

Proceedings of  
The Fifth International Symposium  
on the  
Chemistry of Cement  
Tokyo, 1968

PART I  
**CHEMISTRY OF  
CEMENT CLINKER**  
(Volume I)



The Organizing Committee  
for the Fifth International Symposium  
on the Chemistry of Cement

The Cement Association of Japan

Verein Deutscher Zementwerke e. V.

Düsseldorf, Tannenstr. 2

Proceedings of  
The Fifth International Symposium  
on the  
**Chemistry of Cement**  
Tokyo, 1968

**PART I**  
**CHEMISTRY OF**  
**CEMENT CLINKER**  
**(Volume I)**



Symposium held October 7-11, 1968 at the  
Tokyo Metropolitan Festival Hall, Tokyo

Proceedings published in 4 volumes December 31, 1969

# Contents

## Volume I

	Page
Preface .....	i
List of the Symposium Regular Members .....	iv
Inauguration Speeches at V-ISCC Opening Ceremony .....	
Cement Research—Some Views for the Future F. M. Lea .....	xiii
On the Contribution of Chemical Studies to Japanese Cement Industry S. Nagai .....	xvii
Explanatory Notes .....	xx

## Part I. Chemistry of Cement Clinker

### Session I-1 Structure of Portland Cement Minerals

#### Principal Paper

Structure of portland cement minerals A. Guinier and M. Regourd .....	1
Written Discussion J. Forest .....	32
Oral Discussion Th. Hahn, W. Eysel, P. Brenner and E. Woermann .....	37
K. Tomita .....	39
Y. Ono .....	39
H. E. Schwiete, W. Krönert and K. Deckert .....	40
Authors' closure .....	41

#### Supplementary Paper

I-10 Synthesis and crystallographic investigation of some belites M. Regourd, M. Bigaré, J. Forest and A. Guinier .....	44
I-36 Cation and anion replacements in the structure of tricalcium silicate N. A. Toropov .....	49
I-54 Polymorphism and solid solution of the ferrite phase E. Woermann, W. Eysel and Th. Hahn .....	54
I-55 Crystal chemistry of tricalcium silicate solid solutions Th. Hahn, W. Eysel and E. Woermann .....	61
I-92 A structural study on $\alpha'$ -Ca <sub>2</sub> SiO <sub>4</sub> K. Suzuki and G. Yamaguchi .....	67
Oral Discussion Y. Ono .....	73
Authors' closure .....	73
I-127 New crystallographic data of some calcium silicate phases F. K. F. Liebau .....	74

### Session I-2 Phase Equilibria and Formation of Portland Cement Minerals

#### Principal Paper

Phase equilibria and formation of portland cement minerals R. W. Nurse .....	77
---	----

	Page
<b>Written Discussion</b>	
J. A. Hedvall .....	90
<b>Oral Discussion</b>	
E. Woermann and E. Knoefel .....	90
D. M. Roy .....	91
Author's closure .....	91
<b>Supplementary Paper</b>	
I-9 Manufacture of portland cement from phosphatic raw materials	88
W. Gutt .....	93
I-18 Burnability of raw mixes	
J. P. Sulikowski .....	106
I-38 On kinetics of formation of portland cement clinker	
P. F. Rumyantsev .....	111
I-49 Clinker burning in fluidized bed	
Y. Suzukawa, H. Kono, H. Miyazaki and S. Nakai .....	116
<b>Oral Discussion</b>	
H. Mori .....	121
Authors' closure .....	121
I-75 New compound $\text{Ca}_{12}\text{Si}_4\text{O}_{19}\text{F}_2$ in the system $\text{CaO}-\text{SiO}_2-\text{CaF}_2$ and the role of $\text{CaF}_2$ in the burning of cement clinker	
M. Tanaka, G. Sudoh and S. Akaiwa .....	122
I-82 Formation of double salt in cement burning	
M. Amafuji and A. Tsumagari .....	136
I-94 Problem of admixtures	
M. M. Sichov .....	157
I-98 Mechanisms and kinetics of portland cement clinker formation for an example of the solid state reaction in the presence of a liquid phase	
R. Kondo and S. Choi .....	163
I-133 A refinement of the lime standard formula	
E. Spohn, E. Woermann and D. Knoefel .....	172

### Session I-3 Analysis of Portland Cement Clinker

#### Principal Paper

The analysis of portland cement clinker

    G. Yamaguchi and S. Takagi .....

#### Written Discussion

    P. Terrier .....

    K. E. Palmer and K. T. Greene .....

    T. Sakurai and T. Sato .....

#### Oral Discussion

    H. Uchikawa .....

    Authors' closure .....

#### Supplementary Paper

    I-12 The minor elements in alite (tricalcium silicate) and belite (dicalcium silicate) from some portland cement clinkers as determined by electron probe X-ray microanalysis

        H. G. Midgley .....

    I-37 The effect of chromium oxide on the structural transformations in tricalcium silicate

        A. I. Boikova .....

I-42 The use of thermogravimetric measurements in cement chemistry P. Longuet .....	239
I-64 On the color change of portland cement K. Miyazawa and K. Tomita .....	252
Oral Discussion K. Fujii.....	261
Authors' closure .....	261
I-76 Miscibilities of special elements in tricalcium silicate and alite and the hydration properties of $C_3S$ solid solutions R. Kondo and K. Yoshida .....	262
I-79 Microscopic observations of alite and belite and hydraulic strength of cement Y. Ono, S. Kawamura and Y. Soda .....	275
I-95 Thermal stabilization of $\beta$ - $2CaO \cdot SiO_2$ V. I. Korneev and E. B. Bygalina .....	285
I-101 Properties of substituted dicalcium silicate and alumino-ferrite M. K. Gharpurey and V. N. Pai .....	289
I-105 The effect of minor components on the early hydraulic activity of the major phases of portland cement clinker T. Sakurai, T. Sato and A. Yoshinaga .....	300
I-126 The distribution of alkalis in portland cement clinker H. W. W. Pollitt and A. W. Brown .....	322
I-131 Cement surface area determination by gas adsorption near room temperature A. A. Tabikh .....	334
I-136 The crystallization of compounds in the presence of $Cr_2O_3$ , $P_2O_5$ or $SO_3$ and the properties of the resultant cement Yu. M. Butt, V. V. Timashev and L. I. Malozohn .....	340

### **Session I-4 Chemistry of Calcium Aluminates and their Relating Compounds**

#### **Principal Paper**

The chemistry of calcium aluminates and their relating compounds T. D. Robson .....	349
Oral Discussion K. Mishima .....	365
Author's closure .....	365

#### **Supplementary Paper**

I-78 The crystal structure of $11CaO \cdot 7Al_2O_3 \cdot CaF_2$ P. P. Williams .....	366
I-90 The solid solution in the system $C_2AS$ (Gehlenite)— $CA_2$ and a new ternary phase K. Sugiura and T. Yoshioka .....	370
Oral Discussion Y. Ono and K. Fujii .....	376
Authors' closure .....	376
<b>Author Index for Volume I</b> .....	379
<b>Subject Index for Volume I</b> .....	381

**Contents****Volume II****Part II. Hydration of Cements****Session II-1 Crystal Structures and Properties of Cement  
Hydration Products (Calcium Silicate Hydrates)****Principal Paper**

	Page
The calcium silicate hydrates	
H. F. W. Taylor .....	1
Written Discussion	
J. R. Dyczek .....	27
P. Longuet .....	30
O. P. Mchedrov-Petrosyan, I. P. Vydrov and L. P. Papkova ..	32
Oral Discussion	
U. Ludwig and H. E. Schwiete .....	34
D. M. Roy .....	35

**Session II-2 Crystal Structures and Properties of Cement  
Hydration Products (Hydrated Calcium Aluminates and Ferrites)****Principal Paper**

Crystal structures and properties of cement hydration products (Hydrated calcium aluminates and ferrites)	
H. E. Schwiete and U. Ludwig .....	37
Written Discussion	
M. H. Roberts .....	67
W. Dosch, H. Keller and H. zur Strassen .....	72
Oral Discussion	
A. E. Moore and H. F. W. Taylor .....	77
Authors' closure .....	78

**Supplementary Paper (A) Papers regarding Structures**

II-14 Quaternary calcium aluminate hydrates: Crystal structure of calcium aluminate monobromide hydrate	
F. Le Bel and G. Grasland .....	79
II-15 Contribution to the study of complex aluminates: Hydrated calcium and magnesium monocarboaluminates	
G. Sadran and B. Cottin .....	84
II-19 X-ray investigations of some complex calcium aluminate hydrates and related compounds	
H. J. Kuzel .....	92
II-27 Proton magnetic resonance studies of $C_3AH_6$	
R. Kiriyama, H. Kiriyama and M. Takagawa .....	98
II-29 Calcium aluminate hydrates and related basic salt solid solutions	
M. H. Roberts .....	104
II-77 Crystal structures and reactions of $C_4AH_{12}$ and derived basic salts	
S. J. Ahmed, L. S. D. Glasser and H. F. W. Taylor .....	118
Oral Discussion	
S. Koide .....	127
Authors' closure .....	127

	Page
II-137 The alteration of silicate anions in tobermorite gels H. Funk .....	128
<b>Supplementary Paper (B) Papers regarding Properties</b>	
II-6 Stability of hydrogarnet series terms to sulphate attack B. Marchese and R. Sersale .....	133
II-40 Formation of hydrated gehlenite through the reaction of clay minerals and lime A. Ariizumi .....	138
II-67 Successful prevention of loss of strength in concrete made with high-alumina cement P. K. Mehta .....	148
Oral Discussion	
S. Ueda and R. Kondo .....	151
K. Okada .....	152
Author's closure .....	152
II-68 Amorphous phase in the CaO-Al <sub>2</sub> O <sub>3</sub> -CaCl <sub>2</sub> -H <sub>2</sub> O system F. Tamás .....	153
II-81 Barium aluminate and barium silicate and their hydraulic properties H. Uchikawa and K. Tsukiyama .....	156
<b>Session II-3 Phase Equilibria of Cement-Water</b>	
<b>Principal Paper</b>	
Phase equilibria of cement-water	
P. Seligmann and N. R. Greening .....	179
Oral Discussion	
S. Ueda and R. Kondo .....	200
H. zur Strassen .....	201
Authors' closure .....	201
<b>Session II-4 Kinetics of Hydration of Cements</b>	
<b>Principal Paper</b>	
Kinetics and mechanisms of the hydration of cements	
R. Kondo and S. Ueda .....	203
Written Discussion	
H. N. Stein .....	248
J. H. Taplin .....	249
R. Feldman .....	251
Oral Discussion	
J. Albeck, U. Ludwig and H. E. Schwiete .....	252
Authors' closure .....	254
<b>Supplementary Paper (A) Papers regarding Mechanism</b>	
II-26 The influence of sugars on the hydration of tricalcium aluminate J. F. Young .....	256
II-41 Some principles in cement hydration A. Joisel .....	268
II-43 Contribution of analysis by means of an electron microprobe to the cement chemistry P. Terrier .....	278
Oral Discussion	
R. Kondo and S. Ueda .....	285
D. M. Roy .....	285
Author's closure .....	285

	Page
II-62 The behavior of aluminate ferrite phase during hydration P. Jäger, U. Ludwig and H. E. Schwiete.....	288
II-96 Synthesis of the analogues of portland cement and other binding materials on the basis of acidic-basic reaction N. F. Fedorov .....	293
II-122 Electron microprobe studies of cement phases D. M. Roy and M. W. Grutzeck .....	301
Oral Discussion G. Sudoh .....	310
Authors' closure .....	310
<b>Supplementary Paper (B) Papers regarding Kinetics</b>	
II-35 Mutual interaction of $C_3A$ and $C_3S$ during hydration J. G. M. de Jong, H. N. Stein and J. M. Stevels .....	311
II-44 The mathematical simulation of chemical, physical and mechanical changes accompanying the hydration of cement G. J. C. Frohnsdorff, W. G. Fryer and P. D. Johnson .....	321
II-53 Study on hydration of alumina cement by ultrasonic method S. Koide and K. Okada .....	328
Oral Discussion R. Kondo .....	336
Authors' closure .....	336
II-70 On the hydration kinetics of hydraulic cements J. H. Taplin .....	337
II-73 Effect of the temperature on the early hydration of the system $3CaO \cdot Al_2O_3 - CaSO_4 \cdot 2H_2O - Ca(OH)_2 - H_2O$ H. Mori and K. Minegishi .....	349
II-93 Hydration of tricalcium silicate in a very early stage K. Fujii and W. Kondo .....	362
Oral Discussion S. Ueda .....	371
Authors' closure .....	371
II-118 The hydration mechanism of $C_3A$ and $C_3S$ in the presence of calcium chloride and calcium sulphate N. Tenoutasse .....	372
II-120 The hydration of the ferrite phase of cements W. L. de Keyser and N. Tenoutasse .....	379
<b>Session II-5 Hydration of Portland Cement</b>	
<b>Principal Paper</b>	
Hydration of portland cement L. E. Copeland and D. L. Kantro .....	387
Written Discussion J. G. M. de Jong, H. N. Stein and J. M. Stevels .....	420
Oral Discussion J. H. Taplin .....	421
Authors' closure .....	421
<b>Supplementary Paper</b>	
II-2 Contribution of calcium thiosulphate to the acceleration of the hydration of portland cement and comparison with other soluble inorganic salts K. Murakami and H. Tanaka .....	422
II-4 Significance of total and water soluble alkali contents of cement	

	Page
W. J. McCoy and O. L. Eshenour .....	437
Oral Discussion	
A. W. Brown .....	442
H. G. Smolczyk .....	442
II-22 The influence of lead and zinc compounds on the hydration of portland cement	
W. Lieber .....	444
Oral Discussion	
G. Sudoh .....	453
J. H. Taplin .....	454
Author's closure .....	454
II-47 Some observations upon the determination of heat of hydration of slag and portland cements by the method of differential heat of solution	
G. A. Toubeau .....	455
II-117 The influence of alkali-carbonate on the hydration of cement	
E. M. M. G. Niël .....	472
II-129 Aquous phase in portland cement pastes containing soluble chloride ion	
K. T. Greene and K. E. Palmer .....	487
II-134 The effect of tricalcium aluminate on the hydration of tricalcium silicate and portland cement	
A. Celani, P. A. Moggi and A. Rio .....	492
Oral Discussion	
S. Yamane .....	503
H. N. Stein .....	503
Authors' closure .....	503
<b>Author Index for Volume II</b> .....	505
<b>Subject Index for Volume II</b> .....	509

# Contents

## Volume III

### Part III. Properties of Cement Paste and Concrete

#### Session III-1 Structures and Physical Properties of Cement Pastes

##### Principal Paper

	Page
Structures and physical properties of cement pastes	1
G. J. Verbeck and R. H. Helmuth .....	1
Written Discussion	
S. Diamond .....	32
R. F. Feldman and P. J. Sereda .....	36

##### Supplementary Paper (A) Papers regarding Fundamental

III-8 Changing of the specific surface of cement stone in different conditions of hardening	45
O. P. Mchedlov-Petrosyan and D. A. Uginčius .....	45
Oral Discussion	
R. F. Feldman .....	51
Authors' closure .....	51
III-23 Sorption and length-change scanning isotherms of methanol and water on hydrated portland cement	
R. F. Feldman .....	53
III-34 The structure of cement-stone and the use of compacts as structural models	
I. Soroka and P. J. Sereda .....	67
III-46 Molecular sieve effect in concrete	
R. H. Mills .....	74
Oral Discussion	
R. F. Feldman .....	84
III-50 A statistical study of the effects of trace elements on the properties of portland cement	
R. L. Blaine .....	86
III-71 Cement paste shrinkage-relationships to hydration, Young's modulus and concrete shrinkage	
H. Roper .....	92
III-115 On some main aspects of theory of solidification and strength formation of cement stone and concrete	
I. P. Vyrodov .....	100
III-125 Electron microscopic investigations about the relations between structure and strength of hardened cement paste	
W. Richartz .....	119

##### Supplementary Paper (B) Papers regarding Application

III-1 Comparison of various measurements concerning the kinetics of hydration of portland cements	
S. Popovics .....	129
III-3 Mechanical properties of precompressed cement-mortar specimens	
O. Ishai.....	138
III-33 Determination of plain concrete	
F. O. Slate and B. L. Meyers .....	142

III-72 Correlation of strength and hydration with composition of portland cement	K. M. Alexander, J. H. Taplin and J. Wardlaw.....	152
III-88 Relation between the hydration of alumina cement mortars and their strength in the early stages	K. Mishima .....	167
III-97 Effects of hydration of cement on compressive strength, modulus of elasticity and creep of concrete	S. Seki, K. Kasahara, T. Kuriyama and M. Kawasumi .....	175
III-119 Some recent advances in the study of cement and concrete	H. E. Vivian .....	186

### **Session III-2 Durability of Concrete**

#### **Principal Paper**

##### Durability of concrete

O. Valenta .....	193
------------------	-----

##### Oral Discussion

H. C. Visvesvaraya .....	226
--------------------------	-----

Author's closure .....	228
------------------------	-----

#### **Supplementary Paper**

III-24 Behaviour of mortars and concretes in the temperature range from +20°C to -196°C	G. Tognon .....	229
---	-----------------	-----

##### Oral Discussion

R. F. Feldman .....	248
---------------------	-----

Author's closure .....	249
------------------------	-----

III-25 The influence of temerature on sulphate attack on portland cement mortars	J. H. P. Van Aardt .....	250
--	--------------------------	-----

III-30 The frost resistance of cement grouts for prestressed concrete applications	C. MacInnis .....	260
--	-------------------	-----

III-31 Chemical reactions of strong chloride-solutions with concrete	H. G. Smolczyk .....	274
--	----------------------	-----

III-39 A durability study of concrete using Monte Carlo simulation	K. R. Lauer and W. Gray .....	281
--	-------------------------------	-----

III-59 Measuring gas diffusion for the valuation of open porosity on mortars and concretes	H. E. Schwiete, H. J. Böhme and U. Ludwig .....	295
--	---	-----

III-99 The behaviour of concrete subjected to freezing and thawing as a reference for frost resistivity of concrete	Y. Koh and E. Kamada .....	300
---	----------------------------	-----

III-123 Effect of conversion on properties of concrete using high-aluminous cement	R. Tsukayama .....	316
--	--------------------	-----

III-124 Influence of chloride and hydrocarbonate on the sulphate attack	F. W. Locher .....	328
---	--------------------	-----

##### Oral Discussion

A. W. Brown .....	335
-------------------	-----

Author's closure .....	335
------------------------	-----

III-138 Mechanisms of sulphate expansion of hardened cement pastes	S. K. Chatterji .....	336
--	-----------------------	-----

	Page
<b>Oral Discussion</b>	
A. W. Brown .....	340
Author's closure .....	340
<b>Session III-3 Carbonation of Concrete</b>	
<b>Principal Paper</b>	
Neutralization (carbonation) of concrete and corrosion of reinforcing steel	
M. Hamada .....	343
Written Discussion	
H. G. Smolczyk .....	369
Oral Discussion	
H. G. Smolczyk .....	382
Author's closure .....	383
<b>Supplementary Paper</b>	
III-16 Variation in strength of mortars made of different cements due to carbonation	
W. Manns and K. Wesche .....	385
III-52 Investigations on the carbonation of concrete	
A. Meyer .....	394
III-116 Mechanisms and kinetics on carbonation of hardened cement	
R. Kondo, M. Daimon and T. Akiba .....	402
<b>Session III-4a Hydration of Portland Cement Paste at High-Temperature under Atmospheric Pressure</b>	
<b>Principal Paper</b>	
Hydration of portland cement paste at high temperature under atmospheric pressure	
G. M. Idorn .....	411
Written Discussion	
R. Malinowski.....	428
<b>Session III-4b High-Temperature Curing of Concrete under Atmospheric Pressure</b>	
<b>Principal Paper</b>	
High temperature curing of concrete under atmospheric pressure	
Yu. M. Butt V. M. Kolbasov and V. V. Timashev .....	437
Written Discussion	
J. Jessing and P. Nerenst .....	471
Authors' closure .....	476
<b>Supplementary Paper</b>	
III-65 Influence of cement characteristics on mix proportion for steam cured prestressed concrete	
R. K. Lewis and F. A. Blakey .....	477
III-91 Heat of hydration of portland cement during steam curing under atmospheric pressure	
H. Teramoto and N. Kawada .....	486
III-108 Physical and chemical properties of cement mortar cured at elevated temperatures	
P. Freisleben Hansen, J. Jessing, K. Mønsted and E. Trudsø..	503
Oral Discussion	

H. Teramoto .....	521
Authors' closure .....	521

### Session III-5 High-Temperature Curing of Concrete under High Pressure

#### Principal Paper

High-temperature steam curing of concrete at high pressure	
G. L. Kalousek .....	523
Written Discussion	
W. C. Hansen .....	540
J. Jambor .....	541
S. K. Chopra .....	557
Author's closure .....	560

#### Supplementary Paper

III-80 Hydroxyl ellastadite produced by hydrothermal reaction containing calcium sulphate	
K. Takemoto and H. Kato .....	563
III-87 Some physical properties of aerated concrete under autoclave process	
K. Ono and K. Ojiri .....	570
III-111 Influence of minor components on the strength of calcium silicate hydrate synthesized by hydrothermal reaction	
G. Shikami .....	582
<b>Author Index for Volume III</b> .....	595
<b>Subject Index for Volume III</b> .....	597

# Contents

## Volume IV

### Part IV Admixtures and Special Cements

#### Session IV-1 Use of Surface-Active Agents in Concrete

##### **Principal Paper**

	Page
Use of surface-active agents in concrete R. C. Mielenz .....	1
Oral Discussion	
N. Kudo .....	29
U. Ludwig, H. E. Schwiete and K. Seiler .....	30
R. A. Kuntze and P. Hawkins .....	31
G. J. Frohnsdorff .....	32
J. H. Taplin .....	33
Author's closure .....	33

##### **Supplementary Paper**

IV-5 Possible mechanisms of influence of some admixtures on creep of cement paste E. L. Jessop, M. A. Ward and A. M. Neville .....	36
IV-45 Effect of organic compounds on the hydration reactions of tricalcium aluminate K. E. Daugherty and M. J. Kowalewski, Jr .....	42
Oral Discussion	
S. Koide .....	52
Authors' closure .....	52
IV-51 Abnormally delayed setting of a low-heat portland cement with calcium lignosulphonate admixtures R. Bauset .....	53
IV-89 Investigations on the method of test for setting time of concrete especially for concrete containing water reducing admixture J. Okabe, K. Nakajima and T. Yoshihara .....	58
IV-107 Study on the admixture for aerated concretes including maleic anhydride modified resin K. Akutsu .....	65

#### Session IV-2 Fly Ash and Fly Ash Cement

##### **Principal Paper**

Fly ash and fly ash cement M. Kokubu .....	75
Written Discussion	
H. Abe, S. Nagataki and R. Tsukayama .....	105
T. Sakurai .....	111
Oral Discussion	
B. Mather .....	113
Author's closure .....	113

##### **Supplementary Paper**

IV-7 Hydrated phases after reaction of lime with "Pozzolanic" materials or with blast furnace slags	
---	--

	Page
R. Sersale and P. G. Orsini .....	114
IV-17 Study of reactions between CaO or $3\text{CaO}\cdot\text{SiO}_2$ and $\beta\text{-}2\text{CaO}\cdot\text{SiO}_2$ and power station fly ashes under hydrothermal conditions	
Z. Šauman .....	122
X IV-63 Investigation on the behaviour of natural and artificial puzzolanas	
H. E. Schwiete, P. Kastanja, U. Ludwig and P. Otto .....	135
X IV-135 The different action mechanism of pozzolanic materials and slags in the hydraulic binders	
A. Celani, P. A. Moggi and A. Rio .....	140
<b>Session IV-3 Slags and Slag Cements</b>	
<b>Principal Paper</b>	
Blast furnace slags and slag cements	
F. Schröder .....	149
Written Discussion	
A. Negro .....	199
Oral Discussion	
N. Stutterheim .....	200
J. Forest .....	201
R. R. Hatiangadi .....	202
U. Ludwig, P. Otto and H. E. Schwiete .....	202
Author's closure .....	203
<b>Supplementary Paper (A) Paper regarding Slag</b>	
IV-11 A method of utilizing blast-furnace slag as a strength-improving agent for concrete	
T. Iwai, T. Mori, A. Yoda and M. Oshima .....	208
IV-28 Investigation of the physicochemical processes of hardening of slag portland cement	
V. I. Satarin and Y. M. Syrkin .....	215
IV-48 Co-ordination state of aluminium, magnesium and manganese ions in synthetic slag glasses	
S. K. Chopra and C. Z. Taneja .....	228
IV-100 A contribution to the study of the physical properties of hardened pastes of portland cements containing granulated blast-furnace slag	
C. Cesareni and G. Frigione .....	237
IV-102 Reactive slag-like glasses of the S-A-F-C-M system	
V. N. Pai and R. R. Hatiangadi .....	248
Oral Discussion	
M. Hanada .....	253
Authors' closure .....	253
IV-106 Studies on a method to determine the amount of granulated blast-furnace slag and the rate of hydration of slag in cements	
R. Kondo and S. Ohsawa .....	255
IV-110 Mineral composition of blast-furnace slag	
H. Minato .....	263
IV-113 Portland blast-furnace cements—A case for separate grinding of slag	
N. Stutterheim .....	270
Oral Discussion	
M. Hanada .....	274
S. Gottlieb .....	274
H. Kaiser .....	274

R. R. Hattiangadi .....	275
Author's closure .....	275
IV-121 The role of magnesia and alumina in the hydraulic properties of granulated blast-furnace slags M. Cheron and C. Lardinois .....	277
<b>Supplementary Paper (B) Papers regarding High-Sulphate Slag</b>	
IV-21 Anhydrite cement A. A. Van Haute .....	286
IV-128 Chemistry of slag-rich cements J. C. Yang .....	296
IV-130 A comparative assessment of the resistance of super sulphated, sulphate resistant portland, and ordinary portland cements to solution of various sulphates and dilute mineral acids G. H. Thomas .....	310
<b>Session IV-4 Expansive Cement</b>	
<b>Principal Paper</b>	
Expansive cements	
P. P. Budnikov and I. V. Kravchenko .....	319
Written Discussion	
O. P. Mchedolov-Petrosyan and D. A. Uginčius .....	330
A. Joisel .....	331
Oral Discussion	
J. Calleja .....	335
K. Sugiura .....	335
<b>Supplementary Paper</b>	
IV-66 Nature of hydration products in the system $4\text{CaO} \cdot 3\text{Al}_2\text{O}_3 \cdot \text{SO}_3 - \text{CaSO}_4 - \text{CaO-H}_2\text{O}$ A. Klein and P. K. Mehta .....	336
Oral Discussion	
K. Sugiura .....	340
Authors' closure .....	340
IV-69 Fundamental studies on the expansive cement N. Fukuda .....	341
IV-74 Mineralogical composition of expansive cement clinker rich in $\text{SiO}_2$ and its expansibility T. Nakamura, G. Sudoh and S. Akaiwa .....	351
IV-83 Prevention of drying shrinkage crack by use of the expansive cement with calcium sulphaaluminous cement clinker K. Ohno, S. Nakamura and T. Saji .....	366
IV-85 General behavior of mortar and concrete made of expansive cement with calcium sulphaaluminous cement clinker T. Nishi, T. Harada and Y. Koh .....	389
IV-86 Development of expansive cement with calcium sulphaaluminous cement clinker M. Okushima, R. Kondo, H. Muguruma and Y. Ono .....	419
IV-132 Properties of expansive cement concrete P. Klieger and N. R. Greening .....	439

**Session IV-5 By-product Gypsum from Various Chemical Industries,  
as a Retarder for the Setting of Cement**

**Principal Paper**

Utilization of chemical gypsum for portland cement K. Murakami .....	Page
Written Discussion R. A. Kuntze and P. Hawkins .....	457
Author's closure .....	503
<b>Author Index for Volume IV</b> .....	509
<b>Subject Index for Volume IV</b> .....	511
	515