

Performance of Sustainable and Low-Carbon Cementitious Composites under Aggressive Environmental Conditions

by Fulin Qu

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under the supervision of
Dr. Wengui Li (Principal supervisor)
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CERTIFICATE OF ORIGINAL AUTHORSHIP

I, *Fulin Qu*, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Engineering and Information Technology at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

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LIST OF RESEARCH PAPERS

Journal Papers

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- Fulin Qu, Wengui Li*, Wang Kejin, Shishun Zhang, and Sheng Daichao. "Performance deterioration of fly ash/slag-based geopolymer composites subjected to coupled cyclic preloading and sulfuric acid attacks." *Journal of Cleaner Production* (2021): 128942.
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- Fulin Qu, Wengui Li*, Xiaohui Zeng, Zhiyu Luo, Kejin Wang, and Daichao Sheng. "Effect of microlimestone on properties of self-consolidating concrete with manufactured sand and mineral admixture." *Frontiers of Structural and Civil Engineering* (2020): 1-16.
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- Wengui Li, Fulin Qu*, Wenkui Dong, Geetika Mishra, Surendra P. Shah. "A comprehensive review on self-sensing graphene/cementitious composites: A pathway toward future smart concrete", *Construction & Building Materials*, (2022):127284.

- Fulin Qu, Wengui Li*, Yipu Guo, Shishun Zhang, John L. Zhou, and Kejin Wang. "Chloride-binding capacity of cement-GGBFS-nanosilica composites under seawater chloride-rich environment." *Construction & Building Materials* 342 (2022): 127890.

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TABLE OF CONTENTS

CERTIFICATE OF ORIGINAL AUTHORSHIP	ii
ACKNOWLEDGEMENTS	iii
LIST OF RESEARCH PAPERS	v
TABLE OF CONTENTS	vii
LIST OF FIGURES	xv
LIST OF TABLES	xxi
ABSTRACT	xxiii
CHAPTER 1: INTRODUCTION.....	1
1.1 Background.....	1
1.2 Research objectives and scope.....	4
1.3 Research methodology	5
1.4 Layout of the thesis	6
CHAPTER 2: LITERATURE REVIEW	8
2.1 Sustainable and low-carbon cementitious composites	8
2.2 Cementitious composites under fire environment	11
2.2.1 Properties of cementitious composites at high temperature	11
2.2.2 Physical and chemical changes	13
2.2.3 Test modalities to simulate the fire environment	15
2.3 Cementitious composites under sulfuric acid attack	15
2.3.1 Manifestations of sulfuric attack	15

2.3.2 Sulfuric attack on the properties of cementitious composites.....	17
2.4 Under combined environmental actions and mechanical load	18
2.4.1 The method of mechanical loading	18
2.4.2 Under combined fire attack and mechanical load	19
2.4.3 Under combined sulfuric acid attack and mechanical load	21
2.5. Cementitious composites under marine environment	23
2.5.1 Description of the marine environment	23
2.5.2 Deterioration mechanism of concrete and reinforced concrete structure	26
2.5.3 Marine environment on the macro-scale properties of concrete	34
2.5.4 Reinforced concrete product and infrastructure under marine environment	46
2.6 Summary.....	55
 CHAPTER 3: PERFORMANCE OF LOW-CARBON GEOPOLYMER UNDER FIRE ENVIRONMENT AND MECHANICAL LOAD.....	 57
3.1 Introduction.....	57
3.2 Experiment program.....	59
3.2.1 Raw materials	59
3.2.2 Mix proportion	61
3.2.3 Specimen preparation	62
3.2.4 Experimental methodology	63
3.2.5 Test methods	63
3.3 Hydration heat.....	65

3.4 Residual compressive strength.....	67
3.5 Physical properties	73
3.5.1 Mass change	73
3.5.2 Volume change.....	74
3.5.3 Visual appearance.....	76
3.6 Microstructural characterization	79
3.6.1 X-ray diffraction.....	79
3.6.2 Thermogravimetric analysis.....	81
3.6.3 SEM with energy dispersive X-ray (EDX) analysis.....	83
3.7 General discussions	88
3.8 Summary.....	91
CHAPTER 4: PERFORMANCE OF LOW-CARBON GEOPOLYMER UNDER ACID ENVIRONMENT AND CYCLIC LOAD	94
4.1 Introduction.....	94
4.2 Materials and methodology	96
4.2.1 Raw materials	96
4.2.2 Mix proportion and sample preparations	97
4.2.3 Exposure conditions	98
4.3 Testing procedures	101
4.3.1 Methodology	101
4.3.2 Measurement of degradation depth	103

4.3.3 Microstructure and mineralogical characterization	104
4.3.4 ICP-MS analysis	105
4.4 Change of physical properties	105
4.4.1 Physical appearance	105
4.4.2 Mass change	107
4.5 Changes in mechanical properties and degradation depth	108
4.5.1 Compressive strength	108
4.5.2 Degradation depth	112
4.6 Changes in microstructure and mineralogy	113
4.6.1 X-ray diffraction	113
4.6.2 Fourier transform infrared spectroscopy	115
4.6.3 Thermogravimetric analysis	117
4.6.4 SEM with energy dispersive X-ray (EDX) analysis	118
4.7 Changes in leaching behavior	125
4.8 Deterioration mechanism	126
4.9 Summary	129
CHAPTER 5: PERFORMANCE OF CEMENTITIOUS COMPOSITES WITH SEAWATER AND UNDESALTED SEA-SAND	131
5.1 Introduction	131
5.2 Experimental program	133
5.2.1 Raw materials	133

5.2.2 Mix design and specimen preparation	136
5.3 Experimental methods	137
5.3.1 Isothermal calorimetry.....	137
5.3.2 Compressive strength.....	137
5.3.3 Water sorptivity	138
5.3.4 ICP-MS analysis.....	138
5.3.5 Microstructure characterization.....	139
5.4 Results and discussions	140
5.4.1 Hydration rate.....	140
5.4.2 Compressive strength.....	143
5.4.3 Water sorptivity.....	146
5.4.4 Leaching behaviour	148
5.4.5 X-ray diffraction.....	149
5.4.6 Fourier transform infrared spectroscopy.....	152
5.4.7 Thermogravimetric analysis.....	155
5.4.8 Characterization using SEM and energy dispersive X-ray.....	157
5.5 Mechanism analysis and discussion.....	163
5.6 Summary.....	166
CHAPTER 6: PERFORMANCE OF SEAWATER AND SEA-SAND CEMENTITIOUS COMPOSITES WITH GGBFS AND GLASS FIBER.....	168
6.1 Introduction.....	168

6.2 Materials and specimen preparation.....	171
6.2.1 Raw materials	171
6.2.2 Mix design.....	173
6.2.3 Specimen preparation	174
6.3 Experimental program.....	175
6.3.1 High-temperature exposure.....	175
6.3.2 Physical properties.....	175
6.3.3 Mechanical strengths	176
6.3.4 Microstructure characterization.....	176
6.4 Results and discussions	177
6.4.1 Physical properties.....	177
6.4.2 Compressive and flexural strengths.....	179
6.4.3 X-ray diffraction analysis (XRD).....	183
6.4.4 Fourier transform infrared spectroscopy (FTIR) analysis	185
6.4.5 Thermogravimetric analysis.....	187
6.4.6 BSE with energy dispersive X-ray	189
6.5 Mechanism discussions	196
6.6 Summary.....	200
 CHAPTER 7: CHLORIDE-BINDING CAPACITY OF GGBFS-NS-CEMENT SYSTEM IN SEAWATER AND CHLORIDE SOLUTIONS	 202
7.1 Introduction.....	202

7.2 Experimental program	205
7.2.1 Materials	205
7.2.2 Mix proportion and sample preparation.....	206
7.2.3 Exposure conditions	207
7.3 Test procedures	209
7.3.1 pH measurements	210
7.3.2 Chloride-binding ratio (CBR)	210
7.3.3 Chemical leaching behaviour measurements	211
7.3.4 Phase assemblage analysis	211
7.3.5 Microstructure characterization.....	212
7.3.6 Thermodynamics modeling.....	213
7.4 Results and discussions	214
7.4.1 pH values change.....	214
7.4.2 Chloride-binding capacity.....	215
7.4.3 Chemical leaching behaviour	216
7.4.4. Thermogravimetric analysis (TGA)	219
7.4.5. X-ray diffraction analysis (XRD).....	221
7.4.6 Fourier transform infrared spectroscopy (FTIR).....	224
7.4.7 SEM-EDS test results	227
7.4.8 Ca/Si ratio of hydrated gels.....	229
7.4.9 Amount of hydrated gels.....	231

7.5 Thermodynamic modeling and mechanism discussions	232
7.6 Summary.....	236
CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS.....	238
8.1 Brief Summary.....	238
8.2 Conclusion remarks.....	238
8.3 Recommendations for future works	240
REFERENCES	242

LIST OF FIGURES

Figure 2.1. Forecasted world Portland cement production 1990–2050	9
Figure 2.2. Energy of 40 MPa concrete mixtures	10
Figure 2.3. Emission of 40 MPa concrete mixtures	11
Figure 2.4. Residual stress–strain relationship of concrete exposure to different high temperatures .	12
Figure 2.5. The formation of sulfuric acid in the sewer network	16
Figure 2.6. Types of concrete structures under marine environment	25
Figure 2.7. Chloride induced corrosion mechanism surrounding zone of reinforcement.....	32
Figure 2.8. Different exposure conditions under marine environment	33
Figure 2.9. Changes of compressive strength of concrete at different ages of seawater corrosion.....	39
Figure 2.10. Effects of steel reinforcement corrosion on reinforced concrete structures under marine environment.....	46
Figure 2.11. Comparison of chloride profiles from reinforced concrete beams	48
Figure 2.12. Corrosion current densities of reinforced concrete slabs with or without corrosion inhibitors.....	51
Figure 3.1. XRD patterns of fly ash, GGBFS and OPC.....	61
Figure 3.2. Schematic diagram of geopolymer composites subjected to different steps of testing.....	64
Figure 3.3. Rate of heat generation and cumulative heat of hydration curve of GP and PCP pastes in 24 hrs.....	67
Figure 3.4. Compressive strength change percentage of PCM and GSM mortars	73
Figure 3.5. Effects of preloading on mass changes of mortars after temperature exposure	74

Figure 3.7. Cracking behavior of PCM and GSM at various elevated temperatures 78

Figure 3.8. XRD patterns of fly ash/GGBFS geopolymers and PCP pastes before and after exposure to high temperature 81

Figure 3.9. Thermogravimetric and derivative thermogravimetry curve of GP and PCP pastes before and after exposure to 300, 500 and 700 °C 83

Figure 3.10. SEM images of GSM3 mortars before and after being preloaded 84

Figure 3.11. SEM images with EDX results of GSMs and PCM mortar with 60% USC induced damage before and after exposure 87

Figure 3.12. Schematic diagram of the mechanism of fire resistance after preloading in 100% fly ash GSM, fly ash/slag GSM and 100% PCP mixes 89

Figure 4.1. Experimental methods of combined preloading and acid solutions 99

Figure 4.2. Diagram of preparation of degradation depth, leaching, and microstructure tested mortars 102

Figure 4.3. Degradation depth measurement in accordance with the pH 103

Figure 4.4. Surface appearances of OPM and GPM without preloading after 1, 6 and 18 months exposed to different sulfuric acid solutions 106

Figure 4.5. Mass changes of OPM and GPM specimens subjected to different sulfuric acid solutions for 18 months 108

Figure 4.6. Compressive strength of OPM and GPM before and after exposure to different sulfuric acid solutions for 18 months 109

Figure 4.7. Compressive strength change caused by preloading and sulfuric acid solution 110

Figure 4.8. Degradation depth of OPM and GPM exposed to different sulfuric acid solutions for up to 18 months 113

Figure 4.9. XRD patterns of GPM and OPM mortars after exposure to sulfuric acid for 18 months 114

Figure 4.10. FTIR spectra of GPM and OPM mortars after exposure to sulfuric acid for up to 18 months 116

Figure 4.11. TG and DTG results of OPM and GPM after 18-month exposure to different sulfuric acid solutions 118

Figure 4.12. SEM micrographs with EDX of OPM and GPM after 18-month exposure to 5 % sulfuric acid solution..... 120

Figure 4.13. SEM-EDX elemental line analysis profiles of GPM mortars after 18-month exposure to 5% sulfuric acid solution..... 123

Figure 4.14. Maximum concentrations of different elements in GPM and OPM before and after 18-month exposure to different sulfuric acid solutions..... 126

Figure 4.15. Schematic diagram of deterioration mechanism of OPM and GPM groups with preloading after 18-month exposure to different sulfuric acid solutions 128

Figure 5.1. Particle size distribution curves of sea sand and river sand 135

Figure 5.2. Comparison of specific heat flow of different cement mortar mixtures 141

Figure 5.3. Compressive strength of cement mortars at different curing ages: comparison 144

Figure 5.4. Relative strength of cement mortars compared to DS3 at different curing ages: comparison 145

Figure 5.5. Cumulative absorbed water content of cement mortars after 25 hrs exposure: comparison 147

Figure 5.6. Maximum concentrations of the elements leached from cement mortars after 28-day curing 149

Figure 5.7. Mid-range 2 theta XRD spectra of cement mortars at different curing ages..... 151

Figure 5.8. FTIR analysis on cement mortars with W/C ratio of 0.3 153

Figure 5.9. FTIR analysis on cement mortars with W/C ratio of 0.3 at 28 days curing 154

Figure 5.10. TG and DSC curves of cement mortars after 28-day curing 156

Figure 5.11. Weight loss percentage of calcium hydroxide in mortars by TG analysis 157

Figure 5.12. Microstructure and morphology of cement mortars at curing age of 28 days 159

Figure 5.13. SEM-EDS micrographs and elemental maps of SR1 at 28 days of curing 160

Figure 5.14. EDX phase analysis of different cement mortars at 28 days curing age 162

Figure 6.1. Particle size distribution (PSD) curve of the raw materials used 172

Figure 6.2. Physical transformations and mass change of glass fiber after the furnace test under different heating temperatures 173

Figure 6.3. The time-temperature curve in the furnace oven 175

Figure 6.4. Mass loss of mortars after high-temperature exposures 178

Figure 6.5. Visual appearance of all mortars after exposure to a temperature of 700 °C..... 179

Figure 6.6. Effect of elevated temperature exposure on compressive strength..... 180

Figure 6.7. Effect of elevated temperature exposure on flexural strength..... 182

Figure 6.8. XRD diagrams for mortars before and after high-temperature exposures 184

Figure 6.9. FTIR analysis on mortars before and after high-temperature exposures 186

Figure 6.10. TG and DTG analysis of mortars before and after high-temperature exposures 188

Figure 6.11. Characterization using BSE-EDX (250 magnification) before high-temperature exposure for mixes.....	192
Figure 6.12. Element analysis of FSSM with glass fibre before and after high-temperature exposure	194
Figure 6.13. BSE-EDX analysis of FRRM, FSSM and FSSM-30S before and after high-temperature exposure	195
Figure 6.14. Schematically diagrams for the microstructure change of the binder gels before and after high-temperature exposure.....	197
Figure 7.1. XRD results of OPC, GGBFS, and NS	206
Figure 7.2. The flowchart for the preparation of samples studied.....	207
Figure 7.3. pH values of the supernatants after 6-month exposure to different solutions	215
Figure 7.4. Chloride-binding ratio of well-hydrated cementitious pastes after 6-month exposure to different solutions	216
Figure 7.5. Maximum element concentrations of the supernatants for the well-hydrated cementitious pastes after 6-month exposure to the different solutions	218
Figure 7.6. DTG curves of the well-hydrated cementitious pastes after 6-month exposure to the different solutions	220
Figure 7.7. Calcium hydroxide contents (wt.%) of the well-hydrated cementitious pastes after 6-month exposure to the different solutions.....	221
Figure 7.8. XRD patterns of the well-hydrated cementitious pastes after exposure to the different chloride solutions for 6 months	223
Figure 7.9. FSS contents in the well-hydrated cementitious pastes after 6-month exposure to the different solutions	224

Figure 7.10. FTIR patterns of well-hydrated cementitious pastes after 6-month exposure to the different solutions 227

Figure 7.11. SEM morphologies with EDX of PC-GGBFS-NS1 after 6-month exposure to 1.0 mol/L MgCl₂ solution..... 229

Figure 7.12. The Ca/Si atomic ratios of C–S–H/C–A–S–H gels 231

Figure 7.13. Phase assemblages for well-hydrated Portland cement-GGBFS-NS composites exposed to different chloride solutions..... 233

Figure 7.14. Schematic diagram of the chloride-binding in Portland cement-GGBFS-NS composites after exposure to various salts solutions..... 234

LIST OF TABLES

Table 2.1 The performance of cementitious composites and structures under combined fire attack and mechanical loading	20
Table 2.2 The combined effect of sulfate ions and mechanical loading on the performance of cementitious compositions	23
Table 2.3 Main chemical composition of seawater	27
Table 2.6 Effects of compressive strength of cementitious concrete under marine environment	36
Table 2.7 Diffusion coefficients D_c of cementitious concrete exposed to marine environment	41
Table 2.8 Protection methods for reinforced concrete under marine environment	52
Table 3.1 Physical properties and chemical compositions of fly ash, GGBFS and OPC	60
Table 3.2 Mix proportions for geopolymer and OPC mortars and pastes	62
Table 3.3 Compressive strength of PCM and GSM under different circumstances	69
Table 4.1 Chemical compositions and loss on ignition (LOI) of FA, GGBFS and OPC	97
Table 4.2 Mix proportions of OPM and GPM mortar specimens	98
Table 4.3 Experimental parameters of OPM and GPM exposed to acid solution	100
Table 4.4 Ca/Si or Al/Si atomic ratios of OPM and GPM in non-degraded and degraded area	122
Table 4.5 Performance of OPM and GPM mortars exposed to cyclic preloading and sulfuric acid attack	127
Table 5.1 Chemical and physical properties of Portland cement	134
Table 5.2 Concentration of salt content in seawater based on Botany Bay (Sydney, Australia) and ASTM standard	134

Table 5.3 Chemical composition of unwashed sea sand and river sand (wt%)	135
Table 5.4 Mix proportion of cement mortars	136
Table 5.5 Acceleration rates of cement hydration in comparison to DS3 after 7 days of curing.....	142
Table 6.1 Chemical composition of GGBFS and cement, and mineral physical properties of cement	171
Table 6.2 Chemical compositions in seawater and sea sand from Botany Bay	172
Table 6.3 Mix proportion design of cement mortars	174
Table 6.4 Weight loss of mortar before and after high-temperature exposures	189
Table 7.1 LOI and chemical compositions (%) of OPC and GGBFS	205
Table 7.2 Mix proportion for the composite mixtures (g).....	206
Table 7.3 Exposure conditions with deionized water, seawater, and different chloride solutions....	209

ABSTRACT

Pozzolanic materials, like fly ash (FA) and ground granulated blast-furnace slag (GGBFS), are considered promising binder materials as they are industrial by-products, helping to decrease ordinary Portland cement (OPC) demands and further lessen greenhouse emissions. Therefore, the total or partial replacement of pozzolanic materials for OPC to fabricate sustainable and low-carbon cementitious composites (LCC) has garnered extensive attention for providing enormous environmental benefits for infrastructure and offshore construction. In addition, the durability of LCC under aggressive environmental deterioration (such as fire, acid, and marine environments) is a progressively significant property for concrete structures due to the increasing demand for extended service life and less maintenance.

For total pozzolanic materials replacement for OPC, this work has estimated the performance of fly ash/GGBFS-based geopolymer under combined mechanical loads and aggressive environmental conditions (fire and sulfuric acid attack). For partial pozzolanic materials replacement for OPC, this work has also assessed the performance of cementitious composites with GGBFS under the marine environment. The synergistic effects of seawater and undesalted sea sand on the properties of cementitious composites have been firstly analyzed. And then, the fire resistance of GGBFS-based cementitious composites with seawater and undesalted sea sand has been examined. Finally, the chloride-binding capacity of GGBFS-based cementitious composites in seawater and chloride solutions has also been observed.

The results showed that fly ash/GGBFS-based geopolymer with 20 wt.% GGBFS could be regarded as a remarkable alternative for OPC to achieve extraordinary fire resistance by considering the strength and compatibility variations. The fly ash/GGBFS-based geopolymer with cyclic preloading was also confirmed to exhibit less severe performance deterioration even after 18-month exposure to sulfuric acid attacks. In addition, the results illustrated that the chloride, sulphate, and magnesium ions in

seawater and/or undesalted sea sand were assessed to lead to the phase changes of cementitious composites, including the formation of Friedel's/Kuzel's salts, magnesium hydroxide, and magnesium silicate hydrate, etc. The addition of 30 wt.% GGBFS and 1.0 wt.% glass fibers was also supposed to improve cementitious the fire resistance of cementitious composite with seawater and undesalted sea sand. Additionally, the cementitious composite with 30 wt.% GGBFS and 1.0 wt.% NS having the highest value of chloride-binding ratio was expected to enhance the long-term chloride-binding capacity.

Overall, this thesis improves the current understanding of the performance of low-carbon cementitious composites under aggressive environmental environments to produce more reliable data and ensure the reliability and sustainability of LCC-based construction.