



ALKALI-AGGREGATE REACTION IN CONCRETE

Edited by

Ahmad Shayan

Proceedings of the 10th International Conference on
Alkali-Aggregate Reaction in Concrete

18-23 August 1993

Melbourne

Australia

ALKALI-AGGREGATE REACTION IN CONCRETE



ALKALI-AGGREGATE REACTION IN CONCRETE

Edited by

Ahmad Shayan

**CSIRO Division of Building Construction and Engineering
Melbourne, Australia**

**Proceedings of the 10th International Conference on
Alkali-Aggregate Reaction in Concrete**

**18 - 23 August 1996
Melbourne
Australia**

National Library of Australia Cataloguing -in-Publication data

**International Conference on Alkali-Aggregate Reaction in
Concrete (10th : 1996 : Melbourne, Vic.).
Alkali-Aggregate Reaction in Concrete : Proceedings of the
10th International Conference on Alkali-Aggregate Reaction
in Concrete, 19-23 August 1996, Melbourne, Australia.**

Bibliography.

ISBN 0 646 28124 0.

**1. Alkali-Aggregate Reactions - Congress. 2. Concrete -
Chemistry - Congress. 3. Aggregates (Building Materials)
- Congresses. I. Shayan, A. (Ahmad), 1946-. II. AARC
Australia. III. Title.**

620.136

Preface

Australia was one of the very first few countries that started research in the field of alkali-aggregate reaction (AAR) in the early 1940s, after damage (cracking) reported to some concrete structures in the USA was attributed by STANTON to an expansive reaction between the cement and aggregate phases in the concrete. Although extensive research overseas and at CSIRO in Australia provided greater understanding of the phenomenon of AAR, field cases of damage to concrete structures were few and limited to certain geographical locations, largely in the USA.

In the following decades, increasing numbers of AAR -damaged structures have been identified in many countries around the world, and the early false assumption that AAR was unlikely to occur in certain countries was proven to be wrong. The concern for the damaging effects of AAR is apparent from the numerous publications in this field and the Nine international conferences held on the topic since the mid 1970s, the last being in London in 1992.

Despite extensive research on AAR in Australia in the early days, actual cases of damage to concrete structures only began to be identified in the 1980s; the number increasing considerably towards the 1990s. Given both the reported and recently identified, but unreported, cases of AAR here, a suggestion from the International AAR committee (IAARC) to hold the 10th international meeting in Australia was put to local interest groups before the London meeting. Sufficient enthusiasm and support were expressed for accepting the suggestion of the IAARC, and planning for the 10th meeting in 1996 began

The early prominence of Australia in AAR research makes it fitting that the International AAR Conference should be held here, and it is my hope that the awareness of AAR problems and solutions will be enhanced in our local industry by opportunities to meet with the world's experts in the field.

The 10th IAAR conference has enjoyed considerable support both from the scientific and industrial sectors. The conference proceedings contain around 130 technical papers which will be presented at the conference, and cover the most recent developments in AAR, both in research and practice. The conference is intended to create strong links, and facilitate the interaction between Science, Engineering and Practice. Technical and Trade Exhibitions will also strengthen this link. It is hoped that the delegates will vigorously participate in this interaction and gain the utmost benefit from this highly valuable opportunity.

The gathering together at this conference of so many leading experts is in itself a great success. The sharing of ideas and discussions during the conference, and the bridging of gaps, will further strengthen this achievement. As with other successful conferences, many parties have been instrumental in the success and must be mentioned here and thanked for their efforts.

Various private and public organisations provided the much-needed initial and ongoing financial support which was of great logistical importance and allowed the required activities to proceed at the various preparatory stages of the conference. The list of the Financial Sponsors is given separately, and their generous contributions are gratefully acknowledged

I would like to thank all the authors for their highly valued papers, who have also done an excellent job in preparing their papers on time at various stages of reviewing and amendment. Thanks are due to many local and international colleagues, listed separately, who kindly accepted to referee the submitted papers and helped to improve them where required.

The efforts of the members of the International AAR Committee in providing advice when asked, writing state-of-the-art papers, reviewing other papers and promoting the conference overseas are greatly appreciated..

I sincerely thank the members of the Local Organising Committee and their supporting organisations, whose time and efforts made this conference possible. Particularly, thanks are due to Russell Diggins, conference secretary, for his close attention to all the many tasks demanded of him.

I trust that this collection of papers is of great value not only to the delegates at the conference, but also to those who will venture into the complex areas of AAR research , remediation and management.

Ahmad Shayan
Conference Chairman
August 1996.

Conference Organisation

Local Organising Committee:

Ahmad Shayan (Chairman)
Russell Diggins (Secretary)
Peter Paterson (Treasurer)
Frank Collins (Assist. Secretary)
Ken McGregor
Fred Andrews-Phaedonos
Vin Wallis
Harold Vivian
Brendan Corcoran
Graham Loomes
Warren Green
Lex Ferguson

CSIRO
CSIRO
Pozzolanic Enterprises
Taywood Engineering
VicRoads
VicRoads
Concrete Technology Services
Consultant
Corcoran Shepherd Consultants
GR Loomes & Co.
Taywood Engineering
Consultant

Interstate Liaison:

Alan Carse
Ian Ross
Theo Pandich

Main Roads, Queensland
Main Roads Dept, West. Australia
Roads & Traffic Authority, NSW

International AAR Committee:

M. Berra
S. Diamond
P.E. Grattan-Bellew
G.M. Idorn
K. Kishitani
U. Ludwig
B. Mather
M. Tang
A.K. Mullick
S. Nishibayashi
R.E. Oberholster
H. Olafsson
A.B. Poole
M. Moranville-Regourd
D.A. St John
A. Shayan (Conference Chairman)
N. Tenoutasse

Italy
USA
Canada
Denmark
Japan
Germany
USA
China
India
Japan
South Africa
Iceland
UK
France
New Zealand
Australia
Belgium

Financial Sponsors

The following organisations have financially supported the conference from the early stages of organisation and preparation. Their support has been very important for the success of the conference and is gratefully acknowledged.

- Australin Tourist Commission
- Main Roads Department, Western Australia
- Roads and Traffic Authority, New South Wales
- Main Roads, Queensland
- Pozzolanic Enterprises, Queensland
- Ash Development Association of Australia, New South Wales
- Cement & Concrete Association of Australia
- Australasian Slag Association, New South Wales
- CSR Readymix Australia
- European Research Office, United States Army
- A generous loan by the Federal Department of Industry , Trade and Regional Development, through the Institution of Engineers Australia

Technical & Trade Exhibitions

The following companies are providing Technical and Trade Exhibits at the conference venue:

- Konoike Construction Company, Japan
- Ash Development Association of Australia
- Master Builders Technology (MBT) Australia, Pty Ltd
- FMC Corporation, Lithium Division, North Carolina, USA
- Fosroc International
- Pozzolanic Enterprises Pty Ltd, Queensland
- Dry Treat (Australia)

List of Reviewers for Papers Submitted to The 10th International AAR Conference

Name	Country	Papers Reviewed
1 -Dr. M. Berra	Italy	5
2 -Dr. A. Carse	Australia	4
3 -Mr. F.G. Collins	Australia	6
4 -Mr. B. Corcoran	Australia	5
5 -Prof. S. Diamond	U.S.A.	5
6 -Mr. B. Fournier	Canada	2
7 -Mr. W.J. French	U.K.	2
8 -Dr. P.E. Grattan-Bellew	Canada	5
9 -Mr. W.K. Green	Australia	3
10 -Dr. D.W. Hobbs	U.K.	5
11 -Prof. R.D. Hooton	Canada	2
12 -Dr. G.M. Idorn	Denmark	2
13 -Prof. M. Kawamura	Japan	3
14 -Mr. G. Loomes	Australia	1
15 -Dr. B. Mather	U.S.A.	5
16 -Prof. M. Moranville-Regourd	France	7
17 -Prof. S. Nishibayashi	Japan	3
18 -Dr. P.J. Nixon	U.K.	4
19 -Dr. R.E. Oberholster	S.Africa	5
20 -Prof. C.L. Page	U.K.	2
21 -Dr. A.B. Poole	U.K.	5
22 -Mr. C. Rogers	Canada	2
23 -Prof. D.M. Roy	U.S.A.	2
24 -Mr. M. Salomon	France	2
25 -Dr. A. Shayan	Australia	25
26 -Dr. I. Sims	U.K.	5
27 -Mr. D. Stark	U.S.A.	2
28 -Mr. D.A. St. John	New Zealand	6
29 -Prof. R.N. Swamy	U.K.	5
30 -Prof. M. Tang	P.R.China	4
31 -Mr. N. Thaulow	Denmark	1
32 -Mr. M.D.A. Thomas	Canada	3
33 -Mr. H.E. Vivian	Australia	8
34 -Mr. V. Wallis	Australia	6
35 -Dr. J.G.M. Wood	U.K.	3

Contributors

- Adachi, Y. 1041
Al-Kadhimi, T.K.M. 637
Allen, G.C. 814
Andrei, V. 227, 957
Ashby, J.B. 385
Balendran, R.V. 678
Ballivy, G. 466
Banfill, P.F.G. 637
Barisone, G. 288, 775
Baulande, B. 806
Bayer, D. 622
Berra, M. 483
Berube, M.A. 830, 899, 1056
Bian, Q. 546, 645, 868
Bilodeau, A. 101
Blackwell, B.Q. 492, 554
Blaikie, N.K. 500
Bleszynski, R. 324
Blight, G. 987
Boisvert, L. 1056
Bournazel, J.P. 686, 694, 949
Bowling, A.J. 500
Boyko, S. 271
Braga Reis, M.O. 93, 142
Bragg, D. 243
Braithwaite, M. 271
Brivot, F. 927
Burley, E. 418, 442
Capra, B. 686
Carse, A. 500, 1025
Chouinard, D. 1056
Chu, B.L. 166
Chung, J. 117
Clark, L.A. 394
Collins, F.G. 85, 1018
Connell, M.D. 530
Cope, R.J. 434
Cousy, O. 662
Criaud, A. 957
Dan, Y. 719
Davies, M. 1018
De Casa, G. 483
Demura, K. 846
Deng, M. 195, 251, 265, 310
Diamond, S. 3
Diggins, R.G. 538
Domitru, I. 191
Domon, K. 1010
Dron, R. 927
Duchesne, J. 830, 899
Dunbar, P.A. 324
Durand, B. 466, 522
Ebert, R. 919
Fasseu, P. 583
Feng, H.M. 578
Ferguson, J.A. 703
Fournier, B. 101, 302
Freitag, S.A. 150, 183
French, W.J. 570
Frenette, J. 1056
Frey, R. 219
Fu, P.X. 578
Fujii, M. 591, 995, 1041
Fukuda, H. 1010
Gilbert, S.T. 158
Ginyama, I. 719
Glasser, F.P. 792
Godart, B. 583, 892
Goguel, R. 783
Grace, W.R. 1018
Grattan-Bellew, P.E. 27
Gravel, C. 466
Green, W.K. 85, 1018
Gudmundsson, G. 562
Guedon-Dubied, J-S. 202, 514, 798
Guo, H. 474, 912
Han, S. 195, 973
Hattori, A. 591
Haynes, C.A. 750
Heijnen, W.M.M. 109
Helgason, T.S. 377
Higgins, D.D. 530
Hobbs, D.W. 209, 316
Hooton, R.D. 280
Hori, T. 606
Hornain, H. 514, 978
Huang, Q. 578
Hubert, C. 919
Humphrey, M. 622
Hunger, K-J. 219
Hyun, S-K. 711
Ichitsubo, M. 410
Idorn, G. 15
Imada, K. 995
Inoue, S. 370
Ishii, K. 653
Ivanusec, I. 538
Iwase, H. 458
Iwashita, N. 719
Jehenne, F. 978
Jensen, V. 133
Joly, M. 670
Jones, A.E.K. 394
Joyce, A.S. 767
Kamimoto, H. 606
Karimi, M. 348
Katayama, T. 243, 294, 377
Kawamura, M. 630, 653, 838, 965
Kishitani, K. 332
Kobayashi, K. 1041

Kobayashi, M. 332
 Kobayashi, S. 1003
 Kojima, T. 1033, 1041
 Kondo, H. 294
 Koyanagi, W. 458
 Kuramoto, Y. 876
 Kurihara, S. 591, 1041
 Kuroda, T. 370, 546, 645, 868
 Lagerblad, B. 853
 Laiw, J-C. 614
 Lan, X. 195, 265
 Laplaud, A. 670
 Laporte, F.I. 514
 Larbi, J.A. 109
 Larive, C. 662, 670, 798, 934
 Larsen, E.S. 402
 Le Roux, A. 202, 514, 892
 Leamon, R.J. 235
 Lee, J.H. 39
 Lee, Y. 117
 Leshchinsky, A. 191
 Li, Y.L. 578
 Liang, T. 742
 Liao, J.C. 166
 Livesey, P. 450, 814
 Lombardi, J. 907, 934
 Lu, C.K. 166
 Lu, D. 973
 Macphee, D.E. 792
 Majlesi, Y. 442
 Malhotra, V.M. 101, 302
 Mangialardi, T. 483
 Martineau, F. 514, 798
 Martinet, G. 978
 Massard, P. 907, 934
 Matsuda, Y. 876
 Matsufuji, Y. 1049
 Matsumoto, K. 653
 Matsunaga, A. 719
 Matsushita, H. 1049
 May, I.M. 434
 Mebarki, A. 694
 Michel, M. 583
 Miyagawa, T. 591, 606, 1003
 Moranville-Regourd, M. 51, 686, 949
 Moriya, S. 1010
 Mu, X. 310
 Mukherjee, P.K. 324
 Mullick, A.K. 340
 Muntean, M. 227
 Murata, Y. 719
 Murayama, Y. 1033
 Nadu, M. 271
 Nakamura, T. 719
 Nakamura, Y. 876
 Nakano, K. 426, 719, 1003
 Naruse, H. 719
 Nishibayashi, S. 370, 426, 546, 645, 868
 Nissenbaum, J. 271
 Nixon, P.J. 450, 492
 Noda, K. 1010
 Noh, J. 117
 Oberholster, R.E. 123
 Ochiai, M. 294
 Oh, H-K. 711
 Ohama, Y. 846
 Okabayashi, S. 606
 Okada, K. 995, 1033
 Okawa, Y. 370
 Olafsson, H. 377, 562
 Oltean, A. 227
 Ono, K. 1003
 Ono, Y. 719
 Page, C.L. 822
 Park, C-K. 711
 Patel, H.H. 943
 Pattison, J. 191
 Pavlenko, S.I. 508
 Perami, R. 806
 Perruchot, A. 907, 934
 Pettifer, K. 492
 Pigeon, M. 514, 1056
 Poole, A.B. 943
 Prince, W. 806
 Qian, C. 474, 912
 Radonjic, M. 814
 Ragnarsdottir, K.V. 814
 Rame Gowda, B.M. 727
 Ramezaniapour, A.A. 348
 Rayment, P.L. 750
 Restivo, G. 288, 775
 Rigden, S.R. 418, 442
 Rivest, M. 899
 Rogers, C. 362
 Rokugo, K. 458
 Ross, I. 257
 Roy, D.M. 39
 Saito, M. 965
 Salam, J.M. 418
 Saleh, K. 466
 Salome, F. 599
 Sato, T. 1049
 Schieber, M. 271
 Seki, K. 1033
 Sellier, A. 694, 949
 Shayan, A. 85, 235, 257, 538, 703
 Sheikh, V. 943
 Shirke, J. 727
 Shmelkov, M.A. 508
 Shrimmer, F.H. 734
 Shtakelberg, D. 271
 Shu, Z. 251
 Sibbick, R.G. 822
 Siemes, A.J.M. 109
 Silva, A.S. 93, 142
 Silva, H.S. 93, 142

Sims, I. 175
Smorchevsky, G. 191
Sonoda, K. 1033
St John, D.A. 150, 183
Stark, D. 355
Stokes, D.B. 862, 884
Suzuki, D. 846
Swamy, R.N. 68, 614
Takeda, T. 838
Takemura, K. 410
Takeo, K. 1049
Takeuchi, K. 630, 838
Taki, T. 1010
Tamura, H. 332, 606
Tang, F. 884
Tang, M. 195, 265, 310, 546, 742, 868, 973
Tanikawa, S. 614, 630
Tazawa, E. 410
Thomas, M.D.A. 324, 492, 554
Thorsen, T. 402
Thuret, B. 514
Tochigi, T. 719
Tomita, R. 719
Torii, K. 630, 653
Tragardh, J. 853
Tremblay, S. 466
Tse, W.L. 158
Tye, C. 570
Uchida, T. 1010
Uchida, Y. 458
Ushiyama, H. 719
Venugopal, K. 727
Wakasugi, M. 606
Wang, H.H. 884
Wang, J. 474, 622
Wang, T. 426, 546
Wason, R.C. 340
Wen, H.X. 434, 678
Wieker, W. 919
Wigum, B.J. 758
Wollgam, H. 219
Wood, J.G.M. 450
Wu, X. 546, 868
Xu, Z. 195, 265, 310, 973
Yamaguchi, Y. 995, 1003
Yan, A. 474
Yen, T. 166
Yonekura, A. 410
Yoon, J. 117

NOTICE

The papers contained in this volume have been refereed by international peers, and are considered to constitute the latest information available in the relevant fields. However, no responsibility nor liability is accepted for errors or any consequences arising from the use of information contained herein. Final determination of the suitability of any information, procedure or product, for use contemplated by any user, and the manner of that use, is the sole responsibility of the user. This Proceedings volume is intended as a collection of information only. Expert advice should be obtained at all times with respect to all equipment and procedures when implementation is considered.

CONTENTS

Keynote Lectures	1
Alkali - silica reactions : some paradoxes Diamond, S.	3
Systematic ASR research : Australian Research 1940s' to 1958 Idorn, G.	15
A critical review of accelerated AAR tests Grattan - Bellew, P. E.	27
AAR investigation of concretes for storage of radioactive wastes Roy, D. M., Lee, J.H.	39
Modelling of expansions induced by ASR : New approaches Moranville - Regourd, M.	51
Assessment and rehabilitation of AAR - affected structures Swamy, R. N.	68
National Reviews On Alkali-Aggregate Reactivity	84
Alkali-aggregate reaction in Australia Shayan, A., Green, W.K., Collins, F.G.	85
Alkali-aggregate reactions in Portuguese structures. Some case histories Braga Reis, M.O., Silva, H.S., Silva, A.S.	93
CANMET / Industry Research Consortium on alkali-aggregate reactivity (ASR) Fournier, B., Bilodeau, A., Malhotra, V.M.	101
Alkali-silica reaction in the Netherlands Heijnen, W.M.M., Larbi, J.A., Siemes, A.J.M.	109
Presence of alkali-silica reactive aggregates in Korea Noh, J., Lee, Y., Chung, J., Yoon, J.	117
Case studies of the practical and economical impact of alkali-silica reaction in South Africa Oberholster, R.E.	123
Present experience with aggregate testing in Norway Jensen, V.	133
Geological conditioning of ASR development. A brief evaluation of Portuguese mainland Silva, H.S., Braga Reis, M.O., Silva, A.S.	142
Fifty years of investigation and control of AAR in New Zealand St John, D.A., Freitag, S.A.	150
A case study of the investigation of AAR in Hong Kong Tse, W.L., Gilbert, S.T.	158
Alkali-aggregate reactivity in western Taiwan Yen, T., Chu, B.L., Lu, C.K., Liao, J.C.	166

General Topics On Alkali-Aggregate Reaction	174
Phantom, Opportunistic, Historical and Real AAR - getting diagnosis right Sims, I.	175
Alkali aggregate reaction in existing structures - what can it tell us? Freitag, S.A., St John, D.A.	183
Alkali-Silica Reaction; Ready-Mixed Concrete Producers' view point Leshchinsky, A., Pattison, J., Domitru, I., Smorchevsky, G.	191
Alkali-aggregate reactions in China Tang, M., Deng, M., Xu, Z., Lan, X., Han, S.	195
The French preventitive approach to AAR compared to experience Le Roux, A., Guedon-Dubied, J-S.	202
Diagnosis Of Alkali-Aggregate Reaction In Concrete	208
Diagnosis of the cause of cracking in four structures in which ASR is occurring Hobbs, D.W.	209
Concrete damage caused by greywacke reactions - an AAR? Hunger, K-J., Wollgam , H., Frey, R.	219
Investigation of ASR by physico-chemical analysis in the case of different constructions from Romania Andrei, V., Muntean, M., Oltean, A.	227
Alkali-aggregate reaction in a concrete water storage tank Leamon, R.J., Shayan, A.	235
Alkali-aggregate reaction combined with freeze/thaw in Newfoundland, Canada Petrography using EPMA Katayama T., Bragg, D.	243
Alkali-aggregate reactions in the cement concrete pavements of airport Shu, Z., Deng, M.	251
Alkali aggregate reaction in Western Australia: Investigations on the Causeway Bridge and some aggregate sources Ross, I., Shayan, A.	257
Railway ties affected by alkali-aggregate reactions Deng, M., Xu, Z., Lan, X., Tang, M.	265
Alkali-aggregate reaction experiments in Israeli. Nadu, M., Schieber, M., Nissenbaum, J., Braiman, M., Boyko, S., Shtakelberg, D.	271
Testing For Alkali-Aggregate Reactivity	279
Recent developments in testing for ASR in North America Hooton, R.D.	280
The ASTM C 289 method and the kinetic test in the study of alkali-silica reactivity of Italian alluvial deposits Barisone, G., Restivo, G.	288

Alkali reactivity of some Japanese carbonate rocks based on standard test Katayama, T., Ochiai, M., Kondo, H	294
Inter-laboratory study on the CSA A23.2-14A Concrete Prism Test for alkali-aggregate reactivity in concrete Fournier, B., Malhotra, V.M.	302
Abnormal expansion of coarse-grained calcite in autoclaved method Mu, X., Xu, Z., Deng, M., Tang, M.	310
Long term movements due to alkali-silica reaction and their prediction Hobbs, D.W.	316
A comparison of damage rating index with long-term expansion of concrete prisms due to alkali-silica reaction Dunbar, P.A., Mukherjee, P.K., Bleszynski, R., Thomas, M.D.A.	324
Study on a standard rapid test method for identification of ASR susceptibility of concrete Kishitani, K., Kobayashi, M., Tamura, H.	332
NBRI tests on aggregate containing strained quartz Mullick, A.K., Wason, R.C.	340
Evaluation of Aggregates for AAR using accelerated test methods Ramezaniapour, A.A., Karimi, M.	348
Immersion test to identify cement alkali levels and pozzolans to prevent ASR Stark, D.	355
Multi-laboratory study of accelerated mortar bar test for alkali-silica reaction Rogers, C.	362
Expansion characteristics of AAR in concrete by autoclave method Nishibayashi, S., Kuroda, T., Inoue, S., Okawa, Y.	370
Petrography and alkali-reactivity of some volcanic aggregates from Iceland Katayama, T., Helgason, T.S., Olafsson, H.	377
Blast furnace slag's potential alkali reactivity and long term service Ashby, J.B.	385
Structural Effects Of Alkali-Aggregate Reaction	393
A review of the Institution of Structural Engineers Report "Structural Effects of Alkali-Silica Reaction (1992)" Jones, A.E.K., Clark, L.A.	394
Alkali-silica reactions in damaged concrete - Static and dynamic tests - Material investigations Thorsen, T., Larsen, E.S.	402
Mechanical performance of ASR affected nearly full-scale reinforced concrete column Takemura, K., Ichitsubo, M., Tazawa, E., Yonekura, A.	410

The influence of stress intensity and time of application on the mechanical properties of ASR affected concrete Salam, J.M., Rigden, S.R., Burley, E.	418
Fractal analysis of cracked surface in AAR concrete Wang, T., Nishibayashi, S., Nakano, K.	426
Modelling of the structural behaviour of AAR affected reinforced concrete members May, I.M., Cope, R.J., Wen, H.X.	434
Restraint effects on the performance of various ASR structural elements Majlesi, Y., Rigden, S.R., Burley, E.	442
Relating ASR structural damage to concrete composition and environment Wood, J.G.M., Nixon, P., Livesey, P.	450
Deformation behavior of reinforced concrete beams deteriorated by AAR Koyanagi, W., Rokugo, K., Uchida, Y., Iwase, H.	458
Some considerations on the evaluation of potential residual expansion of AAR affected hydroelectric dams Durand, B., Gravel, C., Saleh, K., Tremblay, S., Ballivy, G.	466
Influence of alkali-aggregate reaction on flexural properties of steel fibre reinforced concrete Qian, C., Guo, H., Wang, J., Yan, A.	474
Preventive Effects Of Mineral Admixtures On AAR	482
Evolution of chemical and physical parameters of blended cement mortars subjected to the NaOH bath test Berra, M., De Cassa, G., Mangialardi, T.	483
An appraisal of UK greywacke deposits and current methods of avoiding AAR Blackwell, B.Q., Thomas, M.D.A., Pettifer, K., Nixon, P.J.	492
The assessment and management of alkali-silica reaction in the Gordon River Power Development intake tower Blaikie, N.K., Bowling, A.J., Carse, A.	500
Effect of silica fume on reducing risk of free lime expansion in cementless concrete Pavlenko, S.I., Shmelkov, M.A.	508
Influence of aggregates and mineral additives on the composition of the pore solution Hornain, H., Thuret, B., Guedon-Dubied, S., Le Roux, A., Laporte, F.I., et al.	514
Review of methods used at Hydro-Quebec to prevent alkali-aggregate reactions in concrete structures Durand, B.	522
Effectiveness of granulated blastfurnace slag in preventing alkali silica reaction Connell, M.D., Higgins, D.D.	530

Long-term effectiveness of flyash in preventing deleterious expansions due to alkali-aggregate reaction in concrete Shayan, A., Diggins, R.G., Ivanusec, I.	
Effect of reactive aggregate powder on suppressing expansion due to alkali-silica reaction Bian, Q., Wu, X., Tang, M., Nishibayashi, S., Kuroda, T. et al.	54
Summary of BRE research on the effect of fly ash on alkali-silica reaction in concrete Thomas, M.D.A., Blackwell, B.Q.	554
Silica Fume in Concrete - 16 years of experience in Iceland Gudmundsson, G., Olafsson, H.	562
Autoclave testing of concrete with respect to AAR French, W.J., Tye, C.	570
Alkali-silica reactive aggregates in Beijing Area Fu, P.X., Li, Y.L., Feng, H.M., Huang, Q.	578
Effects Of Surface Coatings And Cathodic Protection On Alkali-Aggregate Reaction	582
Treatment of structures by water-proof coating Godart, B., Michel, M., Fasseu, P.	583
Effect of various types of silanes on expansion due to alkali-silica reaction Miyagawa, T., Hattori, A., Fujii, M., Kurihara, S.	591
Field evaluation of the mitigating effect of silane treatment on AAR in concrete railway sleepers Salome, F.	599
Effect of concrete surface coating on prevention of alkali silica reaction Wakasugi, M., Kamimoto, H., Miyagawa, T., Tamura, H., Hori, T., Okabayashi, S.	606
A flexible acrylic rubber surface coating, a cure for ASR expansion Tanikawa, S., Laiw, J-C., Swamy, R.N.	614
Control of ASR expansion by coatings Wang, J., Humphrey, M., Bayer, D.	622
Long-term ASR expansion behaviour of concrete cubes in outdoor exposure conditions Kawamura, M., Torii, K., Takeuchi, K., Tanikawa, S.	630
The effect of electrochemical re-alkalisation on alkali-silica expansion in concrete Al-Kadhimi, T.K.M., Banfill, P.F.G.	637
Study of alkali-aggregate reactions in electrical fields Kuroda, T., Nishibayashi, S., Bian, Q.	645
Influence of cathodic protection on cracking and expansion of the beams due to alkali-silica reaction Torii, K., Kawamura, M., Matsumoto, K., Ishii, K.	653

Modelling Of Alkali-Aggregate Reaction	661
Behaviour of AAR-affected concrete. Part 1: Modelling Larive, C., Coussy, O.	662
Behaviour of AAR-affected concrete. Part 2: experimental data for a theoretical model Larive, C., Laplaud, A., Joly, M.	670
Use of analytical methods to estimate concrete deterioration due to AAR Wen, H.X., Balendran, R.V.	678
A mathematical modelling to describe the effects of alkali-aggregates reactions in concrete structures Capra, B., Bournazel, J.P., Moranville-Regourd, M.	686
Modelling the alkali-aggregate reaction within a probabilistic framework Sellier, A., Bournazel, J.P., Mebarki, A.	694
Aggregate Reactivity	702
Reactive quartz gravel from eastern Victoria Shayan, A., Ferguson, J.A.	703
Investigation of alkali-aggregate reaction in aggregates Park, C-K., Hyun, S-K., Oh, H-K.	711
Study on alkali carbonate rock reaction of Japanese limestone aggregate Nakano, K., Ginyama, I., Matsunaga, A., Tochigi, T., Ono, Y., Tomita, R, et al.	719
Pyroclastic and associated basalts of India in relation to AAR Shirke, J., Venugopal, K., Rame Gowda, B.M.	727
Evaluation of an alkali-reactive aggregate undetected by petrographic methods Shrimer, F.H.	734
Concurrence of alkali-silica and alkali-dolomite reaction Liang, T., Tang, M.	742
The alkali-silica reactivity of flint aggregates Rayment, P.L., Haynes, C.A.	750
A classification of Norwegian cataclastic rocks for alkali-reactivity Wigum, B.J.	758
Petrographic aspects of alkali-silica reaction in Eastern Australian concretes Joyce, A.S.	767
Alkali-silica reactivity of some Italian and European flints Barisone, G., Restivo, G.	775
Selective dissolution techniques in AAR investigation : application to an example of failed concrete Goguel, R.	783

Mechanisms Of Alkali-Aggregate Reaction	791
A modelling approach to the prediction of pore fluid alkalinity in concretes Macphee, D.E., Glasser, F.P.	792
Evaluation of the relationships between swelling, cracking, developments of gels Martineau, F., Guedon-Dubied, J-S., Larive, C.	798
A new device for AAR swelling pressure determination Prince, W., Perami, R., Baulande, B.	806
Spectroscopic studies of alkali induced reactions at cement carbonaceous aggregate interfaces Radonjic, M., Ragnarsdottir, K.V., Allen, G.C, Livesey P.	814
Effects Of The Environment On Alkali-Aggregate Reaction	821
Effects of sodium chloride on the alkali-silica reaction in hardened concretes Sibbick, R.G., Page, C.L.	822
Effect of deicing salt and sea water on ASR: new considerations based on experimental data Duchesne, J., Berube, M.A.	830
Role of gypsum in expansion of mortars containing reactive aggregate in NaCl solution Kawamura, M., Takeda, T., Takeuchi, K.	838
Evaluation of alkali-aggregate reaction inhibitors by partial immersion test of concrete in 2.5% NaCl solution Ohama, Y., Demura, K., Suzuki, D.	846
Influence of ASR expansion on the frost resistance of concrete Tragardh, J., Lagerblad, B.	853
Other Preventive Measures For Alkali-Aggregate Reaction	861
Use of Lithium to combat alkali silica reactivity Stokes, D.B.	862
Various chemicals in suppressing expansion due to alkali-silica reaction Bian, Q., Nishibayashi, S., Kuroda, T., Wu, X., Tang, M.	868
Effects of alkali substitution on suppression of AAR Kuramoto, Y., Nakamura, Y., Matsuda, Y.	876
Compatibility of Lithium -based admixture with other concrete admixtures Wang, H.H., Stokes, D.B., Tang, F:	884
Evolution of AAR preventive measures adopted in France Le Roux, A., Godart, B.	892

Theory And Research Topics	898
Alkali contribution by aggregates to concrete Berube, M-A., Duchesne, J., Rivest, M.	899
Do the alkalis belong to the structure of gels products of alkali-aggregate reaction ? Lombardi, J., Massard, P., Perruchot, A.	907
Influence of alkali content on the properties of concrete containing Beijing aggregate	912
Contribution to the chemical reaction mechanism of the alkali-silica-reaction Wieker, W., Hubert, C., Ebert, R.	919
Solid-liquid equilibria in K-C-S-H / H ₂ O systems Dron, R., Brivot, F.	927
Study of Ca-Si gels, products of alkali silica reaction Lombardi, J., Perruchot, A., Massard, P., Larive, C.	934
Microstructure In Alkali-Aggregate Reaction	942
Alkali silica and ettringite expansions in 'steam cured' concretes Poole, A.B., Patel, H.H., Sheikh, V.	943
Microstructure of steam cured concretes deteriorated by alkali-silica reaction Bournazel, J.P., Moranville-Regourd, M., Sellier, A.	949
Alkali-aggregate reactions products identified in concrete after high temperature cure in alkaline solution at 150 C Andrei, V., Criaud, A.	957
Alkali-silica reaction in reactive aggregate-cement paste interfacial regions Saito, M., Kawamura, M.	965
An occurrence of AAR in a cooling tower in China Xu, Z., Lu, D., Han, S., Tang, M.	973
Pop-out formation and bulk cracking of concrete induced by calcareous metamorphic aggregates in tropical environment Jehenne, F., Hornain, H., Martinet, G.	978
Repair And Maintenance Of Structures Affected By Alkali-Aggregate Reaction	986
Engineering properties of reinforced concrete damaged by AAR Blight, G.	987
Maintenance system for highway structures damaged by ASR Okada, K., Fujii, M., Yamaguchi, Y., Imada, K.	995
Evaluation of new materials developed for repairing AAR damaged reinforced concrete structures Miyagawa, T., Ono, K., Nakano, K., Yamaguchi, Y., Kobayashi, S.	1003

An experimental study on AAR-inhibiting effects of various repair methods Domon, K., Moriya, S., Uchida, T., Fukuda, H., Taki, T., Noda, K.	1010
Assessment and management of a marine structure affected by ASR Davies, M.J.S., Grace, W.R., Green, W.K., Collins, F.G.	1018
The asset management of a long bridge structure affected by alkali-silica reaction Carse, A.	1025
Deterioration of reinforced concrete slabs with alkali aggregate reaction Okada, K., Sonoda, K., Kojima, T., Seki, K., Murayama, Y.	1033
An experimental study on strengthening ASR-damaged reinforced concrete members with carbon fiber sheet Fujii, M., Kobayashi, K., Kojima, T. Adachi, Y. Kurihara, S.	1041
Surveys and repairs of AAR-damaged concrete structures : (bridge substructure and water tank) Takeo, K., Matsushita, H., Matsufuji, Y., Sato, T.	1049
Influence of wetting-drying and freezing-thawing cycles, and effectiveness of sealers on ASR Berube, M-A., Chouinard, D., Boisvert, L., Frenette, J.	1056