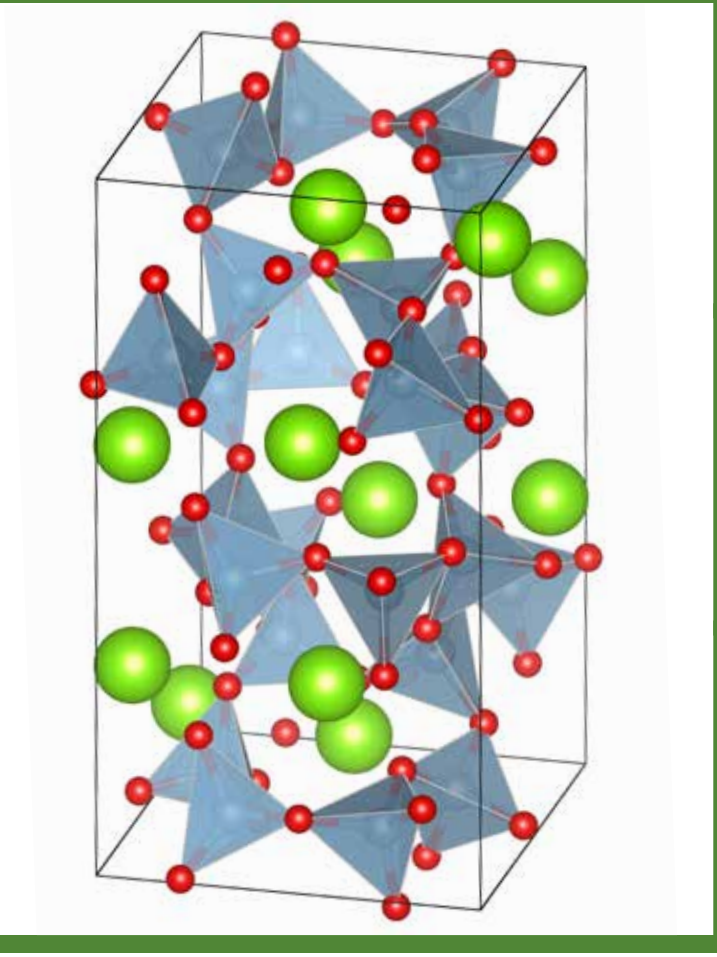
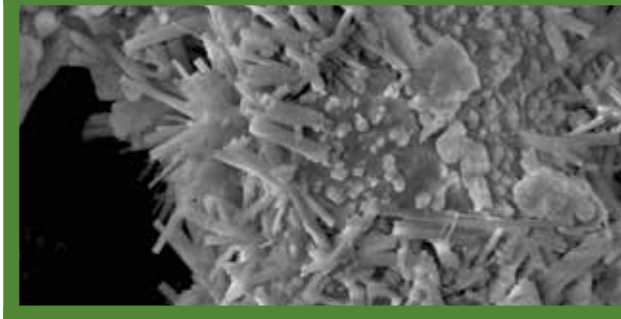
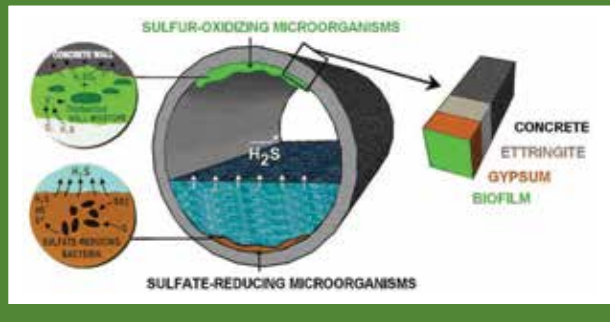
CALCIUM ALUMINATES

Proceedings of the International Conference 2014

Edited by Charles Fentiman, Raman Mangabhai and Karen Scrivener







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CALCIUM ALUMINATES

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Palais des Papes, Avignon, France, 18–21 May 2014

Principal Supporter
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Calucem, Cementos Molins, Çimsa Cement and Górka Cement

Meeting organised by Cement and Concrete Science

Edited by C. H. Fentiman, R. J. Mangabhai and K. L. Scrivener

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Tel: +44 (0) 344 328038, Fax: +44 (0) 344 328005, Email: brepress@ihs.com

EP 104
ISBN 978-1-84806-316-7
First published 2014

Cover photos:
Left: The crystal structure of monocalcium aluminate ($CaAl_2O_4$) produced by Dr Bruno Touzo, Kerneos Aluminate Technologies, for these Proceedings using VESTA software. For more information see Momma K. and Izumi F. *VESTA 3 for three-dimensional visualization of crystal, volumetric and morphology data*. J. Appl. Crystallogr., 2011, 44, 1272–1276.

Top right: The entrance to the Tunnel des Valois photographed in 2013 – Paper 48, page 535 by F. Sorrentino and D. Damidot.

Centre right: Scanning electron microscope image of fresh self-levelling underlayment blend after ageing at 35 °C and 90 % RH for 3 days – Paper 37, page 412, by J. Plank, E. Dubina and M. R. Meier.

Bottom right: Biodeterioration phenomenon in sewer networks – Paper 56, page 632, by J. Herisson, E. D. van Hullebusch, M. Guéguen-Minerbe and T. Chaussadent.

PREFACE

Calcium Aluminates constitute the primary components of Calcium Aluminate Cements (CACs), also known as high-alumina cements (HAC) and sometimes also aluminous cements. In fact they are a range of cements in which calcium aluminates are the principal constituents.

Since the last International Conference (the Centenary Conference) in 2008, we have seen an increase in the use of these cements as a component to make blended cements, with different hydration products. These can be in binary systems, for instance with ground granulated blast-furnace slag or in ternary systems, usually with calcium sulfate and a source of lime (such as Portland cement). Manufacturers of CACs have also introduced new grades of milled calcium aluminates destined for use as components in such blended formulations so having considered this we have dropped the 'cement' part of the title. By doing this we are also recognising papers that feature the use with CACs of calcium aluminate aggregate.

This is now the fourth open International Conference on calcium aluminate cements with previous meetings in London in 1990, Edinburgh in 2001 and more recently the Centenary Conference in Avignon in 2008. The Proceedings of three previous meetings are still widely used as standard texts on CACs, and we anticipate that the same will be true of these Proceedings.

The response to the call for papers has been excellent, and these Proceedings demonstrate a growing interest and real progression in the knowledge and understanding about this class of cement. Not only do we see a continued drive to better understanding of alternative hydratable aluminates but also further exploration in the use of the already mentioned blended systems with papers covering issues such as ageing and effective admixtures for formulated systems, destined for building chemistry and also refractory use.

CACs have always found their way into a wide range of applications and this range seems to be expanding with papers on new areas, such as for dental cements and also use as an admixture, including as an admixture to improve lime based architectural mortars. Their merit in architectural applications is shown by papers dealing with fungal and bacterial attack on concretes. Resistance to biological attack is demonstrated by an excellent set of papers related to biogenic attack consistent with increasing use worldwide as the cement of choice for sewer pipes, especially in warm climates.

It is sometimes difficult to select the best sequence for papers but for this meeting it has been a relatively simple choice as the environmental aspects of CACs are of common interest for all. The opening paper demonstrates the role of CACs as an enabling technology to improving the life cycle analysis (LCA) of drymix formulations.

We would like to thank all the authors for their hard work in preparing their contributions and for meeting the rather tight deadlines that have enabled these Proceedings to be ready in time for the conference. The papers included in these Proceedings have all been reviewed by members of the Scientific Review Panel who have willingly given up their time to read the manuscripts carefully and offer the authors

valuable assistance in refining their papers. We are profoundly grateful to them all as we are to our Scientific Advisors who have provided constant support throughout.

The Editors would like to thank Kerneos Aluminate Technologies, Calucem, Cementos Molins, Çimsa Cement and Górka Cement for their unfailing financial and practical support for this meeting – without their assistance the Conference would not have been possible. In particular, we acknowledge Francois Saucier (Kerneos), Frank Michael Kindler (Calucem), Antonio Bedmar (Cementos Molins), Tuğhan Delibaş (Çimsa Cement) and Piotr Palichleb (Górka Cement), who have been of particular help with the practicalities of organising this event. We also wish to thank the Institute of Materials, Minerals and Mining (IOM^3) for their support and assistance in various ways and in particular for promoting the meeting on their website.

Finally, but certainly not least, the Editors would like to extend particular thanks to Jonathan Silver and Yvonne Wilder of IHS BRE Press for all their hard work in the production of these Proceedings.

The Editors express the wish, on behalf of all authors, that readers find the volume topical and useful in their work: also, that it stimulates further work on this interesting and useful class of materials.

Charles Fentiman — *Cement and Concrete Science, Horsham, UK*
Raman Mangabhai — *Cement and Concrete Science, London, UK*
Karen Scrivener — *EPFL, Lausanne, Switzerland*

May 2014

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Glossary of terms and abbreviations

Cement chemists' shorthand is widely used in these proceedings wherein the following abbreviations are used:

C	CaO
S	SiO_2
A	Al_2O_3
F	Fe_2O_3
Š and $	SO_3

Some examples:

CA	mono calcium aluminate ($CaO \cdot Al_2O_3$)
C_4AF	tetracalcium aluminoferrite ($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$)
$C_3A \cdot C\check{S} \cdot H_{12}$	calcium monosulfoaluminate ($4CaO \cdot Al_2O_3 \cdot SO_3 \cdot 12H_2O$), also called AFm or monosulfate
AH_3	gibbsite ($Al_2O_3 \cdot 3H_2O$)
CAH_{10}	monocalcium aluminate deca hydrate ($CaO \cdot Al_2O_3 \cdot 10H_2O$)
$C\check{S}H_2$	calcium sulfate di hydrate ($CaO \cdot SO_3 \cdot 2H_2O$), also called gypsum

Some commonly used abbreviations related to cement(s):

AFm	monosulfate
AFt	ettringite
CA	mono calcium aluminate
CAC	calcium aluminate cement
HAC	high alumina cement
CH	calcium hydroxide
C_4AF	tetracalcium aluminoferrite (ferrite)
ggbs	ground granulated blast-furnace slag
LCC	low cement castables
LOI	loss on ignition
OPC	ordinary Portland cement
pfa	pulverised-fuel ash
w/c	water/cement ratio
w/s	water/solid ratio

CONTENTS

CALCIUM ALUMINATES

Since its invention in 1908 calcium aluminate cement has been the subject of much research and because of its unique attributes has found its way into many applications. While it is still used to make mortars and concretes in the same way as Portland cements but for challenging environments (heat, abrasion, rapid hardening, chemical resistance, etc.), the last decades have seen its steady growth in a wide range of blended cements systems sold as "dry-mixes", like tile adhesives and self-levelling underlayments. Another growing field of application is for waste water infrastructures as it demonstrates exceptional resistance to microbiologically induced corrosion.

In fact, calcium aluminate cement is often "an enabling technology" that allows solutions to be found for difficult applications where the alternatives may be more costly and environmentally unfriendly. The papers included in these proceedings of the international conference held in Avignon, France, in 2014, demonstrate continuing research and development in academia and industry, with new products and uses regularly coming on stream.

This volume includes recent work on all aspects of calcium aluminates, starting from their mineralogy, hydration and physical performance through to their durability in various environments, including the ongoing evolution of calcium aluminate technology. Attention is also given to their applications, including: admixtures, building chemistry formulations, refractory applications, civil engineering and architectural uses and continued developments for biogenic corrosion resistance applications.

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IHS BRE Press, Willoughby Road
Bracknell, Berkshire RG12 8FB
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ISBN 978-1-84806-316-7