fujita	K. Imai	M. Kawamura
K. Kohno	T. Kojima	W. Koyanagi	K. Kuwabara
S. Morita	S. Nagataki	K. Nakano	K. Nanjo
S. Nishibayashi	K. Ono	Y. Osaka	T. Shiire
E. Tazawa	F. Tomosawa	A. Watanabe	

Executive Committee

S. Nishibayashi (Chairman)			
Y. Fujiwara	M. Kawamura	K. Kobayashi	T. Kojima
T. Miyagawa	K. Nakano	K. Ono	

Program Sub-Committee

M. Kawamura (Chairman)	
K. Sakata	K. Yamura

Co-Sponsors

ASAHI CONCRETE WORKS CO., LTD.
CONSTEC ENGINEERING CO.
GENERAL BUILDING RESEARCH CORPORATION
HANSHIN EXPRESSWAY ADMINISTRATION AND TECHNOLOGY CENTER
JAPAN CIVIL ENGINEERING CONTRACTORS' ASSOCIATION, INC.
JAPAN CONCRETE ADMIXTURE ASSOCIATION
JAPAN FLY ASH ASSOCIATION
KINKI CONCRETE INDUSTRIES CO., LTD.
KONISHI CO., LTD.
MARUI & CO., LTD.
NATIONAL READY MIXED CONCRETE INDUSTRY ASSOCIATION
NETUREN CO., LTD.
NIPPON SLAG ASSOCIATION
NIPPON STRUCTURAL INSPECTION AND TECHNOLOGY ASSOCIATION
SHO-BOND CONSTRUCTION CO., LTD.
THE CEMENT ASSOCIATION OF JAPAN
THE IRON AND STEEL INSTITUTE OF JAPAN
YAMASOU CHEMICAL CO., LTD.
YOSHIDA CONSTRUCTION CO., LTD.

Contributors

ARCHITECTURAL INSTITUTE OF JAPAN
JAPAN SOCIETY OF CIVIL ENGINEERS
THE CEMENT ASSOCIATION OF JAPAN
THE JAPAN CONCRETE INSTITUTE
THE SOCIETY OF MATERIALS SCIENCE, JAPAN

Contents

General Session

			Page
G-1	G.M. Idorn	Alkali-Silica Reactions in Retrospect and Prospect	1
G-2	J. Figg	An Historical Perspective on One-and-Half Decades of AAR Research	9
G-3	S. Nishibayashi	Alkali-Aggregate Reactivity in Japan—A Review	17

Opening Session

O-1	A. Carse P. Dux	Alkali-Silica Reaction in Australian Concrete Structures	25
O-2	D.W. Hobbs	Cracking and Expansion due to Alkali-Silica Reaction in the United Kingdom	31
O-3	S. Chatterji	A Critical Review of the Recent Danish Literature on Alkali-Silica Reaction	37
O-4	D. Van Gemert	Alkali-Aggregate Reaction in Belgium : Concrete Highway and Office Building	43
O-5	D.A. St John	Alkali-Aggregate Reaction in New Zealand —A Continuing Problem	51
O-6	C.A. Rogers	Alkali-Aggregate Reactivity in Canada	57
O-7	H. Ólafsson	AAR Problems in Iceland—Present State	65
O-8	G. Baronio M. Berra	The Occurrence of AAR in a Concrete Structure in Italy	71
O-9	R.E. Oberholster	Alkali-Aggregate Reaction in South Africa : Some Recent Developments in Research	77

Session 1

K-1	S. Diamond	ASR—Another Look at Mechanisms	83
S1A-1	G. West R.G. Sibbick	A Mechanism for Alkali-Silica Reaction in Concrete Roads	95
S1A-2	S. Chatterji	Mechanisms of Alkali-Silica Reaction and Expansion	101
S1A-3	I. Meland	Alkali-Silica Reaction in Tilecovered Concrete	107
S1A-4	M. Kawamura K. Takemoto M. Ichise	Influences of the Alkali-Silica Reaction on the Corrosion of Steel Reinforcement in Concrete	115
S1A-5	H. Uchikawa S. Uchida S. Hanehara	Relationship between Structure and Penetrability of Na Ion in Hardened Blended Cement Paste, Mortar and Concrete	121

			Page
S1A-6	P.J. Nixon C.L. Page J. Hardcastle I. Canham K. Pettifer	Chemical Studies of Alkali Silica Reaction in Concrete with Different Flint Contents	129
S1A-7	T. N. Jones	Mechanism of Reactions Involving British Chert and Flint Aggregates	135
S1A-8	Y. Seno Y. Mori K. Kobayashi	Expansion Properties of Mortars and Variation in Components of Pore Solutions due to Alkali-Aggregate Reaction	141
S1B-1	M. Tang Y. Lu S. Han	Kinetics of Alkali-Carbonate Reaction	147
S1B-2	T. Yonezawa V. Ashworth R.P.M. Procter	The Mechanism of Fixing Cl^- by Cement Hydrates Resulting in the Transformation of NaCl to NaOH	153
S1B-3	A. Carles-Gibergues J.P. Ollivier B. Fournier M.A. Bérubé	A New Approach to the Study of Alkali-Aggregate Reaction Mechanisms	161
S1B-4	L. Struble S. Diamond	Influence of Cement Pore Solution on Expansion	167
Session 2			
K-2	D.W. Hobbs	Effect of Mineral and Chemical Admixtures on Alkali Aggregate Reaction	173
S2A-1	H. Wang J.E. Gillott	The Effect of Superplasticizers on Alkali-Silica Reactivity	187
S2A-2	P.P. Hudec E.Y. Larbi	Chemical Treatments and Additives to Minimize Alkali Reactivity	193
S2A-3	G.K. Moir J.S. Lumley	Influence of Partial Cement Replacement by Ground Granulated Slag on the Expansion of Concrete Prisms Containing Reactive Silica	199
S2A-4	R.N. Swamy M.M. Al-Asali	Effectiveness of Mineral Admixtures in Controlling ASR Expansion	205
S2A-5	H. Nomachi M. Takada K. Harada S. Nishibayashi	Effects of Admixtures on Expansion Characteristics of Concrete Containing Reactive Aggregate	211
S2A-6	A.K. Mullick R.C. Wason C. Rajkumar	Performance of Commercial Blended Cements in Alleviating ASR	217
S2A-7	Chau Lee	Active Alkalis in Cement-Fly Ash Paste	223

S2A-8	Y. Sakaguchi M. Takakura A. Kitagawa T. Hori F. Tomosawa M. Abe	The Inhibiting Effect of Lithium Compounds on Alkali-Silica Reaction	229
S2B-1	G. Samuel R.C. Wason A.K. Mullick	Evaluation of AAR Potential of Limestone Aggregates in India	235
S2B-2	J. Farbiarz D.C. Schuman R.L. Carrasquillo P.G. Snow	Alkali-Aggregate Reaction in Fly Ash Concrete	241
S2B-3	K. Kohno A. Sugimoto T. Kashiwai	Effects of Finely Ground Silica, Silica Fume and Red Mud on Alkali-Silica Reaction and Concrete Strength	247
S2B-4	Y. Ohama K. Demura M. Kakegawa	Inhibiting Alkali-Aggregate Reaction with Chemical Admixtures	253
S2B-5	K. Ukita S. Shigematsu M. Ishii K. Yamamoto K. Azuma M. Moteki	Effect of Classified Fly Ash on Alkali Aggregate Reaction (AAR)	259
S2B-6	T. Kojima S. Amasaki N. Takagi	Effectiveness of Silica Fume in Reducing Damage due to Alkali-Silica Reaction	265
S2B-7	M. Kawamura M. Koike K. Nakano	Release of Alkalis from Reactive Andesitic Aggregates and Fly Ashes into Pore Solution in Mortars	271

Session 3

K-3	P.E. Grattan-Bellew	Test Methods and Criteria for Evaluating the Potential Reactivity of Aggregates	279
S3A-1	S. Chatterji	A Simple Chemical Test Method for the Detection of Alkali-Silica Reactivity of Aggregates	295
S3A-2	M. Ohtsu	Short-Term Evaluation of Mortar Bar Test by Acoustic Emission	301
S3A-3	D. Sorrentino R. Ranc B. Cariou	Methodology of an Industrial Research Laboratory to Assess the Reactivity of Aggregates. Focus on Reproducibility Problems	307
S3A-4	P.P. Hudec J.A. Larbi	Rapid Methods of Predicting Alkali Reactivity	313

			Page
S3A-5	A. Shayan	Experiments with Accelerated Tests for Predicting Alkali-Aggregate Reactivity	321
S3A-6	C.A. Rogers R.D. Hooton	Leaching of Alkalies in Alkali-Aggregate Reaction Testing	327
S3B-1	H. Tatematsu T. Sasaki	Proposal of a New Index for a Modified Chemical Method	333
S3B-2	K. Ishikawa H. Chino K. Katawaki	Study on New Rapid Test Method for Evaluating Aggregate Reactivity	339
S3B-3	S. Miura S. Kanamitsu T. Yamamoto J. Kawanishi	Relation between Dissolution of Aggregate in Alkali Solution and Mortar-Bar Expansion	345
S3B-4	H. Tamura T. Takahashi M. Ohashi	A Test Method on Rapid Identification of the Future Susceptibility of Alkali-Aggregate Reaction in Fresh Concrete (Fresh-Con GBRC Rapid Method)	351
S3B-5	K. Kishitani M. Kobayashi	Development and Standardization of a Rapid Test Method for Identification of the Alkali Reactivity of Aggregates	357
S3B-6	B. Fournier M.A. Bérubé	Alkali-Reactivity Potential of Carbonate Rocks from the St. Lawrence Lowlands (Quebec, Canada)	363
S3C-1	M. Abe F. Tomosawa T. Mano K. Togasaki	A Study on the Simple Rapid Test Method Used to Judge the Alkali Reactivity of Aggregate	369
S3C-2	T. Kanazu H. Ohnuma T. Nakano H. Ishida	Study on the Rapid Estimation Method of Alkali Aggregate Reaction Using Concrete Specimens	375
S3C-3	C. Tashiro K. Yamada	Study of Relationship between Alkali-Aggregate Reaction and Electrical Resistivity	381
S3C-4	S. Kobayashi H. Kawano K. Morihama Y. Ishii	A Study on Accuracy of 40mm Mortar Bar Test	385
S3C-5	S. Kobayashi T. Takaki M. Tsujiko A. Hirama	A Simple Concrete Bar Test with Double Layered Cylindrical Specimens	391
S3C-6	C. Clergue A. Corneille	Search to a New, Rapid and Reliable Test Method with a View to Evaluate the Damage Risk in Concrete due to Alkali-Aggregate Reaction	397
S3D-1	R. Duggan F. Scott	New Test for Deleterious Expansion in Concrete	403

S3D-2	K. Nakano I. Ginyama S. Yoneda F. Shibazaki T. Sone R. Tomita K. Watada Y. Murota Y. Nagao H. Ushiyama Y. Tomita Y. Murata	Study on Expansion Properties of Alkali Reactive Aggregate by Concrete	409
S3D-3	K. Katawaki S. Moriya Y. Wakisaka O. Kato	Comparison of the Results of the Chemical Method and Mortar Bar Expansion Test for Determining Aggregate Reactivity	417
S3D-4	J.W. Schmitt D.C. Stark	Recent Progress in Development of the Osmotic Cell to Determine Potential for Alkali-Silica Reactivity of Aggregates	423
S3D-5	L. Struble M. Brockman	Standard Aggregate Materials for Alkali-Silica Reaction Studies	433
S3D-6	R.D. Hooton C.A. Rogers	Evaluation of Rapid Test Methods for Detecting Alkali- -Reactive Aggregates	439

Session 4

K-4	M. Regourd -Moranville	Products of Reaction and Petrographic Examination	445
S4A-1	M. Tang M. Wang S. Han	Microstructure and Alkali Reactivity of Siliceous Aggregate	457
S4A-2	E. Soers M. Meyskens	Petrographical Research on Alkali-Aggregate Reactions in Concrete Structures in Belgium	463
S4A-3	O. Kato S. Moriya H. Chino K. Ishikawa K. Katawaki	Study on Analytical Techniques for Improving the Chemical Method	469
S4A-4	A. Shayan G. Quick	Microstructure and Composition of AAR Products in Conventional Standard and New Accelerated Testing	475
S4A-5	M.G. Alexander J.R. McIver S.M. Glynn	Assessment of the Deterioration of an Airport Concrete Apron due to AAR	483
S4A-6	K.T. Andersen N. Thaulow	The Application of Undulatory Extinction Angles (UEA) as an Indicator of Alkali-Silica Reactivity of Concrete Aggregates	489

			Page
S4A-7	L.H. Rao S.K. Sinha	Textural and Microstructural Features of Alkali Reactive Granitic Rocks	495
S4A-8	K. Morino	Alkali Aggregate Reactivity of Cherty Rock	501
S4B-1	G. Barisone G. Bottino R. Pavia	Alkali-Silica Reaction Potentially Bearing Minerals in Alluvial Deposits of Calabria, Umbria, and Toscana Regions (ITALY)	507
S4B-2	T. Uno	Alkali-Silica Reactions by Opal Particles in Japan	513
S4B-3	Y. Wakizaka S. Moriya H. Kawano K. Ichikawa	Mineralogical Interpretations of Dissolved Silica and Reduction in Alkalinity of the Chemical Method	519
S4B-4	T. Katayama T. Futagawa	Diagenetic Changes in Potential Alkali-Aggregate Reactivity of Siliceous Sedimentary Rocks in Japan —A Geological Interpretation	525
S4C-1	T. Katayama T. Futagawa	Alkali-Aggregate Reaction in New Brunswick, Eastern Canada—Petrographic Diagnosis of the Deterioration	531
S4C-2	T. Katayama D.A. St John T. Futagawa	The Petrographic Comparison of Some Volcanic Rocks from Japan and New Zealand —Potential Reactivity Related to Interstitial Glass and Silica Minerals	537
S4C-3	T. Nishiyama H. Kusuda K. Nakano	A Few Remarks on Alkali-Reactive Chert Aggregates	543
S4C-4	I. Nishizaki K. Katawaki	The Characterization of ASR Products and Alkalies in Cement Paste	549
S4C-5	K. Natesaiyer K. C. Hover	Some Field Studies of the New Insitu Method for Identification of Alkali Silica Reaction Products	555
S4C-6	J.S. Lumley	Synthetic Cristobalite as a Reference Reactive Aggregate	561
S4C-7	R. Shiraki K. Kobayashi	Quality and Quantity Determinations of Reactive Substances in Volcanic Rocks	567
S4C-8	N. Thaulow J. Holm K.T. Andersen	Petrographic Examination and Chemical Analysis of the Lucinda Jetty Prestressed Concrete Roadway	573

Session 5

K-5	U. Ludwig	Effects of Environmental Conditions on Alkali —Aggregate Reaction and Preventive Measures	583
S5-1	H. Kawakami	A Reinforced Concrete Building Deformed by Alkali Aggregate Reaction	597

S5-2	H. Hamada N. Otsuki T. Fukute	Properties of Concrete Specimens Damaged by Alkali-Aggregate Reaction, Laumontite Related Reaction and Chloride Attack under Marine Environments	603
S5-3	K. Okada M. Tezuka T. Yoshikawa M. Himeno M. Komada	Alkali Aggregate Reaction : An Investigation on Its Causes and Strength Evaluations of Materials Subjected to Its Effects	609
S5-4	S. Nishibayashi K. Yamura K. Sakata	Research on Influence of Cyclic Wetting and Drying on Alkali-Aggregate Reaction	617
S5-5	G. Davies R.E. Oberholster	The Effect of Different Outdoor Exposure Conditions on the Expansion due to Alkali-Silica Reaction	623 ←
S5-6	T. Kurihara K. Katawaki	Effects of Moisture Control and Inhibition on Alkali Silica Reaction	629
S5-7	H. Chen P.E. Grattan-Bellew	Effect of Cement Composition on Expansion of Mortar Bars due to Alkali-Silica Reaction	635
S5-8	K. Kobayashi R. Shiraki K. Kawai	Influence of Alkali Concentration Distribution Occurring in Concrete Members on Expansion and Cracking due to Alkali-Silica Reaction	641

Session 6

K-6	K. Ono	Assessment and Repair of Damaged Concrete Structure	647 X
S6A-1	L.A. Clark K.E. Ng	The Effects of Alkali Silica Reaction on the Punching Shear Strength of Reinforced Concrete Slabs	659
S6A-2	K. Takemura E. Tazawa A. Yonekura Y. Abe	Mechanical Characteristics of Reinforced Concrete Column Affected by Alkali Aggregate Reaction	665
S6A-3	N. Clayton	Structural Performance of ASR Affected Concrete	671
S6A-4	D.K. Doran J.F.A. Moore	Appraisal of the Structural Effects of Alkali-Silica Reaction	677
S6A-5	R.N. Swamy	Structural Implications of Alkali Silica Reaction	683
S6A-6	M. Abe S. Kikuta Y. Masuda F. Tomosawa	Experimental Study on Mechanical Behavior of Reinforced Concrete Members Affected by Alkali-Aggregate Reaction	691
S6B-1	S. Ohno Y. Yoshioka Y. Shinozaki T. Morikawa	The Mechanical Behaviour of Beams Coated after Alkali Silica Reaction Damage	697

			Page
S6B-2	T. Kojima M. Tomita K. Nakano A. Nakaue	Expansion Behavior of Reactive Aggregate Concrete in Thin Sealed Metal Tube	703
S6B-3	K. Okada Y. Mizumoto K. Nakano K. Ono M. Matsumura	Study of Alkali-Silica Reaction by Reinforced Concrete Models	709
S6B-4	A. Shayan I. Ivanusec	Influence of NaOH on Mechanical Properties of Cement Paste and Mortar with and without Reactive Aggregate	715
S6B-5	R. Pleau M.A. Bérubé M. Pigeon B. Fournier S. Raphaël	Mechanical Behavior of Concrete Affected by ASR	721
S6B-6	S. Inoue M. Fujii K. Kobayashi K. Nakano	Structural Behaviors of Reinforced Concrete Beams Affected by Alkali-Silica Reaction	727
S6C-1	G.E. Blight	Experiments on Waterproofing Concrete to Inhibit AAR	733
S6C-2	D. Palmer	Aspects of the Diagnosis of Alkali-Silica Reaction	741
S6C-3	J.F.A. Silveira J.C. Degaspere A.J.C.T. Cavalcanti	The Opening of Expansion Joints at the Moxotō Powerhouse to Counteract the Alkali-Silica Reaction	747
S6C-4	H. Ichihara M. Shimamura I. Koshiishi	Alkali Aggregate Reaction in Railway Prestressed Concrete Bridges	753
S6C-5	S. Nishibayashi K. Yamura K. Sakata	Evaluation of Cracking of Concrete due to Alkali -Aggregate Reaction	759
S6C-6	J.G.M. Wood P. Norris D. Leek	Physical Behaviour of AAR Damaged Concrete in Structures and in Test Conditions	765
S6D-1	M. Ishizuka S. Utoh K. Kuzume M. Sugimoto M. Nishiboshi	Characteristics of Road Structures Damaged by AAR on the Hanshin Expressway due to Continuous Observation	771
S6D-2	M. Tomita T. Miyagawa K. Nakano	Basic Study for Diagnosis of Concrete Structure Affected by Alkali-Silica Reaction Using Drilled Concrete Core	779

S6D-3	J.G.M. Wood R.A. Johnson	An Engineers Perspective on U.K. Experience with Alkali-Aggregate Reaction	785
S6D-4	K. Okada S. Utoh H. Imai K. Ono	Concrete Structures Damaged by Alkali-Silica Reaction	791
S6D-5	A.J.C.T. Cavalcanti J.F.A. Silveira	Investigations on the Moxotō Powerhouse Concrete Affected by Alkali-Silica Reaction	797
S6D-6	S. Kobayashi H. Kawano K. Morihama Y. Ishii	The Background of AAR Preventive Measures Adopted by the Japanese Ministry of Construction	803
S6E-1	S. Raphaël S.L. Sarkar P.- C. Aïtcin	Alkali-Aggregate Reactivity — Is It Always Harmful?	809
S6E-2	M. Takeyoshi K. Katawaki	Study on the Effect of Concrete Surface Coating for Prevention of Alkali Silica Reaction	815
S6E-3	A. Kobayashi K. Kirimura K. Kuboyama T. Kojima	Evaluation of Surface Treatment Effect for Preventing Excessive Expansion due to Alkali-Silica Reaction	821 *
S6E-4	T. Taki M. Takeyoshi K. Noda K. Katawaki	Suppression of Alkali-Aggregate Reaction by Concrete Surface Coating	827
S6E-5	M. Koike K. Katawaki S. Moriya	Development of Injection Materials and the Standard for Repairing Damage to Structures Caused by AAR	833
S6E-6	S. Amasaki N. Takagi	The Estimate for Deterioration due to Alkali-Silica Reaction by Ultrasonic Spectroscopy	839
S6F-1	W. Koyanagi K. Rokugo H. Morimoto H. Iwase	Characteristics and Simulation of Concrete Cracks Caused by AAR	845
S6F-2	K. Katawaki	Recent Diagnosis and Repair Techniques for Damaged Concrete Structure by ASR —a guideline for public works structure—	851 *
S6F-3	<u>S. Moriya</u> H. Obata K. Katawaki M. Koike	Study on the Reducing Reactivity Rate of Concrete Used with Repairing Materials in Laboratory and Field	857

x

			Page
* S6F-4	K. Kobayashi T. Kojima S. Utoh K. Ono M. Matsumura	Repair of Concrete Structures Damaged by Alkali -Silica Reactions and Its Effects	863
S6F-5	M. Fujii T. Miyagawa M. Tomita K. Ono M. Imae	Effect of Coating to Inhibit Alkali-Aggregate Reaction of Concrete Structures	869
S6F-6	M. Fujii K. Kobayashi T. Miyagawa M. Hisada	Surface Treatment for Concrete Structures Damaged by Alkali-Aggregate Expansion	875
S6F-7	F. Tomosawa K. Tamura M. Abe	Influence of Water Content of Concrete on Alkali -Aggregate Reaction	881