

INVESTIGATION OF PITCHSTONE FINES AS A
NOVEL SUPPLEMENTARY CEMENTITIOUS
MATERIAL FOR PORTLAND CEMENT BASED
CONSTRUCTION PRODUCTS

by

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This thesis is submitted in fulfilment of the requirements for the
degree of Doctor of Philosophy

2009

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Acknowledgments

The author would like to express his gratitude to Prof. Abhi S. Ray, my principal supervisor, for his guidance, advice and support throughout my candidature of this thesis. I would also like to thank Dr. Paul S. Thomas, my co-supervisor, for his suggestions, support and many helpful discussions. The author would further like to thank Dr. Rasiah Sri Ravindrarajah, my alternate supervisor, for his assistance and advice.

In allowing this research to progress, I would like to thank the UTS Challenge Grants Scheme, Centre for Built Infrastructure Research, Perlco Pty Limited (in particular Mr. Paul Joyce and Mr. John Haggman for their enthusiastic support) and Cement Australia Pty Limited (Mr. Des Chalmers) for providing financial support.

For their practical support and suggestions, I would like to thank Dr. Hamish Connan and Dr. Barry Liu for their assistance.

I wish to acknowledge and thank the support and technical assistance of the Faculty of Engineering and Information Technology Civil Laboratories staff especially Mr. Rami Haddad and Mr. Warwick Howse. Similarly, for the Faculty of Science staff, I would like to thank Dr. Norman Booth, Mr. Jean-Pierre Guerbois and Mr. Mark Berkahn for their technical support.

A special thank you is reserved for Ms. Marika Müller. Her support and constant encouragement has made this study a memorable experience. Above all, I must thank my family and friends who have helped and supported me throughout this study.

Abstract

Environmental implications associated with the manufacture and consumption of Portland cement (PC) presents a major challenge to the construction industry. For every tonne of PC manufactured, an equivalent amount of carbon dioxide is generated as greenhouse gas emissions. The use of supplementary cementitious materials (SCMs), also known as pozzolans, for the partial replacement of PC aids the reduction in consumption of PC. SCMs, as environmentally friendly 'green solutions', also provide performance-driven engineering properties of long-term strength development and enhanced durability.

Siliceous and aluminous industrial by-products, such as fly ash (FA), silica fume (SF) and ground granulated blast furnace slag (GGBFS) are used as SCMs to partially substitute PC in order to reduce the consumption of PC in cement-based construction materials. In this study, pitchstone fines (PF) which are the by-product of the production of expanded perlite from a naturally occurring pitchstone deposit in the state of Queensland in Australia are investigated. PF are produced in the crushing stage of the operation where particulates of less than 0.5 mm, which constitute as much as 30% of the pitchstone rock, are discarded causing a potential waste problem.

PF being an amorphous aluminosilicate material was investigated as a potential SCM. Initial investigations on an as received grade of PF, passing 150 μm mesh, produced favourable results for small substitutions of PC (10%); however, a significant water demand was noted in the production of mortars, otherwise the poor workability reduced homogeneous compaction in the moulds and resulted in inconsistent samples with low compressive strength. Two factors, reduced particle size and improved flow, were identified as critical for the improvement of mortar properties. In order to demonstrate this, a fine grade PF with an average particle size 10 μm was prepared. The water demand for the finer grade PF was significant and superplasticiser was added to improve flow. After accelerated ageing at elevated temperature the strength of mortars containing increasing PF additions up to 40% demonstrated increased strength.

In order to investigate the further potential of PF, PF mortars were compared to FA mortars (FA being an industry accepted SCM). The PF was graded to a similar particle size distribution to the FA, and was found to produce similar strength. Based on the ASTM standard criteria for classification as a pozzolan, strength activity index (SAI), a relative measure requiring the strength to be within 75% of the control 100% PC mortar, both PF and FA were found to fulfil the criteria at 20% additions at 7 and 28 days ageing. Mortars with 40% additions approached the SAI criteria only at significantly longer periods of ageing (91 days). A further 10 µm grade PF was prepared by bead milling to investigate the standard water curing of PF mortars and compared to a similarly graded FA. Both mortar types produced with 20% and 40% addition levels significantly surpassed the strength of the control PC mortars.

The susceptibility of PF and FA mortars to sulphate attack was investigated by immersing mortar cubes in deionised water and 1 M sodium sulphate. The degree of sulphate attack was monitored by mass gain and compressive strength measurement after 182 days of immersion. The 100% PC control mortar showed significant susceptibility with a large increase in mass gain and a reduction in strength. Both the PF and FA substituted mortars were found to be significantly more resistant to the sulphate solution with lower mass gains and significant improvements in strength relative to the control mortar in deionised water. In the PF and FA mortar samples, ettringite was identified by XRD analysis suggesting that its formation mitigated the effects of sulphate attack.

The investigation of PF as a pozzolan particularly in comparison to FA demonstrated that PF in mortar and concrete exhibited the positive attributes of strength and durability required. This experimental investigation proved that PF may be used as a SCM for the partial replacement of PC. From an engineering perspective, PF, which are hitherto unknown as a SCM for PC-based construction materials, are a viable option for adoption in the manufacture of PC-based construction materials, eventuating in value added benefits of strength improvement and increased resistance to chemical attack. Since the PF studied are currently a by-product of mining, the use of this naturally occurring SCM also helps mitigate the environmental impact at the mine site.

Table of Contents

Table of Contents	i
List of Abbreviations	v
List of Figures.....	vii
List of Tables	xii
1 Introduction.....	1
1.1 Preface	1
1.2 Portland Cement (PC)	2
1.3 Concrete.....	4
1.4 PC Hydration.....	5
1.5 Hydration Reactions and C-S-H Formation	9
1.6 Supplementary Cementitious Materials (SCMs).....	9
1.7 Natural Pozzolans.....	13
1.8 Fly Ash (FA).....	16
1.9 Pitchstone.....	18
1.10 Research Objectives.....	20
1.11 Significance.....	21
1.12 Structure of the Thesis	22
2 Pozzolanic Activity of Pitchstone and Related SCMs.....	24
2.1 Preface	24
2.2 Perlite Aggregate Investigations.....	25
2.2.1 Expanded Perlite Aggregate (EPA)	25
2.2.2 Fine Expanded Perlite Aggregate (FEPA).....	28
2.2.3 Pozzolanic Perlite.....	31

2.3	<i>Pozzolanic Activity</i>	38
2.3.1	Pozzolan Classification	38
2.3.2	Concrete Use	38
2.3.3	Strength Activity Index	39
2.3.4	ASTM C 618-08a Specification Compliance	39
2.4	<i>Sulphate Attack</i>	41
2.4.1	Gypsum Formation	42
2.4.2	Sodium Sulphate (Na ₂ SO ₄) Exposure	42
2.4.3	Ettringite Formation	43
2.4.4	Factors Affecting Rate of Sulphate Attack	44
2.4.5	Mechanical Properties	47
2.4.6	Resistance	48
3	Experimental Procedures	49
3.1	<i>Preface</i>	49
3.2	<i>Raw Materials</i>	50
3.2.1	Shrinkage Limited Portland Cement	50
3.2.2	Pitchstone Fines	52
3.2.3	Fly Ash	56
3.2.4	HI-POZZ™ Fly Ash	56
3.2.5	Densified Silica Fume	56
3.2.6	Single Washed Sand	58
3.2.7	Pitchstone Fine Aggregate	58
3.2.8	Nepean River Sand	59
3.2.9	Kurnell Sand	59
3.2.10	Coarse Aggregate	61
3.2.11	Water	62
3.2.12	Glenium 51 (G 51) Superplasticiser	62
3.3	<i>Sample Preparation Methods</i>	63
3.3.1	Mortar Mix Proportions	63
3.3.2	Mortar Mixing Procedures	64
3.3.3	Mortar 50-mm Cubes and Shrinkage Bars	64
3.3.4	Concrete Mix Proportions and Preparation	65

3.3.5	Concrete 100-mm Diameter Test Cylinders	66
3.4	<i>Methods of Characterisation</i>	67
3.4.1	Scanning Electron Microscopy (SEM)	67
3.4.2	X-Ray Diffraction (XRD)	67
3.4.3	Thermal Analysis	68
3.4.4	Flow and Slump	73
3.4.5	Wet Density (Mass per Unit Volume)	74
3.4.6	Compressive Strength	75
3.4.7	Length Change and Drying Shrinkage.....	77
3.5	<i>Evaluation Methods</i>	79
3.5.1	Pitchstone Fines Assessment	79
3.5.2	Fly Ash Comparison	83
3.5.3	Sulphate Exposure	87
4	Pitchstone Fines Assessment	90
4.1	<i>Preface</i>	90
4.2	<i>Strength Evaluation</i>	91
4.2.1	PC Replacement in Mortar by PF1	91
4.2.2	PC Replacement in Mortar by PF1 Using G 51	96
4.2.3	PC Replacement in Mortar by PF2 Using G 51	113
4.2.4	Fine Aggregate Replacement in Mortar by PFA Using G 51	116
5	Fly Ash Comparison	120
5.1	<i>Preface</i>	120
5.2	<i>Strength Evaluation</i>	121
5.2.1	PC Replacement in Mortar by PF3 and FA Using G 51	121
5.2.2	PC Replacement in Mortar by PF3-SF and FA-SF Using G 51	130
5.2.3	PC Replacement in Mortar by PF4 and FA Using G 51	135
5.2.4	PC Replacement in Mortar by PF5 and HPFA Using G 51	141
5.2.5	PC Replacement in Concrete by PF3 and FA	148
5.3	<i>Drying Shrinkage</i>	155
5.3.1	PC Replacement in Mortar by PF3 and FA Using G 51	155

5.3.2	PC Replacement in Mortar by PF3-SF and FA-SF Using G 51	158
6	Sulphate Exposure	160
6.1	<i>Preface</i>	160
6.2	<i>PC replacement in mortar by PF4, PF5 and FA using G 51</i>	161
6.2.1	pH Measurements	161
6.2.2	Mass Change	165
6.2.3	Strength Evaluation.....	169
6.2.4	X-Ray Diffraction (XRD)	176
6.2.5	Thermal Analysis	180
6.2.6	Strength Comparison	182
7	Summary and Conclusions.....	186
	Bibliography	194
Appendix A	Experimental Results.....	i
A1	<i>DTA-TG-DTG Thermograms</i>	<i>i</i>
Appendix B	List of Publications	xx

List of Abbreviations

10CA	10 mm Coarse Aggregate
20CA	20 mm Coarse Aggregate
AAC	Autoclaved Aerated Concrete
AS	Australian Standards
ASTM	American Society for Testing and Materials
C _c	Calcite
CS	Coarse Sand
C-A-S-H	Calcium Aluminate Silicate Hydrate
C ₂ S	Dicalcium Silicate
C ₃ A	Tricalcium Aluminate
C ₃ S	Tricalcium Silicate
C ₄ AF	Tetracalcium Aluminoferrite
CH	Calcium Hydroxide (Portlandite)
C-S-H	Calcium Silicate Hydrate
DTA	Differential Thermal Analysis
DTG	Differential Thermogravimetry
DTGA	Differential Thermogravimetric Analysis
DW	Deionised Water
E	Ettringite
EPA	Expanded Perlite Aggregate
EPP	Expanded Perlite Powder
FA	Fly Ash
FEPA	Fine Expanded Perlite Aggregate
FESEM	Field Emission Scanning Electron Microscope
FS	Fine Sand
GGBFS	Ground Granulated Blast-Furnace Slag
HPFA	HI-POZZ Fly Ash
KFS	Kurnell Fine Sand
ICCD	International Centre for Diffraction Data
ITZ	Interfacial Transition Zone

JCPDS	Joint Committee on Powder Diffraction Standards
L	Larnite
L _{dx}	Dehydroxylation Mass Loss
L _{dc}	Decarbonation Mass Loss
LOI	Loss on Ignition
LWAC	Light-Weight Aggregate Concrete
NPP	Natural Perlite Powder
P	Portlandite
P1	İzmir Perlite Powder
P2	Erzincan Perlite Powder
PA	Pumice Aggregate
PC	Portland Cement
PF	Pitchstone Fines
PFA	Pitchstone Fine Aggregate
PP	Perlite Powder
PSA	Particle Size Analyses
Q	Quartz
RH	Relative Humidity
SCC	Self Compacting Concrete
SE	Secondary Electrons
SEM	Scanning Electron Microscopy
SF	Silica Fume
SS	Sodium Sulphate
SSD	Saturated Surface Dry
TG	Thermogravimetry
TGA	Thermogravimetric Analysis
W	Water
w/b	Water/Binder
w/c	Water/Cement
w/cm	Water/Cementitious Material
WR	Water Requirement
wt. %	Weight Percent
XRD	X-ray Diffraction
XRF	X-ray Fluorescence

List of Figures

Figure 1.1 Compressive strength development in pastes of pure PC compounds (ACI-Committee-E-701 2001)	6
Figure 1.2 Rates of strength development in concretes made with the different PC types listed in Table 1.2	7
Figure 1.3 Worldwide carbon dioxide (CO ₂) emissions from PC production in the year 1994 (Worrell <i>et al.</i> 2001)	10
Figure 1.4 Greenhouse gas emissions from PC production in the year 2000 (Gt = gigatonnes) (Rehan <i>et al.</i> 2005).....	11
Figure 1.5 Location of Nychum pitchstone deposits in far north Queensland, Australia	18
Figure 1.6 Photographs showing (a) unprocessed pitchstone and (b) processed perlite from pitchstone	19
Figure 3.1 SEM micrograph of PC (x 800).....	51
Figure 3.2 Particle size distributions of sieved and milled PF samples.....	52
Figure 3.3 SEM micrograph of PF1 (x 800).....	53
Figure 3.4 SEM micrograph of PF2 (x 800).....	53
Figure 3.5 SEM micrograph of PF3 (x 800).....	54
Figure 3.6 SEM micrograph of PF4 (x 800).....	54
Figure 3.7 SEM micrograph of PF5 (x 800).....	55
Figure 3.8 SEM micrograph of FA (x 800)	55
Figure 3.9 SEM micrograph of HPFA (x 800)	57
Figure 3.10 SEM micrograph of SF (x 800).....	57

Figure 3.11 Typical DTA-TG-DTG thermogram curves showing thermal decomposition pattern of aged mortar	70
Figure 3.12 Typical DTA-TG-DTG thermogram curves showing thermal decomposition pattern of detritus collected from aged mortar	72
Figure 4.1 Strength activity index (SAI) versus ageing time (d = 24 h) for each mortar type after accelerated water ageing.....	96
Figure 4.2 Compressive strength (f_{cm}) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	99
Figure 4.3 Strength relative to 1 day strength (%) versus time intervals (d = 24 h) for each mortar type after standard curing regime in water	100
Figure 4.4 Strength activity index (SAI) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	101
Figure 4.5 SEM micrograph of control mortar after 28 days ageing (x 2.01 K)	103
Figure 4.6 SEM micrograph of control mortar after 28 days ageing (x 10 K)	103
Figure 4.7 SEM micrograph of control mortar after 28 days ageing (x 20 K)	104
Figure 4.8 SEM micrograph of 20% PF1 mortar after 28 days ageing (x 2.01 K)....	105
Figure 4.9 SEM micrograph of 20% PF1 mortar after 28 days ageing (x 10 K).....	105
Figure 4.10 SEM micrograph of 20% PF1 mortar after 28 days ageing (x 20 K).....	106
Figure 4.11 SEM micrograph of 40% PF1 mortar after 28 days ageing (x 2.01 K)..	107
Figure 4.12 SEM micrograph of 40% PF1 mortar after 28 days ageing (x 10 K).....	108
Figure 4.13 SEM micrograph of 40% PF1 mortar after 28 days ageing (x 20 K).....	108
Figure 4.14 XRD patterns of control mortar after 1, 7 and 28 days (d= 24 h) water ageing (E = ettringite, P = portlandite, Q = quartz, C _c = calcite, L = larnite)....	110

Figure 4.15 XRD patterns of 10% PF1 mortar after 1, 7 and 28 days (d = 24 h) water ageing (E = ettringite, P = portlandite, Q = quartz, C _c = calcite, L = larnite)....	110
Figure 4.16 XRD patterns of 20% PF1 mortar after 1, 7 and 28 days (d = 24 h) water ageing (E = ettringite, P = portlandite, Q = quartz, C _c = calcite, L = larnite)....	111
Figure 4.17 XRD patterns of 40% PF1 mortar after 1, 7 and 28 days (d = 24 h) water ageing (E = ettringite, P = portlandite, Q = quartz, C _c = calcite, L = larnite)....	111
Figure 4.18 XRD patterns of all mortars after 1 day (d = 24 h) water ageing (E = ettringite, P = portlandite, Q = quartz, C _c = calcite, L = larnite).....	112
Figure 4.19 XRD patterns of all mortars after 7 days (d = 24 h) water ageing (E = ettringite, P = portlandite, Q = quartz, C _c = calcite, L = larnite)	112
Figure 4.20 XRD patterns of all mortars after 28 days (d = 24 h) water ageing (E = ettringite, P = portlandite, Q = quartz, C _c = calcite, L = larnite)	113
Figure 4.21 Strength activity index (SAI) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	119
Figure 5.1 Compressive strength (f_{cm}) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	123
Figure 5.2 Strength relative to 3 day strength (%) versus time intervals (d = 24 h) for each mortar type after standard curing regime in water	125
Figure 5.3 Strength activity index (SAI) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	126
Figure 5.4 Compressive strength (f_{cm}) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	132
Figure 5.5 Strength relative to 3 day strength (%) versus time intervals (d = 24 h) for each mortar type after standard curing regime in water	133
Figure 5.6 Strength activity index (SAI) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	134

Figure 5.7 Compressive strength (f_{cm}) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	138
Figure 5.8 Strength relative to 7 day strength (%) versus time intervals (d = 24 h) for each mortar type after standard curing regime in water	139
Figure 5.9 Strength activity index (SAI) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	140
Figure 5.10 Compressive strength (f_{cm}) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water	144
Figure 5.11 Strength relative to 7 day strength (%) versus time intervals (d = 24 h) for each mortar type after standard curing regime in water	146
Figure 5.12 Strength activity index (SAI) versus ageing time (d = 24 h) for each mortar type after standard curing regime in water.....	147
Figure 5.13 Compressive strength (f_{cm}) versus ageing time (d = 24 h) for each concrete type after standard curing regime in water.....	150
Figure 5.14 Strength relative to 7 day strength (%) versus time intervals (d = 24 h) for each concrete type after standard curing regime in water.....	151
Figure 5.15 Strength activity index (SAI) versus ageing time (d = 24 h) for each concrete type after standard curing regime in water.....	153
Figure 5.16 Drying shrinkage increase (S_i) versus air storage age (d = 24 h) for length change of PF3 and FA mortars relative to control mortar	157
Figure 5.17 Drying shrinkage increase (S_i) versus air storage age (d = 24 h) for length change of PF3-SF and FA-SF mortars relative to control mortar.....	159
Figure 6.1 pH of deionised water for each mortar type versus ageing period (d = 24 h)	162
Figure 6.2 pH of 1 M sodium sulphate for each mortar type versus ageing period (d = 24 h)	164

Figure 6.3 Mass change (Δm) relative to 0 day mass versus ageing period (d = 24 h) of each mortar type in deionised water	166
Figure 6.4 Mass change (Δm) versus ageing period (d = 24 h) of each mortar type in 1 M sodium sulphate.....	168
Figure 6.5 Strength activity index (SAI) of each mortar type after 182 days (d= 24 h) in deionised water	171
Figure 6.6 Strength activity index (SAI) of each mortar type after 182 days (d= 24 h) in 1 M sodium sulphate.....	175
Figure 6.7 XRD patterns of control, 20% and 40% PF4 mortars after 182 days (d= 24 h) in 1 M Na ₂ SO ₄ (E = ettringite, C _c = calcite).....	177
Figure 6.8 XRD patterns of control, 20% and 40% PF5 mortars after 182 days (d= 24 h) in 1 M Na ₂ SO ₄ (E = ettringite, C _c = calcite).....	178
Figure 6.9 XRD patterns of control, 20% and 40% FA mortars after 182 days (d= 24 h) in 1 M Na ₂ SO ₄ (E = ettringite, C _c = calcite).....	178
Figure 6.10 XRD patterns of control and 20% PF4, PF5 and FA mortars after 182 days (d= 24 h) in 1 M Na ₂ SO ₄ (E = ettringite, C _c = calcite).....	179
Figure 6.11 XRD patterns of control and 40% PF4, PF5 and FA mortars after 182 days (d= 24 h) in 1 M Na ₂ SO ₄ (E = ettringite, C _c = calcite).....	179
Figure 6.12 Compressive strength for PF4, PF5 and FA additions in mortars after 182 days (d= 24 h) in control (DW) and sulphate (SS) solution	182

List of Tables

Table 1.1 Main chemical compounds formed in the PC kiln (ACI-Committee-E-701 2001)	2
Table 1.2 Type and typical compound composition of PC (ACI-Committee-E-701 2001)	3
Table 1.3 Characteristics of hydration of PC compounds (ACI-Committee-E-701 2001)	8
Table 3.1 Chemical composition of starting materials with oxides and loss on ignition (LOI) are in mass percent	50
Table 3.2 Fraction of particle size less than the value listed in μm	51
Table 3.3 Particle size distribution (sieving method) of Raymond Terrace single washed sand	58
Table 3.4 Particle size distribution (sieving method) of pitchstone fine aggregate	59
Table 3.5 Particle size distribution (sieving method) of Nepean double washed river sand	60
Table 3.6 Particle size distribution (sieving method) of Kurnell single washed sand	60
Table 3.7 Particle size distribution (sieving method) of 10 mm coarse aggregate	61
Table 3.8 Particle size distribution (sieving method) of 20 mm coarse aggregate	61
Table 3.9 Mortar mix designs incorporating PF1 additions	80
Table 3.10 Mortar mix designs incorporating PF1 addition levels with G 51	80
Table 3.11 Mortar mix designs using PF2 additions with G 51	82
Table 3.12 Mortar mix designs using PFA additions with G 51	82
Table 3.13 Mortar mix designs using PF3 and FA additions with G 51	83

Table 3.14 Mortar mix designs using PF3-SF and FA-SF additions with G 51	85
Table 3.15 Mortar mix designs using PF4 and FA additions with G 51	85
Table 3.16 Mortar mix designs using PF5 and HPFA additions with G 51	86
Table 3.17 Concrete mix designs using PF3 and FA additions	87
Table 3.18 Mortar mix designs using PF4, PF5 and FA additions with G 51	89
Table 4.1 Fresh mortar properties of flow and wet density (ρ_{wet}).....	92
Table 4.2 Hardened mortar properties of compressive strength (f_{cm}) and strength activity index (SAI) after accelerated water ageing.....	94
Table 4.3 Fresh mortar properties of flow, wet density (ρ_{wet}) and G 51 volume over total mass (v/w) of mortar.....	97
Table 4.4 Hardened mortar properties of compressive strength (f_{cm}) and strength activity index (SAI) for 1, 7 and 28 days (d = 24 h) water ageing	98
Table 4.5 Hardened mortar properties of compressive strength relative to 1 day strength (f_{cm}/f_{cm1d}) for increasing time intervals (d = 24 h) of water ageing	99
Table 4.6 Fresh mortar properties of flow, wet density (ρ_{wet}) and G 51 volume over total mass (v/w) of mortar.....	114
Table 4.7 Hardened mortar properties of compressive strength (f_{cm}) and strength activity index (SAI) for accelerated water ageing	115
Table 4.8 Fresh mortar properties of flow, wet density (ρ_{wet}) and G 51 volume over total mass (v/w) of mortar.....	116
Table 4.9 : Hardened mortar properties of compressive strength (f_{cm}) and strength activity index (SAI) for 14 and 28 days (d = 24 h) water ageing	117
Table 4.10 Hardened mortar properties of compressive strength (f_{cm}) and strength activity index (SAI) after accelerated water ageing.....	118

Table 5.1 Fresh mortar properties of flow, wet density (ρ_{wet}) and G 51 volume over total mass (v/w) of mortar.....	121
Table 5.2 Hardened mortar properties of compressive strength (f_{cm}) for 3, 7, 14, 28, 56 and 91 days (d = 24 h) water ageing	123
Table 5.3 Hardened mortar properties of compressive strength relative to 3 day strength (f_{cm}/f_{cm3d}) for increasing time intervals (d = 24 h) of water ageing	124
Table 5.4 Hardened mortar properties of strength activity index (SAI) for 3, 7, 14, 28, 56 and 91 days (d = 24 h) water ageing	126
Table 5.5 TG data of L_{dx} , measured CH (CH _M) mass, expected CH (CH _E) mass and percent mass change (Δ CH) of CH _M to CH _E of mortar sampled at core (c) after 28 and 91 days (d = 24 h) water ageing	128
Table 5.6 TG data of L_{dx} , measured CH (CH _M) mass, expected CH (CH _E) mass and percent mass change (Δ CH) of CH _M to CH _E of mortar sampled at surface (s) after 28 and 91 days (d = 24 h) water ageing.....	129
Table 5.7 Fresh mortar properties of flow, wet density (ρ_{wet}) and G 51 volume over total mass (v/w) of mortar.....	130
Table 5.8 Hardened mortar properties of compressive strength (f_{cm}) for 3, 7, 14, 28, 56 and 91 days (d = 24 h) water ageing	132
Table 5.9 Hardened mortar properties of compressive strength relative to 3 day strength (f_{cm}/f_{cm3d}) for increasing time intervals (d = 24 h) of water ageing	133
Table 5.10 Hardened mortar properties of strength activity index (SAI) for 3, 7, 14, 28, 56 and 91 days (d = 24 h) water ageing	134
Table 5.11 Fresh mortar properties of flow, wet density (ρ_{wet}) and G 51 volume over total mass (v/w) of mortar.....	136
Table 5.12 Hardened mortar properties of compressive strength (f_{cm}) for 7, 28, 56 and 91 days (d = 24 h) water ageing.....	137

Table 5.13 Hardened mortar properties of compressive strength relative to 7 day strength (f_{cm}/f_{cm7d}) for increasing time intervals (d = 24 h) of water ageing	138
Table 5.14 Hardened mortar properties of strength activity index (SAI) for 7, 28, 56 and 91 days (d = 24 h) water ageing	140
Table 5.15 Fresh mortar properties of flow, wet density (ρ_{wet}) and G 51 volume over total mass (v/w) of mortar	142
Table 5.16 Hardened mortar properties of compressive strength (f_{cm}) for 7, 28, 56 and 91 days (d = 24 h) water ageing	144
Table 5.17 Hardened mortar properties of compressive strength relative to 7 day strength (f_{cm}/f_{cm7d}) for increasing time intervals (d = 24 h) of water ageing	145
Table 5.18 Hardened mortar properties of strength activity index (SAI) for 7, 28, 56 and 91 days (d = 24 h) water ageing	146
Table 5.19 Fresh concrete properties of slump and wet density (ρ_{wet})	148
Table 5.20 Hardened concrete properties of compressive strength (f_{cm}) for 7, 28, 56 and 91 days (d = 24 h) water ageing	149
Table 5.21 Hardened concrete properties of compressive strength relative to 7 day strength (f_{cm}/f_{cm7d}) for increasing time intervals (d = 24 h) of water ageing	151
Table 5.22 Hardened concrete properties of strength activity index (SAI) for 7, 28, 56 and 91 days (d = 24 h) water ageing	152
Table 5.23 Hardened concrete properties of compressive strength (f_{cm}) and strength activity index (SAI) for 28 and 91 days (d = 24 h) air storage	154
Table 5.24 Hardened mortar properties of length change (ΔL) after 7, 14 and 28 days (d = 24 h) air storage relative to 0 day length and a gauge length of 200 mm ..	155
Table 5.25 Drying shrinkage increase (S_i) of PF3 and FA mortars relative to control mortar after 7, 14 and 28 days (d = 24 h) air storage	157

Table 5.26 Hardened mortar properties of length change (ΔL) after 7, 14 and 28 days (d = 24 h) air storage relative to 0 day length and a gauge length of 200 mm ..	158
Table 5.27 Drying shrinkage increase (S_i) of PF3-SF and FA-SF mortars relative to control mortar after 7, 14 and 28 days (d = 24 h) air storage	159
Table 6.1 pH of deionised water for each mortar type after 0, 1, 28, 56, 84, 112, 140 and 182 days (d = 24 h)	161
Table 6.2 pH in 1 M sodium sulphate for each mortar type after 0, 1, 28, 56, 84, 112, 140 and 182 days (d = 24 h).....	163
Table 6.3 Mass change (Δm) of each mortar type relative to 0 day mass after 28, 56, 84, 112, 140 and 182 days (d = 24 h) in deionised water	165
Table 6.4 Mass change (Δm) of each mortar type relative to 0 day mass after 28, 56, 84, 112, 140 and 182 days (d = 24 h) in 1 M sodium sulphate.....	167
Table 6.5 Compressive strength (f_{cm}) and strength activity index (SAI) of each mortar type after 182 days (d = 24 h) in deionised water	169
Table 6.6 Compressive strength (f_{cm}) and strength activity index (SAI) of each mortar type after 182 days (d = 24 h) in 1 M sodium sulphate	172
Table 6.7 Strength in 1 M sodium sulphate (f_{cm-SS}) relative to strength in deionised water (f_{cm-DW}) of each mortar type after 182 days (d = 24 h) ageing	173
Table 6.8 TG mass loss data representing sulphur trioxide (SO_3) and sulphate (SO_4^{2-}) in mortar after 182 days (d = 24 h) in 1 M Na_2SO_4	180