

EFFECT OF HIGH VOLUME FLY ASH ON PERFORMANCE OF GROUT AND
MASONRY CEMENT MORTAR

BALAMOHAN A/L BALAKRISHNAN

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy

School of Civil Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

FEBRUARY 2020

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, researchers, academicians, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main supervisor, Professor Dr. Mohammad Bin Ismail, I wouldn't have reached this important milestone in my life without his encouragement, guidance, critics and friendship. I am also very thankful to my co-supervisor Dr. Nur Hafizah Abd Khalid and Dr. Yunus Bin Ishak for their guidance, advices and motivation. Without their continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to Universiti Teknologi Malaysia (UTM) for the technical assistance rendered in lab and in supplying the resources in completing my studies.

My fellow postgraduate student should also be recognised for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to my entire family member.

ABSTRACT

Grout and mortar often selected for building repair and restoration works. However, these materials are also deteriorating and failed similarly as per the parent concrete or masonry structure due to environmental exposure, electrochemical reactions and mechanical loading. Previous studies and the available literature indicate that the failure of such repair material is mainly due to improper selection of material without knowing the material's ability in order to improve the repair grout and masonry cement mortar is currently lacking. To address this, high volume fly ash (HVFA) in repair grout and masonry cement mortar is introduced. HVFA is selected as fly ash (FA) waste is still abundance and its unique spherical shape and pozzolanic property is suitable for this study. This research is first carried out by investigating the characteristics of the binders using X-ray Fluorescence Spectrometry (XRF), Scanning Electron Microscope (SEM) and X-Ray Diffraction (XRD). The performance evaluation of grout and mortar has been accomplished with specimens where Ordinary Portland Cement (OPC) and masonry cement (MC) is replaced by Class F FA up to 50%. The grout and mortar were subjected to workability test such as flow, viscosity and spread followed by mechanical properties such as compressive strength, bond strength and flexural strength. Durability of the material is finally evaluated by exposing them to aggressive substances such as acid, chloride and sulphate, and high temperature up to 1000 °C. HVFA results an excellent grout flow time with a reduction over 30% in flow time and maintained a fluid Bingham behaviour over 1 hour. Meanwhile, the mortar has an increment of 15% in spread. The compressive strength, flexural and splitting tensile shows that grout with 40% FA is close to the control value, while 50% FA grout is slightly lower at the end of 360 days. Opposite result is found with masonry cement mortar where HVFA exceeded control at 90 days. HVFA grout experienced approximately 50% lower amount of autogenous shrinkage and time to crack in drying shrinkage evaluation. The porosity of the HVFA grout is reducing with inclusion of FA at 360 days. While the mortar being air-entrained material, slightly affected by fly ash properties that results in additional water absorption. The HVFA's pozzolanic, filler and dilution effect has contributed to remarkable performance against aggressive substances and condition for both materials. Grout being loaded with cement has 40% to 80% higher resistance to the chemical substances as compared to control, while mortar is the range of 80% to 100%. Test result on temperature rise shows HVFA able to reduce over 20 °C in peak temperature. Additionally, the thermal insulation behaviour of HVFA grout indicates slower response to heating by having additional 20 hours in time to reach 100 °C. The comparison between grout and masonry mortar shows good similarity, particularly in chemical resistance. Conclusively, the performance of HVFA in grout and masonry cement mortar has found to be satisfactory and can be used for concrete and masonry repair with increased durability. Both materials can be expected to compliment a sustaining building repair and restoration work.

ABSTRAK

Grout dan mortar kerap dipilih untuk membaik pulih bangunan. Walaubagaimanapun, bahan-bahan ini juga mengalami kemerosotan dan kegagalan sama seperti konkrit atau struktur bata akibat pendedahan kepada alam sekitar, tindak balas elektrokimia dan beban mekanikal. Kajian dan literatur terdahulu menunjukkan bahawa kegagalan bahan pembaikan seperti ini disebabkan oleh pemilihan bahan yang tidak sesuai dan pemahaman untuk menambahbaik grout and mortar masih berkurangan. Untuk menangani masalah ini, “high volume fly ash” (HVFA) telah diperkenalkan dalam grout pembaikan dan mortar untuk kerja bata. HVFA telah dipilih disebabkan sisa “fly ash” (FA) masih banyak didapati dan dalam bentuk yang unik serta sifat “pozzolanic” adalah ciri-ciri yang sesuai untuk kajian ini. Penyelidikan ini dimulakan dengan menyiasat ciri-ciri simen and FA dengan menggunakan X-ray Spectrometry Fluorescence (XRF), Scanning Electron Microscope (SEM) dan X-Ray Diffraction (XRD). Penilaian prestasi grout dan mortar telah dicapai di mana Simen Portland Biasa (OPC) dan masonry cement (MC) digantikan dengan FA Kelas F sehingga 50%. Grout dan mortar tertakluk kepada ujian keboleherjaan seperti aliran, kelikatan dan penyebaran diikuti oleh sifat-sifat mekanikal seperti kekuatan mampatan, kekuatan ikatan dan kekuatan lenturan. Ketahananlasakan bahan-bahan tersebut akhirnya dinilai dengan mendedahkannya kepada bahan kimia agresif seperti asid, klorida dan sulfat serta suhu setinggi 1000 °C. Keputusan HVFA menunjukkan aliran grout yang sangat baik dengan pengurangan 30% masa aliran dan mengekalkan sifat cecair Bingham selepas 1 jam. Selain itu, mortar mempunyai peningkatan penyebaran sehingga 15%. Kekuatan mampatan, tegangan lenturan dan pemisahan pada 360 hari menunjukkan grout dengan 40% FA hampir sama dengan sampel kawalan, manakala grout dengan 50% FA menunjukkan kekuatan lebih rendah. Keputusan sebaliknya diperolehi dengan masonry mortar di mana kekuatan HVFA melebihi nilai kawalan selepas 90 hari. Grout HVFA mengalami pengecutan autogenous dan masa retakan sebanyak 50% lebih rendah didalam penilaian pengecutan pengeringan. Ronggaan pada grout HVFA bekurangan dengan kemasukan FA selepas 360 hari. Sementara itu, mortar yang mengandungi pengudaraan sedikit terjejas oleh sifat FA yang menyebabkan penyerapan air bertambah. Kesan pozzolanic, isian dan pencairan HVFA telah menyumbang kepada ketahananlasakan yang luar biasa terhadap bahan kimia dan keadaan yang agresif untuk kedua-dua bahan. Grout yang mempunyai kandungan simen yang tinggi, mempunyai 40% hingga 80% rintangan manakala mortar mempunyai rintangan antara 80 hingga 100% lebih baik terhadap bahan kimia berbanding dengan nilai kawalan. Hasil ujian pada peningkatan suhu menunjukkan HVFA mampu mengurangkan lebih dari 20 °C suhu puncak. Selain itu, sifat penambat haba HVFA grout menunjukkan tindak balas yang perlahan dan memerlukan tambahan masa sebanyak 20 jam untuk mencapai suhu 100 °C. Perbandingan antara grout dan mortar menunjukkan kesamaan, terutamanya dalam rintangan terhadap bahan kimia. Kesimpulannya, prestasi HVFA di dalam grout dan mortar didapati memuaskan dan boleh digunakan untuk pembaikan konkrit dan kerja bata dengan peningkatan ketahananlasakan. Kedua-dua bahan boleh membantu dalam kerja membaik pulih bangunan yang mampan.

TABLE OF CONTENTS

	TITLE	PAGE
	DECLARATION	iii
	DEDICATION	iv
	ACKNOWLEDGEMENT	v
	ABSTRACT	vi
	ABSTRAK	vii
	TABLE OF CONTENTS	viii
	LIST OF TABLES	xvi
	LIST OF FIGURES	xviii
	LIST OF ABBREVIATIONS	xxviii
	LIST OF SYMBOLS	xxix
	LIST OF APPENDICES	xxx
CHAPTER 1	INTRODUCTION	1
1.1	Problem Background	1
1.2	Background of the Study	2
1.3	Background of the Problem	3
1.4	Aim and Objective of the Study	5
1.5	Scope of Study	5
1.6	Significance of the Study	7
1.7	Layout of the Thesis	8
CHAPTER 2	LITERATURE REVIEW	9
2.1	Introduction	9
2.2	Differences between Concrete, Grout and Masonry Mortar	10
2.2.1	Concrete	10
2.2.2	Grout	11
2.2.3	Masonry Mortar	25
2.3	Cement and Fly Ash Reaction Kinetics	32

2.3.1	Cement Hydration	32
2.3.2	Fly Ash Pozzolanic Reactions	35
2.4	Use of Fly Ash as Cementing Material	37
2.4.1	Background of Fly Ash	37
2.4.2	Current Scenario of Fly Ash Production and Utilization Background in Malaysia and Globally	38
2.4.3	Characteristics of the Fly ash	43
2.4.3.1	Morphology	43
2.4.3.2	Fineness	44
2.4.3.3	Blaine Surface Area	46
2.4.3.4	Specific Gravity	48
2.4.3.5	Chemical Composition	49
2.4.3.6	Mineralogical Composition	51
2.5	High Volume Fly Ash Concept	52
2.6	Effect of Fly Ash on Cement Composites Properties (Grout and Masonry Mortar)	53
2.6.1	Effect of HVFA on Workability Properties	53
2.6.1.1	Effect on Grout Rheological Properties	53
2.6.1.2	Effect on Masonry Cement Mortar Flow Properties	58
2.6.2	Effect of HVFA on Mechanical Properties	61
2.6.2.1	Mechanical Properties of Grout	61
2.6.2.2	Mechanical Properties of Masonry Cement Mortar	64
2.6.3	Effect of HVFA on Durability	67
2.6.3.1	Overview of Grout and Mortar Durability	69
2.6.3.2	Resistance to Chloride Penetration	72
2.6.3.3	Resistance to Acid Attack	74
2.6.3.4	Resistance to Sulphate Attack	76
2.6.3.5	Resistance to High Temperature	78
2.7	Summary and Gap in Literature	79

CHAPTER 3	RESEARCH METHODOLOGY	83
3.1	Introduction	83
3.2	Materials	83
3.2.1	Overview of Cementitious Binders	84
3.2.1.1	Ordinary Portland Cement(CEM I 52.5N)	84
3.2.1.2	Masonry Cement (MC 22.5)	84
3.2.1.3	Supplementary Cementitious Binder (Fly Ash)	85
3.2.2	Fine Aggregates	86
3.2.3	Admixtures	88
3.2.3.1	Superplastizicer	88
3.2.3.2	Expansion Agent	89
3.2.4	Water	89
3.2.5	Characterization of Binders	90
3.2.5.1	Particle Size Distribution	91
3.2.5.3	Soundness	92
3.2.5.5	Strength Activity Index (SAI)	93
3.2.5.6	Element Analysis Using XRF	93
3.2.5.7	Mineralogy Analysis Using X-ray Diffraction (XRD)	95
3.2.5.8	Microstructure Analysis Using Scanning Electron Microscope (SEM) With Energy Dispersive X-Ray (EDS)	95
3.2.5.9	Loss on Ignition (LOI)	97
3.2.6	Design and Proportioning of Grout and Masonry Mortar	97
3.3	Test on Fresh State Properties of Grout and Mortar	99
3.3.1	Flow Test of Grout	100
3.3.2	Spread Test of Grout	102
3.3.3	Mini Slump Cone Test of Grout	103
3.3.4	Viscosity of Grout	103
3.3.5	Spread of Mortar	104

3.3.6	Apparent Density of Grout and Mortar	105
3.3.7	Air Content of Grout and Mortar	106
3.3.8	Expansion and Bleeding of Grout	106
3.3.9	Setting Times of Grout	108
3.3.11	Water Retention of Mortar	109
3.4	Testing on Hardened State of Grout and Masonry Mortar	110
3.4.1	Compressive Strength of Grout and Mortar	110
3.4.2	Flexural Strength of Grout	112
3.4.4	Indirect Tensile Strength of Grout	113
3.4.5	Slant Shear Test of Grout	114
3.4.6	Bond Strength of Masonry Mortar	115
3.5	Durability Testing of Grout and Mortar	116
3.5.1	Dimensional Stability of Grout	118
3.5.1.1	Drying Shrinkage Ring Test	118
3.5.1.2	Autogenous Shrinkage Micrometer Bridge Test	120
3.5.2	Water Absorption of Mortar	121
3.5.3	Apparent Porosity of Grout	122
3.5.4	Chloride Penetration of Grout and Mortar	123
3.5.5	Acid Attack Resistance of Grout and Mortar	125
3.5.6	High Temperature Resistance of Grout	126
3.5.7	Sulphate Attack Resistance of Grout and Mortar	128
3.5.8	Temperature Rise of Grout	129
3.5.9	Thermal Insulation Capacity of Grout	130
3.5.10	Salt Migration Test of Mortar	132
3.7	Summary	133
CHAPTER 4	PHYSICAL AND CHEMICAL CHARACTERISTICS OF MATERIALS	135
4.1	Introduction	135
4.2	Characteristics of OPC, Masonry Cement and Fly ash	135
4.2.1	Physical Properties	135

	4.2.1.1	Morphological Properties	136
	4.2.1.2	Particle Size Distribution	141
	4.2.1.3	Blaine Fineness	142
	4.2.1.4	Strength Activity Index	143
	4.2.1.5	Loss on Ignition	144
	4.2.1.7	Residue 45 μm	145
	4.2.1.8	Specific Gravity	145
	4.2.1.9	Summary of Physical test	146
	4.2.2	Chemical Properties	146
	4.2.2.1	Soundness	147
	4.2.2.2	Mineralogical Composition of Portland and Masonry Cement	148
	4.2.2.4	Mineralogical Phases of Fly Ash	151
4.3		Summary of Characteristics of Binders	152
CHAPTER 5		FRESH STATE PROPERTIES OF GROUT AND MORTAR	153
5.1		Introduction	153
5.2		Grout	153
	5.2.1	Setting Times of Grout	153
	5.2.3	Expansion and Bleeding of Grout	155
	5.2.4	Air Content and Fresh Density of Grout	156
	5.2.5	Time Dependent Flows of Grout	159
	5.2.6	Spread of Grout	161
	5.2.7	Time Dependent Viscosities of Grout	163
5.3		Masonry Cement Mortar	169
	5.3.1	Spread of Mortar	169
	5.3.2	Air Content and Density of Mortar	170
	5.3.3	Water Retention of Mortar	172
5.4		Summary of Fresh State Properties	174
	5.4.1	Grout	174
	5.4.2	Mortar	175

	5.4.3 Differences between Grout and Mortar in Workability	175
CHAPTER 6	MECHANICAL PROPERTIES OF GROUT AND MORTAR	177
6.1	Introduction	177
6.2	Mechanical Properties of Grout	177
	6.2.1 Compressive Strength of Grout	177
	6.2.2 Slant Shear Strength of Grout	179
	6.2.3 Flexural Strength of Grout	181
	6.2.4 Grout's Flexural Strength Versus Compressive Strength	182
	6.2.5 Splitting Tensile Strength of Grout	183
	6.2.6 Grout's Spitting Tensile Strength Versus Compressive Strength	185
6.3	Mechanical Properties of Mortar	186
	6.3.1 Compressive Strength of Mortar	186
	6.3.2 Bond Strength of Mortar	188
6.5	Summary of Mechanical Properties	190
	6.5.1 Grout	190
	6.5.2 Mortar	190
	6.5.3 Differences between Grout and Mortar in Strength Properties	191
CHAPTER 7	BEHAVIOR OF GROUT AND MORTAR EXPOSED TO AGGRESSIVE SUBSTANCES AND CONDITIONS	193
7.1	Introduction	193
7.2	Behavior of Grouts	193
	7.2.1 Harden State Dimensional Stability of Grout	193
	7.2.2 Autogenous Shrinkage Volume Change of Grout	194
	7.2.3 Drying Shrinkage Stability of Grout	195
	7.2.4 Apparent Porosity of Grout	197
	7.2.5 Acid Attack Resistance of Grout	199
	7.2.5.1 Physical Appearance of Grout	199

7.2.5.2	Residual Strength of Grout	203
7.2.5.3	Microstructure Properties of Grout	207
7.2.6	Chloride Penetration Resistance of Grout	214
7.2.6.1	Physical Appearance of Grout	214
7.2.6.2	Chloride Penetration Depth of Grout	215
7.2.6.3	Chloride Diffusion Coefficients of Grout	220
7.2.7	Sulphate Attack Resistance of Grout	222
7.2.7.1	Microstructural Analysis of Grout	225
7.2.8	High Temperature Resistance of Grout	225
7.2.8.1	Colour Change of Grout	226
7.2.8.2	Cracking Tendency of Grout	227
7.2.8.3	Mass Changes of Grout	231
7.2.8.4	Residual Strength of Grout	234
7.2.8.5	Microstructural Analysis of Grout	237
7.2.9	Temperature Rise of Grout	242
7.2.10	Thermal Conductivity Capacity of Grout	244
7.3	Behavior of Masonry Cement Mortar	248
7.3.1	Water Absorption of Mortar	248
7.3.2	Chloride Penetration Resistance of Mortar	249
7.3.2.1	Physical Appearance of Mortar	250
7.3.2.2	Chloride Penetration Depth of Mortar	251
7.3.3	Acid Attack Resistance of Mortar	253
7.3.3.1	Physical Appearance of Mortar	253
7.3.3.2	Mass Changes of Mortar	254
7.3.3.3	Residual Strength of Mortar	255
7.3.3.4	Microstructure Properties of Mortar	257
7.3.4	Sulphate Attack Resistance of Mortar	259
7.3.5	Salt Migration of Mortar	260
7.4	Summary of Durability Assessment	262
7.4.1	Grout	262

7.4.2	Masonry Mortar	263
7.4.3	Differences between Grout and Mortar Durability	264
CHAPTER 8	CONCLUSION AND RECOMMENDATION	267
8.1	Introduction	267
8.2	Conclusions	267
8.3	Contribution of This Research Work	269
8.4	Recommendations	270
REFERENCES		271
LIST OF PUBLICATION		319

LIST OF TABLES

TABLE NO.	TITLE	PAGE
Table 1.1	Summary of scope of study	6
Table 2.1	Summary of grout properties studied	15
Table 2.2	Summary of masonry mortar studied	27
Table 2.3	Crystalline phases of OPC (Siddique and Khan, 2011)	32
Table 2.4	Residue 45 μm of various power plants fly ash	46
Table 2.5	Blaine surface area of various power plants fly ash	47
Table 2.6	Specific gravity of various power plants fly ash	48
Table 2.7	Chemical composition of various power plants fly ash	50
Table 2.8	Crystalline phase composition and glass content of fly ash from various sources (Oey et al., 2015)	52
Table 2.9	Fly ash grout rheology test with different content and type of fly ash	57
Table 2.10	Masonry mortar flow test with different content of fly ash and cement	60
Table 2.11	Fly ash grout strength test with different content and type of fly ash	63
Table 2.12	Strength test of fly ash mortar with different content and fly ash type	65
Table 2.13	Mix proportions and properties studied on cementitious grout	69
Table 2.14	Previous durability studies of masonry mortar	71
Table 2.15	Compressive strength after immersed in MgSO_4 (Vaishnavi and Kanta Rao, 2014)	77
Table 3.1	Composition of masonry cement (ASTM C270, 2014)	85
Table 3.2	Properties of superplasticiser	88

Table 3.3	Mix proportions of grout (% of weight)	98
Table 3.4	Mix proportions of masonry cement mortar (% of weight)	99
Table 4.1	D values of OPC, MC and FA	142
Table 4.2	Physical properties of OPC, MC and FA	146
Table 4.3	Chemical composition of OPC, MC and FA	147
Table 4.4	Soundness of masonry cement and OPC with various level of fly ash	148
Table 4.5	Mineralogical phase of Masonry Cement and OPC	149
Table 4.6	Mineralogical phase of fly ash	151
Table 5.1	Setting times of grout with various level of fly ash.	154
Table 5.2	Expansion and bleeding of grout with various level of fly ash	156
Table 5.3	Air content and fresh density of grout with various level of fly ash.	157
Table 5.4	Air content and density of mortar with various level of fly ash	172
Table 5.5	Differences between grout and mortar in workability	175
Table 6.1	Bond strength of masonry cement mortar containing fly ash	189
Table 6.2	Differences between grout and mortar in strength properties	191
Table 7.1	Volume change of grout after 28 days	195
Table 7.2	Time to crack of grout	197
Table 7.3	Length of bar after exposure to acid	202
Table 7.4	Summary of physical characteristics after exposed to 360 days in H ₂ SO ₄	206
Table 7.5	Percentage reduction in chloride penetration depth	217
Table 7.6	Temperature and time history of grout's heat development	243
Table 7.7	Heating timing of grout specimens	246
Table 7.8	Differences between grout and mortar in chemical resistance	265

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
Figure 1.1	The organisation of the thesis	8
Figure 2.1	The outline of literature review	10
Figure 2.2	Difference of workability, between concrete, mortar and grout when comparing to a standard slump cone height (Amrhein, 1980)	12
Figure 2.3	Common grout application (Harrison, 2000)	12
Figure 2.4	Different application of cement grout employed in previous studies	13
Figure 2.5	Groups of modern mortars (ASTM C270, 2014)	26
Figure 2.6	Types of mortar according to strength (ASTM C270, 2014)	26
Figure 2.7	Hydration progress of cement compounds in relation to duration (Franus et al., 2015)	33
Figure 2.8	Ca(OH) ₂ microstructure inside a cement matrix (Franus et al., 2015)	35
Figure 2.9	Pozzolanic reaction of fly ash	36
Figure 2.10	SEM analysis of fly ash particles and C-S-H (Fauzi et al., 2016)	36
Figure 2.11	Schematic diagram of coal fly ash collection system (Thomas, 2007)	37
Figure 2.12	Coal consumption of Malaysia power plant from 1978 to 2014 (Suruhanjaya Tenaga, 2015)	39
Figure 2.13	Global coal consumption (BGR Federal Institute for Geosciences and Natural Resources, 2016)	40
Figure 2.14	Various use of fly ash waste (American Road & Transportation Builders Association's, 2015)	42

Figure 2.15	Production and reuse of fly ash in United States (American Road & Transportation Builders Association's, 2015)	42
Figure 2.16	Physical appearance of fly ash powder (Dash et al., 2016)	44
Figure 2.17	SEM image of fly ash particles (Ren and Sancaktar, 2019)	44
Figure 2.18	Typical XRD pattern of Class F fly ash (Revathi et al., 2016)	51
Figure 2.19	Schematic flow curves of fluids (Güllü, 2015)	55
Figure 2.20	Rheogram of fly ash slurry (Lee et al., 2017)	56
Figure 2.21	Compressive strength of fly ash grout at 28 days (Mirza et al., 2002)	62
Figure 2.22	Compressive strength of fly ash grout (Shah et al., 2013)	65
Figure 2.23	Potential sources of chemicals that can attack a building unit	68
Figure 2.24	Photos showing severity of wall damage due to durability (a) common due to salt weathering (b) repair in Penang Malaysia due to salt attack ((Ahmad et al., 2010)	68
Figure 2.25	RCPT value for fly ash concrete (Madhavi et al., 2015)	73
Figure 2.26	Colorimetric test in concrete with fly ash (Filho et al., 2013)	74
Figure 2.27	Loss of strength of HVFA concrete after exposed to sulphuric acid (Saoo et al., 2015).	75
Figure 2.28	Sulphuric acid attack in sewage pipes	76
Figure 2.29	Effect of temperature on compressive strength of fly ash concrete (Khan et al., 2013)	79
Figure 2.30	Research gap	81
Figure 3.1	Jimah Power Plant (Jimah, 2019)	86
Figure 3.2	Appearance of sand used in the preparation of grout and mortar	87
Figure 3.3	Framework of characterisation of sand	87
Figure 3.4	Aluminium based expansion agent used in the grout mixture	89

Figure 3.5	Framework for characterization of binder materials	90
Figure 3.6	Malvern Mastersizer 2000 equipment	91
Figure 3.7	Soundness test set-up (a) heating setup (b) specimens	92
Figure 3.8	XRF machine used for elemental analysis	94
Figure 3.9	Steps of preparing the pellet for XRF testing, (a) sample sieving (b) specimen loading (c) pellet making (d) cleaning pellet.	94
Figure 3.10	XRD analysis set-up (a) equipment overview (b) prepared sample	95
Figure 3.11	Set-up for SEM analysis (a) metallization of sample (b) samples on stubs (c) SEM equipment overview (d) specimen loading in SEM equipment.	96
Figure 3.12	Framework of tests for fresh states of grout and mortar	100
Figure 3.13	Set-up for flow test according to ASTM C939 method	101
Figure 3.14	Set-up for flow test according to BS EN 445 method	102
Figure 3.15	Set-up for spread test according to ASTM C939 method	102
Figure 3.16	Dimension of the mini slump cone	103
Figure 3.17	Set-up for viscosity measurement	104
Figure 3.18	Set-up for flow table test	105
Figure 3.19	Set-up for density measurement	105
Figure 3.20	Air meter used for grout and mortar air content measurement	106
Figure 3.21	Test set-up for expansion and bleeding measurement	107
Figure 3.22	Set-up for grout setting time measurement (a) test set-up (b) penetration needle	108
Figure 3.23	Set-up of water suction system for determination of water retention	109
Figure 3.24	Framework hardened state properties measurement	110
Figure 3.25	Preparation of 50 mm cube for test of compressive strength	111

Figure 3.26	Set-up for test for compressive strength	111
Figure 3.27	Set-up for test for flexural strength measurement (a) specimen preparation (b) testing of specimen	112
Figure 3.28	Set-up for test for splitting tensile strength measurement	113
Figure 3.29	Dimension of slanted specimen for slant shear	114
Figure 3.30	Set-up for test for slant shear measurement	115
Figure 3.31	Photographs of pull-out dongle attached to a brick and test apparatus installed	116
Figure 3.32	Framework of test for durability measurement	117
Figure 3.33	Specimen prepared for various durability tests like chemical attack and high temperature	118
Figure 3.34	Setup for restrained ring test, including ring dimensions	119
Figure 3.35	Freshly cast samples	119
Figure 3.36	Samples after demoulding	120
Figure 3.37	Micrometre bridge set-up	121
Figure 3.38	Set-up of the water absorption system (a) schematic diagram (b) layout of specimen	122
Figure 3.39	Specimen prepared for testing for chloride penetration	123
Figure 3.40	Set of samples exposed in the sea environment	124
Figure 3.41	Set-up for measuring depth of chloride penetration	125
Figure 3.42	Set-up of exposure to acid (a) specimens (b) exposure tank	126
Figure 3.43	Set-up for heating of specimens	127
Figure 3.44	Heating and cooling regime of heating test	127
Figure 3.45	Exposure tank for resistance to sulphate attack	129
Figure 3.46	Heat box set-up for heat of hydration measurement	130
Figure 3.47	Heating and cooling set-up of grout for insulation capacity measurement (a) heating (b) cooling	131

Figure 3.48	Set-up of the mortar salt migration test	132
Figure 4.1	Morphology image (a) fly ash (b) OPC (c) masonry cement	137
Figure 4.2	Fly ash cenosphere with hollow interior	139
Figure 4.3	Larger fly ash cenosphere entrapped with smaller particles	139
Figure 4.4	Fly ash cenosphere with thin glass in approximate 1 μm wall	140
Figure 4.5	Fly ash particle with 20 μm thick wall	140
Figure 4.6	Particle size distribution of Masonry cement, fly ash, and OPC	142
Figure 4.7	XRD Pattern of OPC	150
Figure 4.8	XRD pattern of Masonry cement	150
Figure 4.9	XRD pattern of Fly ash	152
Figure 5.1	Formation air pockets caused by gaseous based expansion agent used	158
Figure 5.2	Relationship between air content and density against fly ash content	158
Figure 5.3	Flow time of grouts at different duration measured with ASTM C939 flow method	160
Figure 5.4	Flow time of grouts at different duration measured with EN 445 flow method	161
Figure 5.5	Spread of grouts at different duration measured with EN 445 spread method	162
Figure 5.6	Spread of grouts at different duration measured with custom mini cone method	163
Figure 5.7	Shear rate vs shear stress of grouts at 0 minutes	164
Figure 5.8	Viscosity of grouts at 0 minutes	165

Figure 5.9	Shear rate vs shear stress of grouts at 60 minutes	166
Figure 5.10	Viscosity of grouts at 60 minutes	166
Figure 5.11	Shear rate vs shear stress of grouts at 120 minutes	168
Figure 5.12	Viscosity of grouts at 120 minutes	169
Figure 5.13	Flow of masonry cement mortar with various level of fly ash	170
Figure 5.14	Water retentivity of mortar with various level of fly ash	173
Figure 5.15	Relationship between air content of mortar and water retentivity	173
Figure 6.1	Compressive strength of fly ash grout up to 1 year	178
Figure 6.2	Slant shear bond strength of grouts with concrete interface	180
Figure 6.3	Mode of failures comparing 30% and 50% fly ash grout	180
Figure 6.4	Flexural strength of grout with fly ash	182
Figure 6.5	Relationship between flexural and compressive strength	183
Figure 6.6	Splitting tensile of grout with various level of fly ash	184
Figure 6.7	Relationship between splitting tensile and compressive strength	185
Figure 6.8	Compressive strength of masonry cement mortar with fly ash	188
Figure 7.1	Highlight of the formation of crack in the grout ring test	197
Figure 7.2	Apparent porosity of grout	198
Figure 7.3	Condition of cube specimens after exposure to H ₂ SO ₄ for 28 days	200
Figure 7.4	Condition of cube specimens after exposure to H ₂ SO ₄ for 360 days	200
Figure 7.5	Condition of prism specimens after exposure to H ₂ SO ₄ after 28 days	201

Figure 7.6	Condition of prism specimens after exposure to H ₂ SO ₄ after 360 days	202
Figure 7.7	Corrosion intensity of grout after exposed to H ₂ SO ₄ for 360 days	203
Figure 7.8	Compressive strength loss of grout after exposed to 5% H ₂ SO ₄	205
Figure 7.9	Image showing different zones of deterioration, (A) active in acid attack, (B) yet to be involved in acid reaction	207
Figure 7.10	Abundance of gypsum in OPC grout exposed to sulphuric acid up to 360 days	208
Figure 7.11	Abundance of gypsum in OPC grout exposed to sulphuric acid up to 360 days	209
Figure 7.12	Presence of cracks and unreacted fly ash particles of 50% fly ash grout after 360 days in acid solution shown with different magnification (a) 500 times (b) 5000 times.	209
Figure 7.13	Formation of ettringite noticed on the plain grout.	210
Figure 7.14	The hexagonal shaped monosulphate	211
Figure 7.15	Fibrous C-S-H in 50% fly ash grout after acid attack (a) with 5000 times magnification, (b) with 20,000 times magnification	212
Figure 7.16	Close up of partially reacted fly ash particle	213
Figure 7.17	Chloride penetration in grout after exposed to 28 days in 5% NaCl	215
Figure 7.18	Chloride penetration in grout after exposed to 350 days in 5% NaCl	215
Figure 7.19	Chloride penetration of grout exposed to 5% NaCl solution up to 360 days	216
Figure 7.20	Chloride penetration of grout exposed to sea up to 360 days (3.5% salinity)	218

Figure 7.21	Relationship between grout apparent porosity and level of chloride penetration at 360 days	219
Figure 7.22	Chloride diffusion coefficient of grout exposed to 5% NaCl	221
Figure 7.23	Chloride diffusion coefficient of grout exposed to sea (3.5% salinity)	222
Figure 7.24	Sample appearance after exposure to 2 years in 10% MgSO ₄	223
Figure 7.25	Crack on surface of control grout with 0% fly ash after 2 years in 10% MgSO ₄	223
Figure 7.26	Loss of compressive strength of grout after exposed to 10 % MgSO ₄ for 2 years	224
Figure 7.27	(a) Formation of gypsum crystals in plain grout after exposed to 10% MgSO ₄ for 2 years (b) EDS data of the gypsum crystal.	225
Figure 7.28	Changes in fly ash grout colour due to heating	227
Figure 7.29	Air cooled grouts micro-cracks on surface at 1000 °C at 28 days	228
Figure 7.30	Air cooled grouts micro-cracks on surface at 1000 °C at 360 days	229
Figure 7.31	Water cooled grouts cracks after exposed to 1000 °C at 28 days	229
Figure 7.32	Water cooled grouts cracks after exposed to 1000 °C at 360 days	230
Figure 7.33	Weight difference after exposed to elevated temperature at 28 days	233
Figure 7.34	Weight difference after exposed to elevated temperature at 360 days	233
Figure 7.35	Changes in compressive strength for 28 days air cooled samples	235

Figure 7.36	Changes in compressive strength for 28 days water cooled samples	235
Figure 7.37	Changes in compressive strength for 360 days air cooled samples	236
Figure 7.38	Changes in compressive strength for 360 days water cooled samples	236
Figure 7.39	Plates of Portlandite $\text{Ca}(\text{OH})_2$ crystals in 0% fly ash grout	237
Figure 7.40	Growing of ettringite in plain grout exposed to 1000 °C	238
Figure 7.41	Magnification of ettringite in plain grout exposed to 1000 °C	239
Figure 7.42	Fly ash particle in the cement matrix of HVFA grout	239
Figure 7.43	Grout with 50% fly ash with unreacted fly ash particles	240
Figure 7.44	XRD pattern of OPC grout	241
Figure 7.45	XRD pattern of 50% fly ash grout	241
Figure 7.46	Temperature rise of HVFA grout mixes	242
Figure 7.47	Suspected thermal crack in tunnel retaining wall crack due to temperature rise in grouting material	244
Figure 7.48	Temperature profile of grouts under heating (ambient to 100 °C)	245
Figure 7.49	Temperature profile of grouts under freezing (ambient to -20°C)	246
Figure 7.50	3 hour heating temperature gradient versus grout density	247
Figure 7.51	3 hour freezing temperature gradient versus grout density	247
Figure 7.52	Variation of water absorption by capillarity of mortar mixes	249
Figure 7.53	Depth of chloride penetration as indicated by the purple colour change on the mortar specimens at 28 Days	250
Figure 7.54	Depth of chloride penetration as indicated by the purple colour change on the mortar specimens at 360 Days	250

Figure 7.55	Chloride penetration of mortar exposed to 5% NaCl solution up to 360 days	252
Figure 7.56	Condition of mortar cube specimens after exposed to acid for 360 days	254
Figure 7.57	Changes in specimen mass after exposed to acid for 360 days	255
Figure 7.58	Residual compressive strength of mortar after exposed to 5% H ₂ SO ₄	256
Figure 7.59	SEM-EDS of acid affected plain masonry mortar	258
Figure 7.60	SEM-EDS of acid affected 50% fly ash masonry mortar	258
Figure 7.61	Gypsum crystals noticed in the plain grout after exposed to acid attack.	258
Figure 7.62	Appearance of mortar specimen after exposed to 10% MgSO ₄ for 2 years	259
Figure 7.63	Loss of compressive strength of mortar after exposed to 10% MgSO ₄ after 2 years	260
Figure 7.64	Salt deposit on mortar after 28 days of testing	261
Figure 7.65	Salt deposit are on enlarged image of 0 and 10% fly ash mortar	262
Figure 7.66	Summary of improvement of 50% FA grout over plain grout	263
Figure 7.67	Summary of improve of 50% FA mortar over plain mortar	264

LIST OF ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
BS	-	British Standard
ACI	-	American Concrete Institute
BS EN	-	British Standard, Eurocode
EDS	-	Energy Dispersive X-Ray Spectroscopy
FA	-	Fly ash
GGBS	-	Ground granulated blast furnace slag
SEM	-	Scanning Electron Microscopy
XRD	-	X-Ray Diffraction
XRF	-	X-ray Fluorescence Spectrometry
PFA	-	Pulverised Fuel Ash
OPC	-	Ordinary Portland Cement
MC	-	Masonry cement
HVFA	-	High volume fly ash
MW	-	Megawatt
LOI	-	Loss on ignition
SAI	-	Strength activity index
SP	-	Superplasticiser
SF	-	Silica Fume
POFA	-	Palm oil fuel ash
POCP	-	Palm oil clinker powder
PSD	-	Particle size distributions

LIST OF SYMBOLS

μm	-	Micrometre
cm^2/g	-	Centimetre square per gram
N/s	-	Newton per second
τ	-	Shear stress
γ	-	Shear rate
τ_o	-	Bingham constant
μ	-	Plastic viscosity
N	-	Newton
$^\circ\text{C}$	-	Degree Celsius
S_f	-	Flexural strength
P	-	Load
T	-	Splitting tensile strength
C-S-H	-	Calcium-silicate-hydrate
C_3A	-	Tri-calcium aluminate
CaCO_3	-	Calcium carbonate
CaO	-	Calcium oxide
Ca	-	Calcium
C_4AF	-	Tetra-calcium aluminate Ferrite
C_2S	-	Di-calcium silicate
C_3S	-	Tri-calcium silicate
Ca(OH)_2	-	Calcium hydroxide
CO_2	-	Carbon dioxide
H_2SO_4	-	Sulphuric acid
MgSO_4	-	Magnesium sulphate
UV	-	Ultraviolet

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Appendix A	Sieve Test Results Of Sand	303
Appendix B	Test Results Of Water Used In Grout And Mortar Mixing	304
Appendix C	Cumulative Sieve Passing Of Opc, Mc And Pfa	305
Appendix D	Compressive Strength Data (Grout)	306
Appendix E	Compressive Strength Data (Masonry Mortar)	312
Appendix F	Temperature Development Of Grout (Limited To 40 Hours)	318

CHAPTER 1

INTRODUCTION

1.1 Problem Background

Certainly, cement-based materials are by far the most important building material. Worldwide, more than 10 billion tons are produced each year. The major application of cement composites can be grouped into concrete, grout and mortar. Minimising the environmental impact and energy and CO₂ intensity of cement used for construction is becoming increasingly important as resources decline and the impact of greenhouse emissions becomes more evident. Moreover, durability deficiency of cement composites, which failed prematurely, results in consumptions of additional natural resources, is a major concern in development of sustainable infrastructure systems. This because the repeated repairs carried out on the building requires additional raw material for the manufacturing of the repair material which is not efficient.

Despite the expanding need for concrete repair, the lack of comprehensive data leaves some uncertainty as to how to proceed with the design and execution of durable repairs. The extreme weather conditions in tropical climate make it even more difficult. To achieve a lasting repair, it is essential that the properties of the repair material are properly evaluated so that the repair material can withstand the stresses resulting from the attack from the environment over a designated period of time, without experiencing distress and deterioration.

It is also important to understand that the durability of the building is not the function of concrete alone, but also as to how its components are responding to the exposure conditions of the structure. In this particular, grout and mortar that are used to repair concrete are generally failing due to aggressive condition with equal threat as to concrete. Soil, undersea piers and oil-well grouting requires enormous amounts of

cement and are examples of areas where the grout is used. Such environment can be harmful to cement-based materials. However, very little is known on the behaviour of such materials in the aggressive conditions or the performance evaluation after applications. Moreover, in recent times, the use of masonry cement (MC) for plastering mortar has been introduced as a placement for Ordinary Portland Cement (OPC). Although it is extensively used, the durability characteristics of the material is not established. An understanding of grouts or masonry mortar durability is fundamental to establish the service life of repaired structures. Conventionally, repair materials are used for structural repairs that are capable of carrying a structural load or forming an integral part of a structure. Knowledge of the durability is the key to the long-term performance minimizing the rate of deterioration. Deterioration can be caused by physical or chemical mechanisms. Many of these types of deterioration are time-dependent such as environmental exposure durations. Some types affect the structural integrity, while others affect the chemical stability. For example, high temperature deteriorates the integrity while chemical such as sulphate, disrupts the chemical stability of calcium hydroxide inside the repair material. These differences are important when considering the cement-based materials that will be placed in the aggressive environment.

1.2 Background of the Study

Current global researches are very much aligned to the need of modern civil engineering challenges that emphasis sustainability and development of new materials are expected to be more durable while uses fewer resources. This new challenge has sparked the interest of various field experts in researching new composite materials that has lower carbon foot-print and outstanding durability.

In this study, sanded grout that is suitable for structural repairs such as column enlargement and port restoration that requires high fluidity material was selected. Meanwhile, masonry mortar that is suitable for non-structural application such as plastering was selected. Fly ash from a coal fired power plant was used to carry out partial cement replacement in both materials. Fly ash was selected as the material is

abundantly available in Malaysia and being actively dumped due to lack of consumption and recent expansions in the coal fired power capacity. This results in excess that could not be recovered to be used in concrete alone.

Although fly ash has been used for a long time; this noble practice is hardly applied in repair material such as sanded grout and masonry cement mortar. Limited data is available on the performance evaluation of such grouting and mortar material in aggressive environment. Particularly when comes to grout, rheology is critical and fly ash is an important material that could help in the concrete repair application. After all, fly ash is still abundantly available and being dumped actively in Malaysia and globally. This is what the study is trying to bridge the gap. The research believes that any new knowledge that could help the consumption of fly ash is always beneficial although it is not the primary aim of the research.

1.3 Background of the Problem

Material engineers lack looking on durability problem of other components of civil engineering material such as repair grout and masonry mortar as there are lack of code of practices on durability for such materials and increasing amount of repair materials deterioration reported. Typically, materials such as grout and mortar used are made solely from OPC and the use of composite cements for such applications is still lacking. Since OPC grout or mortar is more susceptible for deterioration, the use of blended cement for such repair material could be beneficial. The following highlights the problem related to these materials.

- i. Grouting materials contains approximately 50% of cement, which translates into about 1000 kg/m^3 . As compared to concrete that typically has a cement content of 400 kg/m^3 , this high cement content makes the material more vulnerable to large possibilities of durability problems as compared to concrete. However, there is lack of studies on the durability of grouts used for concrete repairs.

- ii. Masonry mortar is often made with OPC. In recent times, the use of masonry cement made of different chemistry has been introduced. However, there are lack of studies on the durability of masonry mortar made with masonry cement is available. The potential use of masonry cement mortar in the repair application and as a protection material needs to be exploited. Moreover, it has been reported that mortar used for plastering do deteriorates under certain circumstances.
- iii. Both grout and masonry mortars have some similarities, both uses same grading of fillers, however, special additives and type of primary binder set them apart. Therefore, as indicated by previous studies that certain supplementary cementitious materials such fly ash can significantly affect the material properties; this must be further investigated for the use in the grouting and plastering material.
- iv. Although fly ash is used in many places, the quantity is often limited to around 30% including in concrete and very scant information can be found on the use of HVFA in repair grout or masonry cement mortar. Therefore, high volume fly ash concept will be exploited in grouting and masonry mortar system that is applicable for repair and protection works.
- v. Solid waste management is a global challenge and fly ash is big part it. Globally the use of coal is expanding radically, including in Malaysia with commissioning of expansion of coal fired power plant. Considering the amount of fly ash waste materials available in Malaysia and the desire to address the environmental problems posed by this waste and even though there is a clear economic and environmental benefit associated with the use of such waste materials, limited information is available on high volume application of such materials.

1.4 Aim and Objective of the Study

The ultimate aim of the study is to make sanded concrete repair grout and the masonry cement mortar a better engineered material as compared to concrete. This will be done by investigating the fresh state, strength and durability of grout and masonry mortar containing high volume fly ash. Additionally, the main purpose of this work is to explore the use of high-volume fly ash in grout and masonry mortar that will be beneficial for repair works or concrete protection works. It is carried out by studying the effect of high volume fly ash on the workability, strength and durability of the grout and mortar. In order to accomplish the overall purpose, the following objectives are included in the evaluation of these materials.

- i. To characterize the micro-structure and the physio-chemical characteristics of the binders (Ordinary Portland Cement, Masonry Cement and fly ash) and the repair materials containing HVFA.
- ii. To determine the optimum level of mixture proportions for OPC grout and masonry cement mortar using fly ash by studying the stability, rheology and strength properties of grout and mortar for variable duration.
- iii. To investigate the behaviour of the grout and mortar containing high volume fly ash under aggressive environment in a long-term exposure setting.

1.5 Scope of Study

The study would be experimental in nature and focus on the development and use of high volume fly ash in sanded repair grout and masonry cement mortar. Replacement levels of cement with fly ash ranges from 0 to 50%. The study emphasizes rheology, strength and durability behaviour the grout and mortar, which is believed to be within the limits set by the objectives. The results of the study cannot be applied in general terms, except for PFA that possess similar characteristics. Cost effectiveness of materials has not been considered in this study. This of course does not intend to neglect the study economy to background, but rather it is believed that

technical issues have to be understood and fixed right before the economic aspect of the study is determined. Extent of content that will be covered by the means of the scope of the research is presented in Table 1.1.

Table 1.1 Summary of scope of study

Criteria		Limitation	
Primary Binder	Grout	OPC Class 52.5N	high clinker content – in loading capacity repairs
	Mortar	Masonry Cement Class 22.5X	low clinker content – for non-structural repairs
Supplementary Cementitious Material	Fly ash from Jimah Power Plant (Due as latest power plant in Malaysia)		
Partial cement replacement level	Up to 50%, with increment of 10% of weight, but emphasising HVFA material with 40 & 50% fly ash.		
Mix proportions	Grout	OPC, fly ash, sand, admixtures, water	
	Mortar	Masonry cement, fly ash, sand, water	
Admixtures used	Grout	Superplasticiser & expansion agent	
	Mortar	NIL	
Evaluation	Workability, mechanical properties and durability		
Exposure condition	Natural: Sea tidal zone		
	Artificial: Indoor		
Aggressive substances	Sulphuric acid, magnesium sulphate, calcium chloride		
Subjected to fire resistance	Heating up to 1000 °C		
Long term exposure durations	360 Days (sulphuric acid, calcium chloride)		
	720 Days (magnesium sulphate)		

1.6 Significance of the Study

The significant findings of this research will be beneficial in the following ways:

- i. Overcome common durability deficiency in repair materials and assist material engineers to select robust repair materials which could provide longer service life compared to current conventional materials. This contributes to the body of knowledge on extended use of HVFA in a durable concrete repair grout and masonry mortars.
- ii. Encourage the use of masonry cement with HVFA for concrete or brick protection. This will further consumption of the fly ash, particularly in current times where the ash output from the coal fired plant is at serious increasing trend.
- iii. Partial replacement of cement with fly ash will result in lower emission of carbon dioxide from the cement manufacturing industry and lower consumption of natural resources such as limestone as cement's main raw material.
- iv. Due to high adoptability, the final product can be easily commercialized for mutual benefit of the institution and the industry. This will facilitate the introduction of practically functional green materials in the construction industry that can further help the global initiative on green building index system.

REFERENCES

- AASHTO T259. (2012). Standard method of test for resistance of concrete to chloride ion penetration. American Association of State and Highway Transportation Officials.
- Abderrahmane, M., and Moh-Amokrane, A. (2015). Rheological characterization of oil cement suspensions. *Journal of Physics: Conference Series*, 602, 1–6. <https://doi.org/10.1088/1742-6596/602/1/012030>
- Abdulkareem, O. A., Mustafa Al Bakri, A. M., Kamarudin, H., Khairul Nizar, I., and Saif, A. A. (2014). Effects of elevated temperatures on the thermal behavior and mechanical performance of fly ash geopolymer paste, mortar and lightweight concrete. *Construction and Building Materials*, 50, 377–387. <https://doi.org/10.1016/j.conbuildmat.2013.09.047>
- Abu Bakar, B. H. (1998). *Influence of anisotropy and curing on deformation of masonry*. University of Leeds, United Kingdom.
- Abubakar, S. I. (2015). *Durability and thermal gravimetric analysis of high volume fuel ash concrete*. Universiti Teknologi Malaysia.
- ACI 301. (1999). Specifications for Structural Concrete. *American Concrete Institute*.
- Ahmad, A. G., Fadzilah, H., Rahman, A., and Rahman, H. (2010). Treatment of salt attack and rising damp in heritage buildings in Penang, Malaysia. *Journal of Construction in Developing Countries*, 15(1), 16. Retrieved from [http://web.usm.my/jcdc/vol15_1_2010/JCDC Vol 15\(1\) ART 5 \(93-113\).pdf](http://web.usm.my/jcdc/vol15_1_2010/JCDC_Vol_15(1)_ART_5_(93-113).pdf)
- Allahverdi, A., and Škvára, F. (2006). Sulfuric acid attack on hardened paste of geopolymer cements Part 2. Corrosion mechanism at mild and relatively low concentrations. *Ceramics - Silikaty*, 50(1), 1–4. [https://doi.org/10.1016/S0167-577X\(02\)01009-1](https://doi.org/10.1016/S0167-577X(02)01009-1)
- Allan, M. L. (1997). Rheology of latex-modified grouts. *Cement and Concrete Research*, 27(12), 1875–1884. [https://doi.org/10.1016/S0008-8846\(97\)00205-6](https://doi.org/10.1016/S0008-8846(97)00205-6)
- American Road & Transportation Builders Association's. (2015). *Production and Use of Coal Combustion Products in the U.S.*
- Amit, E., Ahirwar, K., Joshi, P. R., Soni, E. K., and Ash, I. F. (2015). Laboratory

- analysis of fly ash mix cement concrete for rigid pavement. *Journal of Engineering Research and Applications*, 5(2), 86–91.
- Amrhein, J. E. (1980). Grout - The third ingredient. *Masonry Industry Magazine*, 19, 1922. Retrieved from <http://masonryadvisorycouncil.org>
- APEREC. (2015). Production and use of coal combustion products in the U.S. - market forecast through 2033. *American Coal Ash Association*, (june), 1–47.
- Arjunan, P., Silsbee, M. R., and Roy, D. M. (2001). Chemical activation of low calcium fly ash part II: effect of mineralogical composition on alkali activation. In *International Ash Utilization Symposium* (pp. 1–8). Kentucky, USA.
- Asadi, I., Sha, P., Fitri, Z., and Abu, B. (2018). Thermal conductivity of concrete – A review. *Journal of Building Engineering Journal*, 20(July), 81–93. <https://doi.org/10.1016/j.jobee.2018.07.002>
- Asia Pacific Energy Research Centre. (2016). *APEC energy demand and supply outlook*. Asia Pacific Energy Research Centre (APEREC). Retrieved from <http://aperc.ieej.or.jp/>
- Assaad, J. J. (2015). Correlating water extraction to viscosity variations of injection grouts. *Construction and Building Materials*, 77, 74–82. <https://doi.org/10.1016/j.conbuildmat.2014.12.024>
- Assaad, J. J., and Daou, Y. (2014). Cementitious grouts with adapted rheological properties for injection by vacuum techniques. *Cement and Concrete Research*, 59, 43–54. <https://doi.org/10.1016/j.cemconres.2014.01.021>
- ASTM C1012. (2004). Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution. *Annual Book of ASTM Standards, American Society for Testing and Materials*, 4–7.
- ASTM C109. (2010). Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in . or [50-mm] Cube Specimens). *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0109>
- ASTM C128. (2015). Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0128-15.2>
- ASTM C1403. (2013). Standard Test Method for Rate of Water Absorption of

- Masonry Mortars. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C1403-13.2>
- ASTM C1437. (2013). Standard Flow Method for Flow of Hydraulic Cement Mortar. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C1437-15>
- ASTM C144. (2018). Standard Specification for Aggregate for Masonry Mortar. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0144-11.2>
- ASTM C1506. (2015). Standard Test Method for Water Retention of Hydraulic Cement-Based Mortars and. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C1506-09.2>
- ASTM C185. (2015). Standard Test Method for Air Content of Hydraulic Cement Mortar. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0185-08.2>
- ASTM C188. (2014). Standard Test Method for Density of Hydraulic Cement. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0188-09.2>
- ASTM C204. (2016). Standard Test for Fineness of Hydraulic Cement by Air-Permeability Apparatus. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0204-07.2>
- ASTM C207. (2011). Standard Specification for Hydrated Lime for Masonry Purposes. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0207-06R11>
- ASTM C267. (2012). Standard Test Methods for Chemical Resistance of Mortars , Grouts , and Monolithic Surfacing and Polymer Concretes. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0267-01R06.2>
- ASTM C270. (2014). Standard Specification for Mortar for Unit Masonry. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0270-19AE01>
- ASTM C311. (2017). Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/C0311-11a.2>
- ASTM C348. (2002). Flexural Strength of Hydraulic-Cement Mortars. *Annual Book*

- of ASTM Standards, American Society for Testing and Materials.*
<https://doi.org/10.1520/C0348-19>
- ASTM C430. (2015). Standard Test Method for Fineness of Hydraulic Cement by the 45- μm (No . 325) Sieve. *Annual Book of ASTM Standards, American Society for Testing and Materials.* <https://doi.org/10.1520/C0430-08.2>
- ASTM C496. (2004). Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete. *Annual Book of ASTM Standards, American Society for Testing and Materials.* <https://doi.org/10.1520/C0496>
- ASTM C618. (2014). Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use. *Annual Book of ASTM Standards, American Society for Testing and Materials.* <https://doi.org/10.1520/C0618>
- ASTM C882. (2005). Standard Test Method for Bond Strength of Latex Systems Used With Concrete By. *Annual Book of ASTM Standards, American Society for Testing and Materials.* https://doi.org/10.1520/C0882_C0882M-13A
- ASTM C939. (2016). Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method). *Annual Book of ASTM Standards, American Society for Testing and Materials.* <https://doi.org/10.1520/C0939-10.2>
- ASTM C940. (2010). Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory. *Annual Book of ASTM Standards, American Society for Testing and Materials.* <https://doi.org/10.1520/C0940-10a.2>
- ASTM C952. (2015). Standard Test Method for Bond Strength of Mortar to Masonry Units. *Annual Book of ASTM Standards, American Society for Testing and Materials.* <https://doi.org/10.1520/C0952-12.2>
- ASTM C953. (2010). Standard Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory. *Annual Book of ASTM Standards, American Society for Testing and Materials.* <https://doi.org/10.1520/C0953-10.2>
- ASTM D2196. (2010). Standard Test Methods for Rheological Properties of Non-Newtonian Materials by Rotational Viscometer. *Annual Book of ASTM Standards, American Society for Testing and Materials.* <https://doi.org/10.1520/D2196-18E01>
- ASTM D7348. (2013). Standard Test Methods for Loss on Ignition (LOI) of Solid

- Combustion Residues. *Annual Book of ASTM Standards, American Society for Testing and Materials*. <https://doi.org/10.1520/D7348-13>
- Athanasopoulou, A. (2016). Improvement of soil engineering characteristics using lime and fly ash. *European Scientific Journal May*, 7881(5), 132–141.
- Atiş, C. D. (2005). Strength properties of high-volume fly ash roller compacted and workable concrete, and influence of curing condition. *Cement and Concrete Research*, 35(6), 1112–1121. <https://doi.org/10.1016/j.cemconres.2004.07.037>
- Awal, A. S. M. A., Shehu, I. A., and Ismail, M. (2015). Effect of cooling regime on the residual performance of high-volume palm oil fuel ash concrete exposed to high temperatures. *Construction and Building Materials*, 98, 875–883.
- Aydin, S., Karatay, Ç., and Baradan, B. (2010). The effect of grinding process on mechanical properties and alkali-silica reaction resistance of fly ash incorporated cement mortars. *Powder Technology*, 197(1–2), 68–72. <https://doi.org/10.1016/j.powtec.2009.08.020>
- Ayob, A., Mohd Zahid, M. Z. A., Mohammad Zaki, M. F., A. Hamid, S. H., Mohammad Yussuf, M. A.-H., and Mohd Yunus, A. N. (2014). Physical , morphological and strength properties of Jana Manjung coal ash mixture for geotechnical applications. In *4th International Malaysia-Ireland Joint Symposium on Engineering, Science and Business*. Penang, Malaysia. <https://doi.org/10.13140/2.1.1126.5921>
- Azadi, M. R., Taghichian, A., and Taheri, A. (2017). Optimization of cement-based grouts using chemical additives. *Journal of Rock Mechanics and Geotechnical Engineering*, 9(4), 623–637. <https://doi.org/10.1016/j.jrmge.2016.11.013>
- Bagchi, S. S., Ghule, S. V., and Jadhav, R. T. (2012). Fly ash fineness - Comparing residue on 45 micron sieve with Blaine's surface area. *Indian Concrete Journal*, 86(8), 39–42.
- Bakar, B., Ibrahim, M., and Johari, M. (2009). A review: durability of fired clay brick masonry wall due to salt attack. *International Journal of Integrated Engineering*, 1(2), 111–127. Retrieved from http://penerbit.uthm.edu.my/ejournal/images/stories/IJIE12/IJIE_vol_1_issue_2_A10.pdf
- Balaji N.C., Mani Monto, Reddy B.V., and Venkatarama. (2013). Thermal performance of the building walls. *Building Simulation Application*, 151–159. Retrieved from <http://www.ibpsa.org/proceedings/BSA2013/16.pdf>

- Balakrishnan, B., and Awal, A. S. M. A. (2014). Durability properties of concrete containing high volume Malaysian fly ash. *International Journal of Research in Engineering and Technology*, 03(04), 529–533.
- Baltazar, L. G., Henriques, F. F. M. A., and Cidade, M. T. (2014). Effect of hydrophobic silica fume on the rheological behaviour of injection grouts. In *Advances in Civil, Environmental, and Material Research*. Busan, Korea.
- Baltazar, L. G., Henriques, F. M. A., and Jorne, F. (2012). Optimisation of flow behaviour and stability of superplasticized fresh hydraulic lime grouts through design of experiments. *Construction and Building Materials*, 35, 838–845. <https://doi.org/10.1016/j.conbuildmat.2012.04.084>
- Baltazar, L. G., Henriques, F. M. A., Jorne, F., and Cidade, M. T. (2014). Combined effect of superplasticizer, silica fume and temperature in the performance of natural hydraulic lime grouts. *Construction and Building Materials*, 50, 584–597. <https://doi.org/10.1016/j.conbuildmat.2013.10.005>
- Barbhuiya, S., and Kumala, D. (2017). Behaviour of a sustainable concrete in acidic environment. *Sustainability (Switzerland)*, 9(9). <https://doi.org/10.3390/su9091556>
- Barr, S., McCarter, W. J., and Suryanto, B. (2015). Bond-strength performance of hydraulic lime and natural cement mortared sandstone masonry. *Construction and Building Materials*, 84, 128–135. <https://doi.org/10.1016/j.conbuildmat.2015.03.016>
- Bautista, J. W., Liu, B. A., Crockett, J. B., Roxas, C. L., and Obra, T. J. (2015). Drying shrinkage of fly ash mortar mixed with seawater. *Applied Mechanics and Materials*, 802, 118–123. <https://doi.org/10.4028/www.scientific.net/amm.802.118>
- Beemamol, U. S., Nizad, A., and Nazeer, M. (2013). Investigations on cement mortar using ceramic tailing sand as fine aggregate. *American Journal of Engineering Research (AJER)*, 3, 28–33. Retrieved from www.ajer.org
- Bentz, D. P. (2014). Activation energies of high-volume fly ash ternary blends: Hydration and setting. *Cement and Concrete Composites*, 53(July 2014), 214–223. <https://doi.org/10.1016/j.cemconcomp.2014.06.018>
- Bentz, D. P., and Ferraris, C. F. (2010). Rheology and setting of high volume fly ash mixtures. *Cement and Concrete Composites*, 32(4), 265–270. <https://doi.org/10.1016/j.cemconcomp.2010.01.008>

- Benyounes, K., and Benmounah, A. (2014). Effect of bentonite on the rheological behavior of cement grout in presence of superplasticizer. *International Journal of Civil, Architectural, Structural and Construction Engineering*, 8(11), 1140–1143.
- Bernama. (2017, October 2). TNB's RM6 bln Manjung 5 power plant commences ops. *New Straits Times*. Retrieved from <https://www.nst.com.my/news/nation/2017/09/285240/tnbs-rm6-bln-manjung-5-power-plant-commences-ops>
- Berndt, M. L. (2010). Strength and permeability of steel fibre reinforced grouts. *Construction and Building Materials*, 24(9), 1768–1772. <https://doi.org/10.1016/j.conbuildmat.2010.02.011>
- BGR Federal Institute for Geosciences and Natural Resources. (2016). *Reserves, Resources and Availability of Energy Resources*. Hannover, Germany. Retrieved from www.bgr.bund.de
- Bhardwaj, B. B., Choudhury, B., and Sapkota, G. (2013). Effect of gradation of fine aggregate on development of hairline cracks in wall plaster. *Indian Journal of Applied Research*, (May), 222–223. <https://doi.org/10.15373/2249555X/MAY2013/68>
- Bhattacharjee, U., and Kandpal, T. C. (2002). Potential of fly ash utilisation in India. *Energy*, 27(2), 151–166. [https://doi.org/10.1016/S0360-5442\(01\)00065-2](https://doi.org/10.1016/S0360-5442(01)00065-2)
- Bilir, T., Gencil, O., and Topcu, I. B. (2015). Properties of mortars with fly ash as fine aggregate. *Construction and Building Materials*, 93, 782–789. <https://doi.org/10.1016/j.conbuildmat.2015.05.095>
- Bochen, J. (2015). Weathering effects on physical-chemical properties of external plaster mortars exposed to different environments. *Construction and Building Materials*, 79, 192–206. <https://doi.org/10.1016/j.conbuildmat.2014.12.079>
- Borinaga-Treviño, R., Pascual-Muñoz, P., Calzada-Pérez, M. Á., and Castro-Fresno, D. (2014). Freeze-thaw durability of cement-based geothermal grouting materials. *Construction and Building Materials*, 55, 390–397. <https://doi.org/10.1016/j.conbuildmat.2014.01.051>
- Brachaczek, W. (2018). Microstructure of renovation plasters and their resistance to salt. *Construction and Building Materials*, 182, 418–426. <https://doi.org/10.1016/j.conbuildmat.2018.06.068>
- Bras, A., Gião, R., Lúcio, V., and Chastre, C. (2013). Development of an injectable

- grout for concrete repair and strengthening. *Cement and Concrete Composites*, 37(1), 185–195. <https://doi.org/10.1016/j.cemconcomp.2012.10.006>
- Bras, A., and Henriques, F. M. A. (2012). Natural hydraulic lime based grouts - The selection of grout injection parameters for masonry consolidation. *Construction and Building Materials*, 26(1), 135–144. <https://doi.org/10.1016/j.conbuildmat.2011.05.012>
- Bras, A., Henriques, F. M. A., and Cidade, M. T. (2010). Effect of environmental temperature and fly ash addition in hydraulic lime grout behaviour. *Construction and Building Materials*, 24(8), 1511–1517. <https://doi.org/10.1016/j.conbuildmat.2010.02.001>
- Bredy, P., Chabannet, M., and Pera, J. (1989). Microstructure and porosity of metakaolin blended cements. *Proceedings of Materials Research Society Symposium*, 17, 431–436. <https://doi.org/10.1017/CBO9781107415324.004>
- Brookfield. (2010). More solutions to sticky problems: a guide to getting more from your Brookfield viscometer (pp. 1–53). Brookfield Engineering Labs.
- Brouwers, H. J. H., and Eijk, R. J. Van. (2003). Chemical reaction of fly ash. In *11th International Congress on the Chemistry of Cement*. (pp. 791–800). South Africa.
- BS 5328. (1991). Concrete Part 1. Guide to specifying concrete. *British Standard Institution*.
- BS EN 197. (2011). BS EN 197 Part-1 Composition, specifications and conforming criteria for common cements. *British Standard Institution*.
- BS EN 445. (2007). Grout for prestressing tendons. *British Standard Institution*.
- Bullard, J. W., Jennings, H. M., Livingston, R. A., Nonat, A., Scherer, G. W., Schweitzer, J. S., ... Thomas, J. J. (2011). Mechanisms of cement hydration. *Cement and Concrete Research*, 41(12), 1208–1223. <https://doi.org/10.1016/B978-0-08-100693-1.00008-4>
- Celik, F., and Canakci, H. (2015). An investigation of rheological properties of cement-based grout mixed with rice husk ash (RHA). *Construction and Building Materials*, 91, 187–194. <https://doi.org/10.1016/j.conbuildmat.2015.05.025>
- Chancey, R. T., Stutzman, P., Juenger, M. C. G., and Fowler, D. W. (2010). Comprehensive phase characterization of crystalline and amorphous phases of a Class F fly ash. *Cement and Concrete Research*, 40(1), 146–156.

<https://doi.org/10.1016/j.cemconres.2009.08.029>

- Chandra, S., and Bendapudi, K. (2015). Contribution of fly ash to the properties of mortar and concrete. *International Journal of Earth Sciences and Engineering*, 04(October 2011), 1017–1023.
- Chindaprasirt, P., Buapa, N., and Cao, H. T. (2005). Mixed cement containing fly ash for masonry and plastering work. *Construction and Building Materials*, 19(8), 612–618. <https://doi.org/10.1016/j.conbuildmat.2005.01.009>
- Chindaprasirt, P., Chotithanorm, C., Cao, H. T., and Sirivivatnanon, V. (2007). Influence of fly ash fineness on the chloride penetration of concrete. *Construction and Building Materials*, 21(2), 356–361. <https://doi.org/10.1016/j.conbuildmat.2005.08.010>
- Christy, C. F., and Tensing, D. (2010). Effect of class-F fly ash as partial replacement with cement and fine aggregate in mortar. *Indian Journal of Engineering and Materials Sciences*, 17(2), 140–144.
- Coutinho, J. (1998). *Improvement of the durability of concrete by treatment of the moulding*. University of Porto, Portugal.
- Cultrone, G., Sebastián, E., and Huertas, M. O. (2007). Durability of masonry systems: A laboratory study. *Construction and Building Materials*, 21(1), 40–51. <https://doi.org/10.1016/j.conbuildmat.2005.07.008>
- Cyr, M., Trinh, M., Husson, B., and Casaux-Ginestet, G. (2013). Design of eco-efficient grouts intended for soil nailing. *Construction and Building Materials*, 41, 857–867. <https://doi.org/10.1016/j.conbuildmat.2012.12.020>
- Das, A., Jain, M. K., and Singh, G. (2012). Engineering properties of coal ash for mine filling application. *Mining Engineers' Journal*, 13(12), 20–23.
- Dash, S. K., Kar, B. B., Mukherjee, P. S., and Mustakim, S. M. (2016). A comparison among the physico-chemical-mechanical of three potential aggregates fabricated from fly ash. *Journal of Civil & Environmental*, 6(4). <https://doi.org/10.4172/2165-784X.1000243>
- Davey, N. (1971). *History of building materials*. (N. Davey, Ed.). Michigan: Phoenix House.
- De la Varga, I., and Graybeal, B. A. (2014). Dimensional stability of grout-type materials used as connections between prefabricated concrete elements. *Journal of Materials in Civil Engineering*, 27(9), 04014246. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0001212](https://doi.org/10.1061/(asce)mt.1943-5533.0001212)

- del Río Merino, M., Santa Cruz Astorqui, J., Villoria Sáez, P., Santos Jiménez, R., and González Cortina, M. (2018). Eco plaster mortars with addition of waste for high hardness coatings. *Construction and Building Materials*, *158*, 649–656. <https://doi.org/10.1016/j.conbuildmat.2017.10.037>
- Delhomme, F., Ambroise, J., and Limam, A. (2012). Effects of high temperatures on mortar specimens containing Portland cement and GGBFS. *Materials and Structures*, *45*(11), 1685–1692. <https://doi.org/10.1617/s11527-012-9865-7>
- Deo, S. V., and Pofale, A. D. (2015). Parametric study for replacement of sand by fly ash for better packing and internal curing. *Open Journal of Civil Engineering*, (5), 118–130. <https://doi.org/10.4236/ojce.2015.51012>
- Detphan, S. (2018). Portland Cement containing fly ash, expanded perlite, and plasticizer for masonry and plastering mortars. *International Journal of GEOMATE*, *15*(48). <https://doi.org/10.21660/2018.48.47794>
- Domone, P. L., Yongmo, X., and Banfill, P. F. G. (1999). Developments of the two-point workability test for high-performance concrete. *Magazine of Concrete Research*, *51*(3), 171–179.
- Donatello, S., Palomo, A., and Fernández-Jiménez, A. (2013). Durability of very high volume fly ash cement pastes and mortars in aggressive solutions. *Cement and Concrete Composites*, *38*, 12–20. <https://doi.org/10.1016/j.cemconcomp.2013.03.001>
- Drozhzhin, V. S., Danilin, L. D., Shpirt, M. Y., Mikhail, D., Potemkin, G. a, and Pikulin, I. V. (2005). Formation processes of hollow microspheres in the fly ash from electric power stations. In *World of Coal Ash (WOCA)* (pp. 1–14). Kentucky, USA. Retrieved from <http://www.flyash.info>
- Du, J, Shen, X., Feng, G., Zhu, W., and Xu, C. (2016). Hydration mechanism of fly ash cement and grouting simulation experiment. *Chemical Engineering Transactions*, *51*(2011), 565–570. <https://doi.org/10.3303/CET1651095>
- Du, Jun, Zhu, W., Feng, G., Liang, W., Shen, X., and Xu, C. (2016). Rheological characteristics of power-law cement grouts based on time-dependent behavior of viscosity. *Chemical Engineering Transactions*, *51*, 1111–1116. <https://doi.org/10.3303/CET1651186>
- Eklund, D., and Stille, H. (2008). Penetrability due to filtration tendency of cement-based grouts. *Tunnelling and Underground Space Technology*, *23*(4), 389–398. <https://doi.org/10.1016/j.tust.2007.06.011>

- Ekolu, S. O., Diop, S., Azene, F., and Mkhize, N. (2016). Disintegration of concrete construction induced by acid mine drainage attack. *Journal of the South African Institution of Civil Engineering*, 58(1), 34–42. <https://doi.org/10.17159/2309-8775/2016/v58n1a4>
- Faseyemi, V. A. (2005). Investigation on fly ash as a partial cement replacement in concrete. *International Journal of Scientific and Engineering Research*. Retrieved from <https://pdfs.semanticscholar.org/e665/c35f4e87675aa7a25074de50bbb21ea5ffd0.pdf>
- Fauzi, A., Nuruddin, M. F., Malkawi, A. B., and Abdullah, M. M. A. B. (2016). Study of fly ash characterization as a cementitious material. *Procedia Engineering*, 148, 487–493. <https://doi.org/10.1016/j.proeng.2016.06.535>
- Filho, J. H., Medeiros, M. H. F., Pereira, E., Helene, P., and Isaia, G. C. (2013). High-volume fly ash concrete with and without hydrated lime: chloride diffusion coefficient from accelerated test. *Journal of Materials in Civil Engineering*, 25(3), 411–418. [https://doi.org/10.1061/\(ASCE\)MT.1943-5533.0000596](https://doi.org/10.1061/(ASCE)MT.1943-5533.0000596)
- Fonseca, F. S., Godfrey, R. C., and Siggard, K. (2015). Compressive strength of masonry grout containing high amounts of class F fly ash and ground granulated blast furnace slag. *Construction and Building Materials*, 94, 719–727. <https://doi.org/10.1016/j.conbuildmat.2015.07.115>
- Franus, W., Panek, R., and Wdowin, M. (2015). Sem investigation of microstructures in hydration products of portland cement. In *Springer Proceedings in Physics* (Vol. 164, pp. 105–112). https://doi.org/10.1007/978-3-319-16919-4_14
- Freeman, R. B., and Carrasquillo, R. L. (1991). Influence of the method of fly ash incorporation on the sulphate resistance of fly ash concrete. *Cement & Concrete Composites*, 13, 209–217. Retrieved from http://www.osti.gov/energycitations/product.biblio.jsp?osti_id=6202996
- Gajendran, K. A., Anuradha, R., and Venkatasubramani, G. S. (2015). Studies on relationship between compressive and splitting tensile strength of high performance concrete. *ARPJN Journal of Engineering and Applied Sciences*, 10(14), 6151–6156.
- Gao, Y., Hu, C., Zhang, Y., Li, Z., and Pan, J. (2017). Investigation on microstructure and microstructural elastic properties of mortar incorporating fly ash. *Cement and Concrete Composites*. <https://doi.org/10.1016/j.cemconcomp.2017.09.008>

- Gesoğlu, M., Güneyisi, E., and Özbay, E. (2009). Properties of self-compacting concretes made with binary, ternary, and quaternary cementitious blends of fly ash, blast furnace slag, and silica fume. *Construction and Building Materials*, 23(5), 1847–1854. <https://doi.org/10.1016/j.conbuildmat.2008.09.015>
- Ghosh, A., Ghosh, A., and Neogi, S. (2018). Reuse of fly ash and bottom ash in mortars with improved thermal conductivity performance for buildings. *Heliyon*, 4(11), e00934. <https://doi.org/10.1016/j.heliyon.2018.e00934>
- Gingos, G. ., and Sutan, N. M. (2011). Effect of PFA on Strength and Water Absorption of Mortar. *UNIMAS E-Journal of Civil Engineering*, 2(March), 7–11.
- Glinicki, M. A., Józwiak-Niedzwiedzka, D., and Dabrowski, M. (2019). The influence of fluidized bed combustion fly ash on the phase composition and microstructure of cement paste. *Materials*, 12(7). <https://doi.org/10.3390/ma12172838>
- González-Kunz, R. N., Pineda, P., Bras, A., and Morillas, L. (2017). Plant biomass ashes in cement-based building materials. Feasibility as eco-efficient structural mortars and grouts. *Sustainable Cities and Society*, 31, 151–172. <https://doi.org/10.1016/j.scs.2017.03.001>
- Gopalakrishnan, R., and Chinnaraju, K. (2016). Durability of alumina silicate concrete based on slag/fly-ash blends against acid and chloride environments. *Materials and Technology*, 50(6), 929–937.
- Graham E.C. (2010). Corrosion protection properties of low-density concrete cellular grout for steel surfaces. In *CIGMAT-2010 Conference & Exhibition*. Claremont, CA.
- Grahame, T., and Schlesinger, R. (2007). Health effects of airborne particulate matter: Do we know enough to consider regulating specific particle types or sources? *Inhalation Toxicology*, 19, 457–481.
- Granneman, S. J. C., Lubelli, B., and van Hees, R. P. J. (2019). Effect of mixed in crystallization modifiers on the resistance of lime mortar against NaCl and Na₂SO₄ crystallization. *Construction and Building Materials*, 194, 62–70. <https://doi.org/10.1016/j.conbuildmat.2018.11.006>
- Graymont. (2019). Mortar mix designs. Retrieved from <https://www.graymont.com/en/markets/building-construction/mortar/mortar-mix-designs>

- Güllü, H. (2015). On the viscous behavior of cement mixtures with clay, sand, lime and bottom ash for jet grouting. *Construction and Building Materials*, *93*, 891–910. <https://doi.org/10.1016/j.conbuildmat.2015.05.072>
- Güllü, H., Canakci, H., and Al Zangana, I. F. (2017). Use of cement based grout with glass powder for deep mixing. *Construction and Building Materials*, *137*, 12–20. <https://doi.org/10.1016/j.conbuildmat.2017.01.070>
- Gupta, L. K., and Vyas, A. K. (2018). Impact on mechanical properties of cement sand mortar containing waste granite powder. *Construction and Building Materials*, *191*, 155–164. <https://doi.org/10.1016/j.conbuildmat.2018.09.203>
- Gutberlet, T., Hilbig, H., and Beddoe, R. E. (2015). Acid attack on hydrated cement - Effect of mineral acids on the degradation process. *Cement and Concrete Research*, *74*, 35–43. <https://doi.org/10.1016/j.cemconres.2015.03.011>
- Haddad, R., and Shannag, M. J. (2008). Performance of Jordanian masonry cement for construction purposes. *Jordan Journal of Civil Engineering*, *2*(1), 20–31.
- Han, F., He, X., Zhang, Z., and Liu, J. (2017). Hydration heat of slag or fly ash in the composite binder at different temperatures. *Thermochimica Acta*, *655*(July), 202–210. <https://doi.org/10.1016/j.tca.2017.07.002>
- Harrison, D. M. (2000). *A comparison between epoxy and cement grouts, or which product should we use?* Houston, Texas: Gulf Publishing Company. <https://doi.org/http://dx.doi.org/10.1016/B978-0-12-416585-4.00003-1>
- Hoffman, G. K. (1997). Pozzolans and Supplementary Cementitious Materials. *World*, 1161–1172.
- Hossain, M. M., Karim, M. R., Hasan, M., Hossain, M. K., and Zain, M. F. M. (2016). Durability of mortar and concrete made up of pozzolans as a partial replacement of cement: A review. *Construction and Building Materials*, *116*, 128–140. <https://doi.org/10.1016/j.conbuildmat.2016.04.147>
- Huang, W. H. (1997). Properties of cement-fly ash grout admixed with bentonite, silica fume, or organic fiber. *Cement and Concrete Research*, *27*(3), 395–406.
- Huang, W. H. (2001). Improving the properties of cement-fly ash grout using fiber and superplasticizer. *Cement and Concrete Research*, *31*(7), 1033–1041. [https://doi.org/10.1016/S0008-8846\(01\)00527-0](https://doi.org/10.1016/S0008-8846(01)00527-0)
- Hussin, M. W., Abdul Shukor Lim, N. H., Sam, A. R. M., Samadi, M., Ismail, M. A., Ariffin, N. F., ... Lateef, H. (2015). Long term studies on compressive strength of high volume nano palm oil fuel ash mortar mixes. *Jurnal Teknologi*, *77*(16),

- 15–20. <https://doi.org/10.11113/jt.v77.6387>
- Hwang, J. Y. (1997). Unburned carbon from fly ash - A hidden treasure. Michigan Technological University.
- Ibrahim, Z. (2014). Power-Gen Asia. In *POWER-GEN Asia*. Kuala Lumpur.
- Imbin, S., Dullah, S., Asrah, H., Kumar, P. S., Rahman, M. E., and Mannan, M. A. (2013). Performance of concrete grout under aggressive chloride environment in sabah. *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, 7(1), 63–67.
- Islam, M. (2010). Strength behaviour of mortar using fly ash as partial replacement of cement. *Concrete Research Letters*, 1(3), 98–106. <https://doi.org/10.3329/mist.v3i0.8053>
- Ismail, I., Bernal, S. A., Provis, J. L., San Nicolas, R., Brice, D. G., Kilcullen, A. R., ... Van Deventer, J. S. J. (2013). Influence of fly ash on the water and chloride permeability of alkali-activated slag mortars and concretes. *Construction and Building Materials*, 48, 1187–1201. <https://doi.org/10.1016/j.conbuildmat.2013.07.106>
- ISO 13320. (2009). International standard.
- Jain, A., and Islam, N. (2013). Use of fly ash as partical replacement of cement in sand. *International Journal of Innovative Research in Science, Engineering and Technology*, 2(5), 1323–1332.
- Jawed, A., Vashsith, V., and Sharma, B. (2017). Effect of high temperature on fly ash concrete. *SSRG International Journal of Civil Engineering*, 4(6), 48–51. <https://doi.org/10.1007/s13369-013-0606-1>
- Jimah. (2019). JEV Power Plant aerial photo. Retrieved from <http://www.jimahev.com.my/gallery/jev-power-plant-aerial-photo>
- Jiménez, J. R., Ayuso, J., López, M., Fernández, J. M., and De Brito, J. (2013). Use of fine recycled aggregates from ceramic waste in masonry mortar manufacturing. *Construction and Building Materials*, 40, 679–690.
- John, M., and Colin, M. (1994). Should air-entrained mortars be used. *Aberdeen's Magazine of Masonry Construction*, 7(9), 419–422.
- Jolicoeur, C., To, T. C., Benoît, É., Hill, R., Zhang, Z., and Pagé, M. (2009). Fly ash-carbon effects on concrete air entrainment: Fundamental studies on their origin and chemical mitigation. *3rd World of Coal Ash, WOCA Conference - Proceedings*, 1–23.

- Jorne, F., Henriques, F. M. A., and Baltazar, L. G. (2015). Evaluation of consolidation of different porous media with hydraulic lime grout injection. *Journal of Cultural Heritage*, 16(4), 438–451. <https://doi.org/10.1016/j.culher.2014.10.005>
- Joseph, K. V, Francis, F., Chacko, J., Das, P., and Hebbar, G. (2013). Fly ash cenosphere waste formation in coal fired power plants and its application as a structural material- A review. *International Journal of Engineering Research & Technology (IJERT)*, 2(8), 18–21.
- Kamal, H., M, E. H., A, A. J., S, A. S., and Taha, M. (2011). Development of Cement Grout mixes for treatment of underground cavities in Kuwait. *International Journal of Civil and Structural Engineering*, 2(2), 424–434.
- Kazemian, S. (2012). Physical properties of cement-sodium silicate grout with kaolinite. In *4th International Conference on Grouting and Deep Mixing* (pp. 1–25). New Orleans, Louisiana.
- Kazemian, S., Prasad, A., and Huat, B. B. K. (2010). Rheological behavior of grout in context of Newtonian and non-Newtonian Fluids. *Electronic Journal of Geotechnical Engineering*, 15, 1103–1115.
- Khairul Nizar, I., Al Bakri, A. M. M., Abdullah, A., Kamarudin, H., Rafiza, A. R., and Yahya, Z. (2014). Study on physical and chemical properties of fly ash from different area in Malaysia. *Key Engineering Materials*, 594–595(January), 985–989. <https://doi.org/10.4028/www.scientific.net/kem.594-595.985>
- Khan, M. N. N., Jamil, M., Karim, M. R., Zain, M. F. M., and Kaish, A. B. M. A. (2017). Filler effect of pozzolanic materials on the strength and microstructure development of mortar. *KSCE Journal of Civil Engineering*, 21(1), 274–284. <https://doi.org/10.1007/s12205-016-0737-5>
- Khan, M. S., Prasad, J., and Abbas, H. (2013). Effect of high temperature on high-volume fly ash concrete. *Arabian Journal for Science and Engineering*, 38(6), 1369–1378.
- Khayat, K. H., Yahia, A., and Sayed, M. (2008). Effect of supplementary cementitious materials on rheological properties, bleeding, and strength of structural grout. *ACI Materials Journal*, 105(6), 585–593. <https://doi.org/10.14359/20200>
- Khayat, K. H., Yahina, A., and Duffy, P. (1999). High-performance cement grout for post-tensioning applications. *ACI Materials Journal*, 96(4), 471–477. <https://doi.org/10.14359/648>

- Khyaliya, R. K., Kabeer, K. I. S. A., and Vyas, A. K. (2017). Evaluation of strength and durability of lean mortar mixes containing marble waste. *Construction and Building Materials*, 147, 598–607. <https://doi.org/10.1016/j.conbuildmat.2017.04.199>
- Kim, H. K., and Lee, H. K. (2013). Effects of high volumes of fly ash , blast furnace slag , and bottom ash on flow characteristics , density , and compressive strength of high-strength mortar. *Journal of Materials in Civil Engineering*, 25(May), 662–665. [https://doi.org/10.1061/\(ASCE\)MT.1943-5533.0000624](https://doi.org/10.1061/(ASCE)MT.1943-5533.0000624).
- Kondraivendhan, B., and Bhattacharjee, B. (2015). Flow behavior and strength for fly ash blended cement paste and mortar. *International Journal of Sustainable Built Environment*, 4(2), 270–277. <https://doi.org/10.1016/j.ijbsbe.2015.09.001>
- Koplitiz, S. N., Jacob, D. J., Sulprizio, M. P., Myllyvirta, L., and Reid, C. (2017). Burden of disease from rising coal-fired power plant emissions in southeast asia. *Environmental Science and Technology*, 51(3), 1467–1476. <https://doi.org/10.1021/acs.est.6b03731>
- Krishnamoorthy, T. S., Gopalakrishnan, S., Balasubramanian, K., Bharatkumar, B. H., and Rama Mohan Rao, P. (2002). Investigations on the cementitious grouts containing supplementary cementitious materials. *Cement and Concrete Research*, 32(9), 1395–1405. [https://doi.org/10.1016/S0008-8846\(02\)00799-8](https://doi.org/10.1016/S0008-8846(02)00799-8)
- Kurda, R., de Brito, J., and Silvestre, J. D. (2019). Water absorption and electrical resistivity of concrete with recycled concrete aggregates and fly ash. *Cement and Concrete Composites*, 95(October 2018), 169–182. <https://doi.org/10.1016/j.cemconcomp.2018.10.004>
- Kutchko, B. G., and Kim, A. G. (2006). Fly ash characterization by SEM-EDS. *Fuel*, 85(17–18), 2537–2544. <https://doi.org/10.1016/j.fuel.2006.05.016>
- Lawrence, P., Ringot, E., and Husson, B. (2006). About the measurement of the air content in mortar. *Materials and Structures*, 32(8), 618–621. <https://doi.org/10.1007/bf02480498>
- Le, Q. X., Dao, V. T. N., Torero, J. L., Maluk, C., and Bisby, L. (2018). Effects of temperature and temperature gradient on concrete performance at elevated temperatures. *Advances in Structural Engineering*, 21(8), 1223–1233. <https://doi.org/10.1177/1369433217746347>
- Ledesma, E. F., Jiménez, J. R., Fernández, J. M., Galvín, A. P., Agrela, F., and Barbudo, A. (2014). Properties of masonry mortars manufactured with fine

- recycled concrete aggregates. *Computers and Chemical Engineering*, 71, 289–298. <https://doi.org/10.1016/j.conbuildmat.2014.08.080>
- Lee, H., Ismail, M., and Lee, H. (2016). Study on the pozzolan reaction degree of palm oil fuel ash as a mineral admixture for sustainable concrete. In *Proceedings of the Korea Concrete Institute Conference* (pp. 1–4). Korea.
- Lee, J. K., Ko, J., and Kim, Y. S. (2017). Rheology of fly ash mixed tailings slurries and applicability of prediction models. *Minerals*, 7(9), 165. <https://doi.org/10.3390/min7090165>
- Li-xiong, G., Yan, Y., and Ling, W. (2004). Research on sintered fly ash aggregate of high strength and low absorption of water. In *Proceedings of International workshop on Sustainable development and Concrete Technology* (pp. 151–157). Beijing, China.
- Li, G, and Wu, X. (2005). Influence of fly ash and its mean particle size on certain engineering properties of cement composite mortars. *Cement and Concrete Research*, 35(6), 1128–1134. <https://doi.org/10.1016/j.cemconres.2004.08.014>
- Li, Gengying, and Wu, X. (2005). Influence of fly ash and its mean particle size on certain engineering properties of cement composite mortars. *Cement and Concrete Research*, 35(6), 1128–1134. <https://doi.org/10.1016/j.cemconres.2004.08.014>
- Li, Gengying, and Zhao, X. (2003). Properties of concrete incorporating fly ash and ground granulated blast-furnace slag. *Cement and Concrete Composites*, 25(3), 293–299. [https://doi.org/10.1016/S0958-9465\(02\)00058-6](https://doi.org/10.1016/S0958-9465(02)00058-6)
- Li, S., Sha, F., Liu, R., Zhang, Q., and Li, Z. (2017). Investigation on fundamental properties of microfine cement and cement-slag grouts. *Construction and Building Materials*, 153, 965–974. <https://doi.org/10.1016/j.conbuildmat.2017.05.188>
- Liao, F., and Huang, Z. (2018). Modeling cracks of reinforced concrete slabs under fire conditions. *Journal of Structural Engineering*, 144(5), 04018030. [https://doi.org/10.1061/\(ASCE\)ST.1943-541X.0001996](https://doi.org/10.1061/(ASCE)ST.1943-541X.0001996)
- Lim, S. K., Tan, C. S., Chen, K. P., Lee, M. L., and Lee, W. P. (2013). Effect of different sand grading on strength properties of cement grout. *Construction and Building Materials*, 38, 348–355. <https://doi.org/10.1016/j.conbuildmat.2012.08.030>
- Lothenbach, B., Scrivener, K., and Hooton, R. D. (2011). Supplementary cementitious

- materials. *Cement and Concrete Research*, 41(12), 1244–1256.
<https://doi.org/10.1016/B978-0-08-100693-1.00008-4>
- Luso, E., and Lourenço, P. B. (2017). Bond strength characterization of commercially available grouts for masonry. *Construction and Building Materials*, 144, 317–326. <https://doi.org/10.1016/j.conbuildmat.2017.03.179>
- Madhavi, T. C., Luther, S. M., Velan, S., Kumar, P., Raju, S., and Mathur, D. (2015). Chloride Penetration in Fly Ash Concrete. *International Journal of Research in Engineering & Technology*, 04(01), 134–140.
- Malquori, G. (1960). Hydration, setting and hardening of Portland cement. In *Proceedings of the Fourth International Symposium on Chemistry of Cement*. Washington, D.C.
- Marczewska, J. (2018). Influence of the fly ash and the prior freezing and thawing on the sulphate resistance of cement mortars. *MATEC Web of Conferences*, 174, 02004. <https://doi.org/10.1051/mateconf/201817402004>
- Mardani-Aghabaglou, A., Andiç-Çakir, Ö., and Ramyar, K. (2013). Freeze-thaw resistance and transport properties of high-volume fly ash roller compacted concrete designed by maximum density method. *Cement and Concrete Composites*, 37(1), 259–266.
<https://doi.org/10.1016/j.cemconcomp.2013.01.009>
- Mardani-Aghabaglou, A., Inan Sezer, G., and Ramyar, K. (2014). Comparison of fly ash, silica fume and metakaolin from mechanical properties and durability performance of mortar mixtures view point. *Construction and Building Materials*, 70, 17–25. <https://doi.org/10.1016/j.conbuildmat.2014.07.089>
- Markou, I. N., and Atmatzidis, D. K. (2002). Development of a pulverized fly ash suspension grout. *Geotechnical and Geological Engineering*, 20(2), 123–147.
<https://doi.org/10.1023/A:1015071621943>
- Marthong, C., and Agrawal, T. P. (2012). Effect of fly ash additive on concrete properties. *International Journal of Engineering Research and Applications*, 2(August), 1986–1991.
- Marzouki, A., Lecomte, A., Beddey, A., Diliberto, C., and Ben Ouezdou, M. (2013). The effects of grinding on the properties of Portland-limestone cement. *Construction and Building Materials*, 48, 1145–1155.
<https://doi.org/10.1016/j.conbuildmat.2013.07.053>
- Matesová, D., Bonen, D., and Shah, S. (2006). Factors affecting the resistance of

- cementitious materials at high temperatures and medium[0] heating rates. *Materials and Structures*, 39(9), 919–935. <https://doi.org/10.1617/s11527-006-9198-5>
- Matthews, S., Holton, I., Morlidge, J., and Pool, R. (2003). A thematic network on performance based on rehabilitation of reinforced concrete structures. *Concrete*, pp. 58–59.
- McCarthy, M. J., and Dhir, R. K. (2005). Development of high volume fly ash cements for use in concrete construction. *Fuel*, 84(11), 1423–1432. <https://doi.org/10.1016/j.fuel.2004.08.029>
- Meddah, M. S., Zitouni, S., and Belaabes, S. (2015). Effect of size and content of coarse aggregate on the compressive strength of concrete. *International Journal of Engineering Research and Applications*, 5(1), 67–75. <https://doi.org/10.1016/j.conbuildmat.2009.10.009>
- Mehmannavaz, T., Sumadi, S. R., Bhutta, M. A. R., Samadi, M., and Sajjadi, S. M. (2014). Low carbon footprint mortar from pozzolanic waste material. *Research Journal of Applied Sciences, Engineering and Technology*, 7(16), 3374–3379.
- Mehta, P. K. (1994). *Testing and correlation of fly ash properties with respect to pozzolanic behavior*. Pola Alto, CA.
- Mehta, P. K. (1998). Role of fly ash in sustainable Development concrete. In *Proceedings of forum on fly ash and environment*.
- Mehta, P. K. (2004). High-performance, high-volume fly ash concrete for sustainable development. *International Workshop on Sustainable Development and Concrete Technology*, 3–14. Retrieved from http://web.pdx.edu/~cgriffin/references/Mehta_2004_HVFA_Concrete.pdf
- Miltiadou-Fezans, A., and Tassios, T. P. (2013). Stability of hydraulic grouts for masonry strengthening. *Materials and Structures*, 46(10), 1631–1652. <https://doi.org/10.1617/s11527-012-0005-1>
- Mirza, J., Mirza, M. S., Roy, V., and Saleh, K. (2002). Basic rheological and mechanical properties of high-volume fly ash grouts. *Construction and Building Materials*, 16(6), 353–363. [https://doi.org/10.1016/S0950-0618\(02\)00026-0](https://doi.org/10.1016/S0950-0618(02)00026-0)
- Misra, A., Ramteke, R., and Bairwa, M. L. (2007). Study on strength and durability characteristics of fly ash concrete. *Journal of Engineering and Applied Sciences*, 2(5), 54–59.

- Mo, E. G., Thomas, M. D. A., and Fahim, A. (2017). Cement and Concrete Research Performance of high-volume fly ash concrete in marine environment. *Cement and Concrete Research*, 102(June), 0–1. <https://doi.org/10.1016/j.cemconres.2017.09.008>
- Mohammadi, J., and South, W. (2016). Effects of Intergrinding 12% Limestone with Cement on Properties of Cement and Mortar. *Journal of Advanced Concrete Technology*, 14(5), 215–228. <https://doi.org/10.3151/jact.14.215>
- Mohammed, B. S., Haruna, S., Wahab, M. M. A., Liew, M. S., and Haruna, A. (2019). Mechanical and microstructural properties of high calcium fly ash one-part geopolymer cement made with granular activator. *Heliyon*, 5(9), e02255. <https://doi.org/10.1016/j.heliyon.2019.e02255>
- Mohammed, M. H., Pusch, R., Knutsson, S., and Hellström, G. (2014). Rheological properties of cement-based grouts determined by different techniques. *Engineering*, 06(05), 217–229. <https://doi.org/10.4236/eng.2014.65026>
- Mokhtar, R., Abdelouahed, K., and Abdessamed, M. (2018). Contribution in the study of the durability of plaster mortar based on sand of dunes reinforced by date palm fibers. *Civil Engineering Research Journal*, 4(5), 1–6. <https://doi.org/10.19080/CERJ.2018.04.555650>
- Molnar, L. M., and Manea, D. L. (2016). New types of plastering mortars based on marble powder slime. *Procedia Technology*, 22, 251–258. <https://doi.org/10.1016/j.protcy.2016.01.076>
- Monteiro, P. J. M., and Kurtis, K. E. (2003). Time to failure for concrete exposed to severe sulfate attack. *Cement and Concrete Research*, 33(7), 987–993. [https://doi.org/10.1016/S0008-8846\(02\)01097-9](https://doi.org/10.1016/S0008-8846(02)01097-9)
- Mounanga, P., Khelidj, A., Loukili, A., and Baroghel-Bouny, V. (2004). Predicting Ca(OH)₂ content and chemical shrinkage of hydrating cement pastes using analytical approach. *Cement and Concrete Research*, 34(2), 255–265. <https://doi.org/10.1016/j.cemconres.2003.07.006>
- Muhardi, A., Marto, A., Kassim, K. A., Makhtar, A. M., Wei, L. F., and Lim, Y. S. (2010). Engineering characteristics of Tanjung Bin coal ash. *Electronic Journal of Geotechnical Engineering*, 15 K, 1117–1129.
- Mujah, D. (2016). Compressive strength and chloride resistance of grout containing ground palm oil fuel ash. *Journal of Cleaner Production*, 112, 712–722. <https://doi.org/10.1016/j.jclepro.2015.07.066>

- Mukherjee, S., Mandal, S., and Adhikari, U. B. (2013). Comparative study on physical and mechanical properties of high slump and zero slump high volume fly ash concrete (HVFAC). *Global Nest Journal*, 15(4), 578–584.
- Nadeem, A., Memon, S. A., and Lo, T. Y. (2013). Mechanical performance, durability, qualitative and quantitative analysis of microstructure of fly ash and Metakaolin mortar at elevated temperatures. *Construction and Building Materials*, 38, 338–347. <https://doi.org/10.1016/j.conbuildmat.2012.08.042>
- Naganathan, S., and Linda, T. (2013). Effect of fly ash fineness on the performance of cement mortar. *Jordan Journal of Civil Engineering*, 7(3), 326–331.
- Nasser, K. W., and Marzouk, H. M. (1979). Properties of mass concrete containing fly ash at high temperatures. In *ACI Journal Proceedings* (Vol. 76, pp. 537–550).
- Nath, P., and Sarker, P. K. (2013). Effect of mixture proportions on the drying shrinkage and permeation properties of high strength concrete containing class F fly ash. *KSCE Journal of Civil Engineering*, 17(6), 1437–1445. <https://doi.org/10.1007/s12205-013-0487-6>
- Nayaka, R. R., Alengaram, U. J., Jumaat, M. Z., and Yusoff, S. B. (2018). Microstructural investigation and durability performance of high volume industrial by-products-based masonry mortars. *Construction and Building Materials*, 189, 906–923. <https://doi.org/10.1016/j.conbuildmat.2018.09.020>
- Nazri, F. M., Jaya, R. P., Abu Bakar, B. H., and Ahmadi, R. (2017). Fire resistance of ultra-high performance fibre reinforced concrete due to heating and cooling. *MATEC Web of Conferences*, 87, 01021. <https://doi.org/10.1051/matecconf/20178701021>
- Nilsson, L. (2009). Rapid determination of the chloride diffusivity in concrete by applying an electrical field, 99.
- Nordin, N., Abdullah, M. M. A. B., Tahir, M. F. M., Sandu, A. V., and Hussin, K. (2016). Utilization of fly ash waste as construction material. *International Journal of Conservation Science*, 7(1), 161–166. Retrieved from <http://search.ebscohost.com/login.aspx?direct=true&db=vth&AN=113480308&lang=es&site=ehost-live>
- Oey, T., Huang, C., Worley, R., and Ho, S. (2015). Linking fly ash composition to performance in cementitious systems. In *World of Coal Ash (WOCA)*. Nashville, TN.
- Ortega, J. M., Albaladejo, A., Pastor, J. L., Sánchez, I., and Climent, M. A. (2013).

- Influence of using slag cement on the microstructure and durability related properties of cement grouts for micropiles. *Construction and Building Materials*, 38, 84–93. <https://doi.org/10.1016/j.conbuildmat.2012.08.036>
- Ortega, J. M., Esteban, M. D., Rodríguez, R. R., Pastor, J. L., Ibanco, F. I., Sánchez, I., and Climent, M. A. (2017). Long-term behaviour of fly ash and slag cement grouts for micropiles exposed to a sulphate aggressive medium. *Materials*, 10(6). <https://doi.org/10.3390/ma10060598>
- Ortega, J. M., Pastor, J. L., Albaladejo, A., Sánchez, I., and Climent, M. A. (2014). Durability and compressive strength of blast furnace slag-based cement grout for special geotechnical applications. *Materiales de Construcción*, 64(313), e003. <https://doi.org/10.3989/mc.2014.04912>
- Owen, P. L. (1979). Fly ash and its usage in concrete. *Journal of Concrete Society*, 13(7), 21–26.
- Pandey, S. K. (2014). Coal fly ash: Some aspects of characterization and environmental impacts. *Journal of Environmental Science, Computer Science and Engineering & Technology*, 3, 921–937.
- Pantazopoulos, I. A., Markou, I. N., Christodoulou, D. N., Droudakis, A. I., Atmatzidis, D. K., Antiohos, S. K., and Chaniotakis, E. (2012). Development of microfine cement grouts by pulverizing ordinary cements. *Cement and Concrete Composites*, 34(5), 593–603. <https://doi.org/10.1016/j.cemconcomp.2012.01.009>
- Papayianni, I., and Anastasiou, E. K. (2010). An investigation of the behavior of raw calcareous fly ash in mortar mixtures. In *World of Coal Ash (WOCA)* (pp. 1–10). Lexington, KY, USA.
- Pastor, J. L., Ortega, J. M., Flor, M., López, M. P., Sánchez, I., and Climent, M. A. (2016). Microstructure and durability of fly ash cement grouts for micropiles. *Construction and Building Materials*, 117, 47–57. <https://doi.org/10.1016/j.conbuildmat.2016.04.154>
- Peng, G. F., and Huang, Z. S. (2008). Change in microstructure of hardened cement paste subjected to elevated temperatures. *Construction and Building Materials*, 22(4), 593–599. <https://doi.org/10.1016/j.conbuildmat.2006.11.002>
- Petre, I., Moanță, A., and Muntean, M. (2012). Ordinary Portland cement with advanced fineness used for grout mixes. *UPB Scientific Bulletin, Series B: Chemistry and Materials Science*, 74(4), 103–112.

- Poon, C. S., Lam, L., and Wong, Y. L. (2000). A study on high strength concrete prepared with large volumes of low calcium fly ash. *Cement and Concrete Research*, 30(3), 447–455. [https://doi.org/10.1016/S0008-8846\(99\)00271-9](https://doi.org/10.1016/S0008-8846(99)00271-9)
- Posi, P., Kasemsiri, P., Lertnimoolchai, S., and Chindaprasirt, P. (2019). Effect of fly ash fineness on compressive, flexural and shear strengths of high strength-high volume fly ash jointing mortar. *International Journal of GEOMATE*, 16(54), 36–41. <https://doi.org/10.21660/2019.54.4662>
- Preetha, R., Kishore, G. V. V. S. ., Laharia, A. ., and Pillai, C. . (2013). Heat evolution of fly ash concrete. *The Indian Concrete Journal*, 32(5), 7–16. [https://doi.org/10.1016/S0008-8846\(01\)00755-4](https://doi.org/10.1016/S0008-8846(01)00755-4)
- Pusch, R. (1994). Waste disposal in rock. *Developments in Geotechnical Engineering* 76. <https://doi.org/10.1016/B978-0-444-89449-6.50007-4>
- Quennoz, A. (2011). *Hydration of C3A with calcium sulfate alone and in the presence of calcium silicate*. EPFL. <https://doi.org/10.5075/epfl-thesis-5035>
- Rahman, M., Håkansson, U., and Wiklund, J. (2012). Application of the Ultrasound Velocity Profiling + Pressure Difference (UVP + PD) method for cement based grouts. In *8th International Symposium on Ultrasonic Doppler Methods for Fluid Mechanics and Fluid Engineering* (pp. 41–44).
- Rahman, M., Wiklund, J., Kotzé, R., and Håkansson, U. (2017). Yield stress of cement grouts. *Tunnelling and Underground Space Technology*, 61, 50–60. <https://doi.org/10.1016/j.tust.2016.09.009>
- Rai, B., Kumar, S., and Satish, K. (2014). Effect of fly ash on mortar mixes with quarry dust as fine aggregate. *Advances in Materials Science and Engineering*, 1–8. <https://doi.org/10.1155/2014/626425>
- Rajamane, N. P., Nataraja, M. C., Lakshmanan, N., Dattatreya, J. K., and Sabitha, D. (2012). Sulphuric acid resistant ecofriendly concrete from geopolymerisation of blast furnace slag. *Indian Journal of Engineering and Materials Sciences*, 19(5), 357–367.
- Ramos, T., Matos, A. M., and Sousa-Coutinho, J. (2014). Strength and durability of mortar using cork waste ash as cement replacement. *Materials Research*, 17(4), 893–907. <https://doi.org/10.1590/S1516-14392014005000092>
- Rashad, A. M. (2015). A brief on high-volume Class F fly ash as cement replacement – A guide for Civil Engineer. *International Journal of Sustainable Built Environment*, 4(2), 278–306. <https://doi.org/10.1016/j.ijbsbe.2015.10.002>

- Ravindrarajah, R. S. (2003). Bleeding of fresh concrete containing cement supplementary materials. *Ninth East Asia-Pacific Conference on Structural Engineering and Construction*, (December), 16–18.
- Ravindrarajah, R. S., Lopez, R., and Reslan, H. (2002). Effect of elevated temperature on the properties of high-strength concrete containing cement supplementary materials. *9th International Conference on Durability of Building Materials and Components*, (1956), 9.
- Ren, X., and Sancaktar, E. (2019). Use of fly ash as eco-friendly filler in synthetic rubber for tire applications. *Journal of Cleaner Production*, 206, 374–382. <https://doi.org/10.1016/j.jclepro.2018.09.202>
- Revathi, Jeyalakshmi, Rajamane, Sivasakthi, and Dhinesh. (2016). Studies on physio chemical properties of fly ash for their effective alkali activation materials and methods. *SOJ Materials Science & Engineering*, 3(3), 1–6. <https://doi.org/10.15226/sojmse.2016.00129>
- Rodríguez, A., Gutiérrez-González, S., Horgnies, M., and Calderón, V. (2013). Design and properties of plaster mortars manufactured with ladle furnace slag. *Materials and Design*, 52, 987–994. <https://doi.org/10.1016/j.matdes.2013.06.041>
- Rommel, E., and Kurniawati, D. (2016). The improvement of properties fly-ash as cementitious for green concrete. *International Journal of Science and Research*, 5(8), 1765–1769. <https://doi.org/10.21275/24081601>
- Rotaru, A., and Boboc, V. (2010). Physical properties of pozzolana fly ash from thermal power plant of Iasi, Romania – a cement-like material for substructure works. In *Proceedings of the International Conference on Risk Management, Assessment and Mitigation Physical* (Vol. 6, pp. 427–436). ROMANIA.
- Ruano, G., Isla, F., Luccioni, B., Zerbino, R., and Giaccio, G. (2018). Steel fibers pull-out after exposure to high temperatures and its contribution to the residual mechanical behavior of high strength concrete. *Construction and Building Materials*, 163, 571–585. <https://doi.org/10.1016/j.conbuildmat.2017.12.129>
- Saengsoy, W., Nguyen, T., Chatchawan, R., and Tangtermsirikul, S. (2016). Effect of moisture content of wet fly ash on basic properties of mortar and concrete. In *Fourth International Conference on Sustainable Construction Materials and Technologies*. Las Vegas, USA.
- Saha, A. K. (2018). Effect of class F fly ash on the durability properties of concrete.

- Sustainable Environment Research*, 28(1), 25–31.
<https://doi.org/10.1016/j.serj.2017.09.001>
- Şahmaran, M., Keskin, S. B., Ozerkan, G., and Yaman, I. O. (2008). Self-healing of mechanically-loaded self consolidating concretes with high volumes of fly ash. *Cement and Concrete Composites*, 30(10), 872–879.
<https://doi.org/10.1016/j.cemconcomp.2008.07.001>
- Sakai, E., Miyahara, S., Ohsawa, S., Lee, S. H., and Daimon, M. (2005). Hydration of fly ash cement. *Cement and Concrete Research*, 35(6), 1135–1140.
<https://doi.org/10.1016/j.cemconres.2004.09.008>
- Sandra, C., Luís, C., José, A., Fernando, T., Victor, F., and António, T. (2014). High temperatures behaviour of mortars with incorporation of phase change materials. In *1º Congresso Luso-Brasileiro de Materiais de Construção Sustentáveis* (pp. 1–12). Coimbra, Portugal.
- Saoo, S., Das, B. B., Rath, A. K., and Kar, B. B. (2015). Acid, alkali and chloride resistance of high volume fly ash concrete. *Indian Journal of Science and Technology*, 8(19), 326–332. <https://doi.org/10.17485/ijst/2015/v8i>
- Sarkar, S., Halder, A., and Bishnoi, S. (2016). Shrinkage in concretes containing fly ash. In *UKIERI Concrete Congress*. Jalandhar, India.
- Sasiekalaa, K., and Malathy, R. (2012). Behaviour of mortar containing silica fume and fly used for ferrocement laminates. *Journal of Industrial Pollution Control*, 28(1), 13–20.
- Satish Chandra, C., Takhelmayum, G., and Deepa, T. (2013). Study on Flow and Compressive Strength Properties of Mortars Using Fly Ash and Lime. *International Journal of Engineering Science and Innovative Technology (IJESIT)*, 2(6), 309–315.
- Satish, K., Kumar, S., and Rai, B. (2017). Self compacting concrete using fly ash and silica fumes as pozzolanic material. *Journal of Engineering Technology (ISSN: 0747-9964)*, 6(2), 394–407.
- Satyarnoa, I., Solehudina, A. P., Meyartoa, C., Hadiyatmoko, D., Muhammada, P., and Afnana, R. (2014). Practical method for mix design of cement-based grout. *Procedia Engineering*, 95(Scescm), 356–365.
<https://doi.org/10.1016/j.proeng.2014.12.194>
- Sejnoha, M. (2014). Fire resistance of concrete with fly ash content – experimental analysis. *Engineering Mechanics*, 21(3), 159–165.

- Seo, S. K., Chu, Y. S., Shim, K. B., and Jeong, J. H. (2016). A study on physical properties of mortar mixed with fly-ash as functions of mill types and milling times. *Journal of the Korean Ceramic Society*, 53(4), 435–443. <https://doi.org/10.4191/kcers.2016.53.4.435>
- Sha, F., Li, S., Liu, R., Li, Z., and Zhang, Q. (2018). Experimental study on performance of cement-based grouts admixed with fly ash, bentonite, superplasticizer and water glass. *Construction and Building Materials*, 161, 282–291. <https://doi.org/10.1016/j.conbuildmat.2017.11.034>
- Shah, R. A., and Pitroda, J. (2013). Effect of water absorption and sorptivity on durability of pozzocrete mortar. *International Journal of Emerging Science and Engineering*, 4(15), 2319–6378.
- Shah, R. A., Pitroda, J., and Ash, F. (2013). Fly ash Class F : opportunities for development of low cost mortar mortar compositions. *Nternational Journal of Innovative Technology and Exploring Engineering (IJITEE) I*, 2(4), 112–115.
- Shakir, A. A., and Mohammed, A. A. (2015). Durability property of fly ash, quarry dust and billet scale bricks. *Journal of Engineering Science and Technology*, 10(5), 591–605.
- Shang, H. S., and Yi, T. H. (2013). Behavior of HPC with fly ash after elevated temperature. *Advances in Materials Science and Engineering*, 2013. <https://doi.org/10.1155/2013/478421>
- Shannag, M. J. (2002). High-performance cementitious grouts for structural repair. *Cement and Concrete Research*, 32(5), 803–808. [https://doi.org/10.1016/S0008-8846\(02\)00710-X](https://doi.org/10.1016/S0008-8846(02)00710-X)
- Shi, C., and Stegemann, J. A. (2000). Acid corrosion resistance of different cementing materials. *Cement and Concrete Research*, 30(5), 803–808. [https://doi.org/10.1016/S0008-8846\(00\)00234-9](https://doi.org/10.1016/S0008-8846(00)00234-9)
- Shivakumara, B., Prabhakara, H. R., and Prakash, K. B. (2013). Effect of sulphate attack on strength characteristic of fiber reinforced high volume fly ash concrete, 3(5), 1153–1161.
- Shrivastava, Y., Bajaj, K., and Ash, F. (2012). Performance of fly ash and high volume fly ash concrete in pavement design type. In *IACSIT Coimbatore Conferences* (Vol. 28, pp. 188–192). Singapore.
- Siddique, R., and Khan, M. I. (2011). *Supplementary cementing materials* (11th Editi). Berlin Heidelberg: Springer.

- Silva, P., and de Brito, J. (2013). Electrical resistivity and capillarity of self-compacting concrete with incorporation of fly ash and limestone filler. *Advances in Concrete Construction*, 1(1), 65–84. <https://doi.org/10.12989/acc.2013.1.1.065>
- Sim, J., and Park, C. (2011). Compressive strength and resistance to chloride ion penetration and carbonation of recycled aggregate concrete with varying amount of fly ash and fine recycled aggregate. *Waste Management*, 31(11), 2352–2360. <https://doi.org/10.1016/j.wasman.2011.06.014>
- Singh, L. P., Ali, D., Tyagi, I., Sharma, U., Singh, R., and Hou, P. (2019). Durability studies of nano-engineered fly ash concrete. *Construction and Building Materials*, 194, 205–215. <https://doi.org/10.1016/j.conbuildmat.2018.11.022>
- Sinsiri, T., Teerakit, P., Jaturapitakkul, C., and Kiattikomol, K. (2006). Effect of finenesses of fly ash on expansion of mortars in magnesium sulfate. *ScienceAsia*, 32(1), 063. <https://doi.org/10.2306/scienceasia1513-1874.2006.32.63>
- Sivakumar, S., and Kameshwari, B. (2015). Influence of fly ash, bottom ash, and light expanded clay aggregate on concrete. *Advances in Materials Science and Engineering*, 2015. <https://doi.org/10.1155/2015/849274>
- Skalny, J., Gebauer, J., and Odler, I. (2000). Material science of concrete special volume: calcium hydroxide in concrete. In *Workshop on the Role of Calcium Hydroxide in Concrete* (pp. 59–72). Florida.
- Somna, R., Jaturapitakkul, C., and Amde, A. M. (2012). Effect of ground fly ash and ground bagasse ash on the durability of recycled aggregate concrete. *Cement and Concrete Composites*, 34(7), 848–854. <https://doi.org/10.1016/j.cemconcomp.2012.03.003>
- Sonebi, M. (2006). Rheological properties of grouts with viscosity modifying agents as diutan gum and welan gum incorporating pulverised fly ash. *Cement and Concrete Research*, 36(9), 1609–1618. <https://doi.org/10.1016/j.cemconres.2006.05.016>
- Sonebi, M., Lachemi, M., and Hossain, K. M. A. (2013). Optimisation of rheological parameters and mechanical properties of superplasticised cement grouts containing metakaolin and viscosity modifying admixture. *Construction and Building Materials*, 38, 126–138. <https://doi.org/10.1016/j.conbuildmat.2012.07.102>

- Sonebi, M. (2002). Experimental design to optimize high-volume of fly ash grout in the presence of welan gum and superplasticizer. *Materials and Structures*, 35(July), 373–380. <https://doi.org/10.1617/13752>
- Sonebi, Mohammed. (2001). Factorial design modelling of mix proportion parameters of underwater composite cement grouts. *Cement and Concrete Research*, 31(11), 1553–1560. [https://doi.org/10.1016/S0008-8846\(01\)00583-X](https://doi.org/10.1016/S0008-8846(01)00583-X)
- Soren, A. (2013). *Effect of elevated temperature on fly ash based geopolymer mortar*. Jadapur University.
- Spychał, E. (2015). The effect of lime and cellulose ether on selected properties of plastering mortar. *Procedia Engineering*, 108, 324–331. <https://doi.org/10.1016/j.proeng.2015.06.154>
- Suruhanjaya Tenaga. (2015). National Energy Balance. Putrajaya: Suruhanjaya Tenaga.
- Taha, A. A. (2018). Performance of high-volume fly ash self-compacting concrete exposed to external sulfate attack. *Sixth International Conference on the Durability of Concrete Structures*, 502(July).
- Tahir, A. A., and Sabir, M. (2005). A study on durability of fly ash-cement mortars. In *30th Conference on Our World in Concrete and Structures* (p. 7). Singapore.
- Tan, O., Zaimoglu, A. S., Hınıslıoglu, S., and Altun, S. (2005). Taguchi approach for optimization of the bleeding on cement-based grouts. *Tunnelling and Underground Space Technology*, 20(2), 167–173. <https://doi.org/10.1016/j.tust.2004.08.004>
- Tang, Z., Ma, S., Ding, J., Wang, Y., and Zheng, S. (2013). Current status and prospect of fly ash utilization in China. In *2013 world of coal ash (WOCA)* (pp. 22–27). Lexington, KY. Retrieved from <http://www.flyash.info/>
- Tanyildizi, H., and Coskun, A. (2008). The effect of high temperature on compressive strength and splitting tensile strength of structural lightweight concrete containing fly ash. *Construction and Building Materials*, 22(11), 2269–2275. <https://doi.org/10.1016/j.conbuildmat.2007.07.033>
- Temiz, H., and Kantarci, F. (2014). Investigation of durability of CEM II B-M mortars and concrete with limestone powder, calcite powder and fly ash. *Construction and Building Materials*, 68, 517–524. <https://doi.org/10.1016/j.conbuildmat.2014.06.078>
- Teymen, A. (2017). Effect of mineral admixture types on the grout strength of fully-

- grouted rockbolts. *Construction and Building Materials*, 145, 376–382.
<https://doi.org/10.1016/j.conbuildmat.2017.04.046>
- Thikare, N. B., Shinde, S. N., and Patil, R. N. (2016). Study of fly ash mortar : compressive strength. *International Journal of Advance Research and Innovative Ideas in Education*, 2(3), 4564–4568.
- Thomas, M. D. A. (2007). Optimizing the use of fly ash in concrete. *Portland Cement Association*, 24.
- Thorstensen, R. T., and Fidjestol, P. (2015). Inconsistencies in the pozzolanic strength activity index (SAI) for silica fume according to EN and ASTM. *Materials and Structures/Materiaux et Constructions*, 48(12), 3979–3990.
<https://doi.org/10.1617/s11527-014-0457-6>
- Tian, B., and Cohen, M. D. (2000). Does gypsum formation during sulfate attack on concrete lead to expansion? *Cement and Concrete Research*, 30(1), 117–123.
[https://doi.org/10.1016/S0008-8846\(99\)00211-2](https://doi.org/10.1016/S0008-8846(99)00211-2)
- Tian, W., and Han, N. (2017). Experiment analysis of concrete’s mechanical property deterioration suffered sulfate attack and drying-wetting cycles. *Advances in Materials Science and Engineering*, 2017.
<https://doi.org/10.1155/2017/5673985>
- Tittelboom, K. V., and Belie, N. D. (2009). A critical review on test methods for evaluating the resistance of concrete against sulfate attack. In *Concrete in aggressive aqueous environments, performance, testing and modeling*. Toulouse, France. https://doi.org/10.1007/978-94-007-5413-3_10
- Tkaczewska, E., and Małolepszy, J. (2009). Hydration of coal-biomass fly ash cement. *Construction and Building Materials*, 23(7), 2694–2700.
<https://doi.org/10.1016/j.conbuildmat.2008.12.018>
- Torii, K., Taniguchi, K., and Kawamura, M. (1995). Sulfate resistance of high content fly ash concrete. *Cement and Concrete Research*, 25(4), 759–768.
- Turgut, P. (2010). Masonry composite material made of limestone powder and fly ash. *Powder Technology*, 204(1), 42–47.
<https://doi.org/10.1016/j.powtec.2010.07.004>
- Upadhyay, R., Srivastava, V., Herbert, A., and Mehta, P. K. (2014). Effect of fly ash on flexural strength of portland pozzolona cement concrete. *Journal of Academia and Industrial Research (JAIR)*, 3(5), 218–220.
- Uysal, M., Yilmaz, K., and Ipek, M. (2012). The effect of mineral admixtures on

- mechanical properties, chloride ion permeability and impermeability of self-compacting concrete. *Construction and Building Materials*, 27(1), 263–270. <https://doi.org/10.1016/j.conbuildmat.2011.07.049>
- Vaishnavi, M., and Kanta Rao, M. (2014). Durability of high volume fly ash concrete. *International Journal of Engineering Research & Technology*, 3(8), 872–876. Retrieved from <http://hdl.handle.net/1822/5626>
- Wan Yusof, W. Y., Adnan, S. H., Jamellodin, Z., and Mohammad, N. S. (2015). Strength development of fine grained mortar containing palm oil fuel ash as a partial cement replacement. *Applied Mechanics and Materials*, 773–774, 964–968. <https://doi.org/10.4028/www.scientific.net/amm.773-774.964>
- Wang, H., and Wang, H. (2008). Effect of elevated temperatures on properties and color intensities of fly ash mortar. *Computers and Concrete*, 5(2), 89–91.
- Wang, X. S. (2014). Mineralogical and chemical composition of magnetic fly ash fraction. *Environmental Earth Sciences*. <https://doi.org/10.1007/s12665-013-2571-0>
- Wesche, K. (1990). *Fly ash in concrete properties and performance* (RILEM Repo). Paris, France: Chapman and Hall. Retrieved from https://books.google.ee/books/about/Fly_Ash_in_Concrete.html?id=rYantCm-44MC&pgis=1
- Yahia, A. (2011). Shear-thickening behavior of high-performance cement grouts - Influencing mix-design parameters. *Cement and Concrete Research*, 41(3), 230–235. <https://doi.org/10.1016/j.cemconres.2010.11.004>
- Yahia, A., and Khayat, K. H. (2001). Analytical models for estimating yield stress of high-performance pseudoplastic grout. *Cement and Concrete Research*, 31(5), 731–738. [https://doi.org/10.1016/S0008-8846\(01\)00476-8](https://doi.org/10.1016/S0008-8846(01)00476-8)
- Yazici, H. (2008). The effect of silica fume and high-volume Class C fly ash on mechanical properties, chloride penetration and freeze-thaw resistance of self-compacting concrete. *Construction and Building Materials*, 22(4), 456–462. <https://doi.org/10.1016/j.conbuildmat.2007.01.002>
- Yazici, Ş., and Arel, H. Ş. (2012). Effects of fly ash fineness on the mechanical properties of concrete. *Sadhana - Academy Proceedings in Engineering Sciences*, 37(3), 389–403. <https://doi.org/10.1007/s12046-012-0083-3>
- Yerramala, A., C, R., and V, B. D. (2012). Influence of fly ash replacement on strength properties of cement mortar. *International Journal of Engineering Science and*

Technology, 4(08), 3657–3665.

- Youn, B. Y., and Breitenbücher, R. (2014). Influencing parameters of the grout mix on the properties of annular gap grouts in mechanized tunneling. *Tunnelling and Underground Space Technology*, 43, 290–299. <https://doi.org/10.1016/j.tust.2014.05.021>
- Yu, J., Li, X., Fleming, D., Meng, Z., Wang, D., and Tahmasebi, A. (2012). Analysis on characteristics of fly ash from coal fired power stations. *Energy Procedia*, 17, 3–9. <https://doi.org/10.1016/j.egypro.2012.02.054>
- Yuyou, Y., Zengdi, C., Xiangqian, L., and Haijun, D. (2016). Development and materials characteristics of fly ash- slag-based grout for use in sulfate-rich environments. *Clean Technologies and Environmental Policy*, 18(3), 949–956. <https://doi.org/10.1007/s10098-015-1040-8>
- Zhang, M. H., Bilodeau, A., Bouzoubaa, N., and Malhotra, V. M. (1998). Mechanical properties and durability of concrete made with high volume fly ash blended cements. *SP178 Sixth CANMETACIJCI Conference Fly Ash Silica Fume Slag Natural Pozzolans in Concrete*, 178, 575–603. Retrieved from <http://www.concrete.org/pubs/journals/abstractdetails.asp?ID=5999>
- Zhang, S. P., and Zong, L. (2014). Evaluation of relationship between water absorption and durability of concrete materials. *Advances in Materials Science and Engineering*, 1–9. <https://doi.org/10.1155/2014/650373>
- Zhang, Z., Qian, S., and Ma, H. (2014). Investigating mechanical properties and self-healing behavior of micro-cracked ECC with different volume of fly ash. *Construction and Building Materials*, 52, 17–23. <https://doi.org/10.1016/j.conbuildmat.2013.11.001>
- Zohreh Heydariha, J., Das, S., and Banting, B. (2017). Effect of grout strength and block size on the performance of masonry beam. *Construction and Building Materials*, 157, 685–693. <https://doi.org/10.1016/j.conbuildmat.2017.09.130>