

INFLUENCE OF CARBONATION ON MOISTURE TRANSPORT PROPERTIES OF CONCRETE TREATED WITH WATERPROOFING CHEMICALS

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PROPERTIES OF CONCRETE TREATED WITH
WATERPROOFING CHEMICALS

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Certificate

This is to certify that the thesis entitled “INFLUENCE OF CARBONATION ON MOISTURE TRANSPORT PROPERTIES OF CONCRETE TREATED WITH WATERPROOFING CHEMICALS”, being submitted by Mr. Lav Singh, to the Indian Institute of Technology Delhi, for the award of the degree of ‘Doctor of Philosophy’ in Department of Civil Engineering is a record of the bonafide research work carried out by him under my supervision and guidance. He has fulfilled the requirements for submission of this thesis, which to the best of our knowledge has reached the requisite standard.

The material contained in the thesis has not been submitted in part or full to any other University or Institute for the award of any other degree or diploma.

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Abstract

The imperative need for the adoption of low-clinker cements, driven primarily by the need to reduce CO₂ emissions from cement production, is accompanied by enormous durability challenges. Foremost among these challenges is corrosion of reinforcement, which is widely recognized as the most common form of deterioration of reinforced concrete structures. While chloride ingress remains the most common cause of corrosion, environmental carbon dioxide (CO₂) ingress, which leads to a process known as carbonation, is also a significant contributor. The alkaline environment created by cement is neutralized by this carbonation process. However, the carbonation of low-clinker cements, which release less CO₂ due to their raw material composition, has special characteristics. These cements have a lower ability to bind CO₂, allowing it to penetrate deeper into the concrete and lower the pH, reducing the protection of the steel reinforcement and initiating the corrosion process.

However, accelerated carbonation of concrete does not necessarily lead to a faster corrosion of reinforcement. This phenomenon depends on factors such as moisture and oxygen availability in the environment of the reinforcement. Blended cements, including those with reduced clinker content, exhibit slower moisture transport, which likely slows the rate of reinforcement corrosion. However, with carbonation, the transport rate increases significantly, making the reinforcement susceptible to accelerated corrosion and consequently shortening the service life of the structures.

This study attempts to explore some of the possible strategies to contain moisture penetration into carbonated concrete, thereby reducing the corrosion rate in low clinker cements that have inherently higher carbonation rates. The effect of these strategies on gas transport will also be investigated to determine the impact on oxygen availability in the vicinity of the reinforcement.

The research compares various blended cements categorised by their clinker content with ordinary Portland cement (OPC). Two of these cements are conventional cements with fly ash (PPC) and slag (PSC), while the others use combinations of fly ash and slag (composite cement) and a of limestone and calcined clay (LC³). Various transport properties such as air permeability, sorption characteristics, water permeability, and permeable porosity are studied using standardized tests on mortars before and after carbonation, with and without the application of waterproofing agents. These waterproofing agents, categorized as crystalline and hydrophobic, are extensively studied by incorporation into the mortar mix and surface

application on the specimens. The results provide insights into the mechanisms controlling the transport processes within the microstructure. It is found that the microstructure is affected by both the carbonation process and the presence of waterproofing compounds. However, it was observed that gas transport behaves differently than moisture transport.

In agreement with previous literature, it is observed that blended cements, especially those with a lower clinker content, carbonate faster, which is associated with increased moisture and gas transport. The application of waterproofing chemicals was found to affect transport properties to varying degrees, depending on factors such as the type of compound, application method, and cement type. While most of these compounds do not attenuate the rate of carbonation in the specimens, they significantly affect the transport properties. Hydrophobic chemicals lead to a more significant reduction in transport rates compared to crystalline compounds, especially in carbonated specimens.

In summary, this study highlights the potential of these waterproofing compounds as a relatively simple method of reducing moisture transport in carbonated concretes composed of low-clinker cements. This reduction in moisture transport can effectively match or exceed the rates observed in concretes made with OPC and promises comparable or longer service life for structures built with these sustainable, low-clinker cements. Upon the application of certain types of waterproofing compounds, moisture transport in blended cement mortars can be reduced to the similar on course levels as OPC mortars. These techniques promise to increase the service life of reinforced concrete structure built using blended cements.

सार

कम-क्लिंगर सीमेंट को अपनाने की अनिवार्य आवश्यकता, जो मुख्य रूप से सीमेंट उत्पादन से CO_2 उत्सर्जन को कम करने की आवश्यकता से प्रेरित है, के साथ-साथ भारी स्थायित्व चुनौतियां भी हैं। इन चुनौतियों में सबसे प्रमुख है सुदृढीकरण का क्षरण, जिसे व्यापक रूप से प्रबलित कंक्रीट संरचनाओं की गिरावट का सबसे आम रूप माना जाता है। जबकि क्लोराइड घुसपैठ संक्षारण का सबसे आम कारण बनी हुई है, पर्यावरणीय कार्बन डाइऑक्साइड (CO_2) घुसपैठ, जो कार्बोनेशन के रूप में जानी जाने वाली प्रक्रिया की ओर ले जाती है, भी एक महत्वपूर्ण योगदानकर्ता है। सीमेंट द्वारा निर्मित क्षारीय वातावरण इस कार्बोनेशन प्रक्रिया द्वारा निष्प्रभावी हो जाता है। हालाँकि, कम-क्लिंगर सीमेंट के कार्बोनेशन में, जो अपने कच्चे माल की संरचना के कारण कम CO_2 छोड़ते हैं, विशेष विशेषताएं हैं। इन सीमेंटों में CO_2 को बांधने की क्षमता कम होती है, जिससे यह कंक्रीट में अधिक गहराई तक प्रवेश कर पाता है और pH कम कर देता है, जिससे स्टील सुदृढीकरण की सुरक्षा कम हो जाती है और संक्षारण प्रक्रिया शुरू हो जाती है।

हालाँकि, कंक्रीट के त्वरित कार्बोनेशन से सुदृढीकरण का तेजी से क्षरण नहीं होता है। यह घटना सुदृढीकरण के वातावरण में नमी और ऑक्सीजन की उपलब्धता जैसे कारकों पर निर्भर करती है। मिश्रित सीमेंट, जिनमें कम क्लिंगर सामग्री शामिल है, धीमी नमी परिवहन प्रदर्शित करते हैं, जो संभवतः सुदृढीकरण क्षरण की दर को धीमा कर देता है। हालाँकि, कार्बोनेशन के साथ, परिवहन दर काफी बढ़ जाती है, जिससे सुदृढीकरण त्वरित जंग के प्रति संवेदनशील हो जाता है और परिणामस्वरूप संरचनाओं का सेवा जीवन छोटा हो जाता है।

यह अध्ययन कार्बोनेटेड कंक्रीट में नमी के प्रवेश को रोकने के लिए संभावित रणनीतियों का पता लगाने का प्रयास करता है और इस प्रकार स्वाभाविक रूप से उच्च कार्बोनेशन दर के साथ कम क्लिंगर सीमेंट में संक्षारण दर को कम करता है। सुदृढीकरण के आसपास ऑक्सीजन की उपलब्धता पर प्रभाव निर्धारित करने के लिए गैस परिवहन पर इन रणनीतियों के प्रभाव की भी जांच की जाएगी।

शोध में विभिन्न मिश्रित सीमेंटों की तुलना साधारण पोर्टलैंड सीमेंट (OPC) से की गई है, जो कि उनके क्लिंगर सामग्री की विशेषता है। इनमें से दो सीमेंट फ्लाई ऐश (PPC) और स्लैग (PSC) वाले पारंपरिक सीमेंट हैं, जबकि अन्य फ्लाई ऐश और स्लैग (मिश्रित सीमेंट) के मिश्रण और चूना पत्थर और कैल्क्लाइंड मिट्टी (LC^3) के संयोजन का उपयोग करते हैं। जलरोधी एजेंटों के आवेदन के साथ और बिना कार्बोनेशन से पहले और बाद में मोर्टार पर मानकीकृत परीक्षणों का उपयोग करके वायु पारगम्यता, सोखना विशेषताओं, पारगम्यता और पारगम्य छिद्र जैसे विभिन्न परिवहन गुणों का अध्ययन किया जाता है।

क्रिस्टलीय और हाइड्रोफोबिक के रूप में वर्गीकृत इन वॉटरप्रूफिंग एजेंटों का मोर्टार मिश्रण में शामिल करके और नमूनों पर सतह पर आवेदन करके बड़े पैमाने पर अध्ययन किया जाता है।

पिछले साहित्य के साथ सहमति में, यह देखा गया है कि मिश्रित सीमेंट, विशेष रूप से कम क्लिंकर सामग्री वाले, तेजी से कार्बोनेट होते हैं, जो बढ़ी हुई नमी और गैस परिवहन से जुड़ा होता है। यह पाया गया है कि वॉटरप्रूफिंग रसायनों का उपयोग परिवहन गुणों को अलग-अलग डिग्री तक प्रभावित करता है, जो कि यौगिक के प्रकार, अनुप्रयोग विधि और सीमेंट के प्रकार जैसे कारकों पर निर्भर करता है। हालाँकि इनमें से अधिकांश यौगिक नमूनों में कार्बोनेशन की दर को कम नहीं करते हैं, लेकिन वे परिवहन गुणों को महत्वपूर्ण रूप से प्रभावित करते हैं। हाइड्रोफोबिक रसायन, विशेष रूप से कार्बोनेटेड नमूनों में, क्रिस्टलीय यौगिकों की तुलना में परिवहन दरों में अधिक महत्वपूर्ण कमी लाते हैं।

संक्षेप में, यह अध्ययन कम-क्लिंकर सीमेंट से बने कार्बोनेटेड कंक्रीट में नमी परिवहन को कम करने की अपेक्षाकृत सरल विधि के रूप में इन वॉटरप्रूफिंग यौगिकों की क्षमता पर प्रकाश डालता है। नमी परिवहन में यह कमी ओपीसी से बने कंक्रीट में देखी गई दरों से प्रभावी रूप से मेल खा सकती है या उससे अधिक हो सकती है और इन टिकाऊ, कम-क्लिंकर सीमेंट से निर्मित संरचनाओं के लिए तुलनीय या लंबी सेवा जीवन का वादा करती है।

Table of Content

Certificate.....	i
Acknowledgment	ii
Abstract	iii
सारा.....	v
Table of Content	vii
List of Figures	xi
List of Tables	xviii
Chapter 1: Introduction	1
1.1 Background & Context.....	1
1.2 Thesis Objectives.....	3
1.3 Thesis Organization	4
Chapter 2: Literature Review.....	5
2.1 OPC – Primary hydration mechanism, products	5
2.2 Blended Cement – Secondary hydration mechanism, products	6
2.3 Carbonation – Reaction Mechanism, Products.....	8
2.4 Factors Affecting Carbonation	9
2.5 Need for protective measures against carbonation	10
2.6 Waterproofing Techniques and Chemicals.....	11
2.7 Brief Literature on Waterproofing Techniques and Chemicals.....	14
2.7.1 Introduction and mechanism to waterproofing techniques.....	14
2.8 Research Gap	17
Chapter 3: Material & Methods	19
3.1 Introduction	19
3.2 Raw Materials.....	19
3.2.1 Cement	19

3.2.2 Fly Ash	19
3.2.3 Ground Granulated Blast Furnace Slag (GGBS)	20
3.2.4 Limestone Calcined Clay (LC ²)	20
3.2.5 Indian Standard sand	20
3.3 Characterization of Raw Materials	21
3.3.1 Physical Properties	21
3.3.2 Chemical Composition	24
3.3.3 Mineralogical composition	26
3.4 Protective Techniques & Waterproofing Methods	30
3.4.1 Integral Waterproofing Admixture – IWA	31
3.4.2 Cementitious Surface Coating – SC	32
3.4.3 Hydrophobic Impregnation – HI	33
3.5 Blend Design, Specimens, Experimental Parameters and Variables	34
3.6 Sample Preparation	36
3.7 Experimental Test Methods	37
3.7.1 Sorptivity Test	37
3.7.2 Boiling Water Test	39
3.7.3 Oxygen Permeability Test	40
3.7.4 Water permeability Test	44
3.8 Accelerated Carbonation Process	44
3.9 Experimental Methodology	45
Chapter 4: Influence of various SCMs on transport properties in low clinker cement	46
4.1 Introduction	46
4.2 Influence of SCMs on sorption characteristics in blended cements	47
4.3 Influence of SCMs on permeable porosity in blended cements	50
4.3 Influence of SCMs on air permeability in blended cements	56
4.4 Influence on water permeation in LCC	56

4.5 Inferences.....	57
Chapter 5: Sensitivity of transport properties in low clinker cements to carbonation process	58
5.1 Introduction	58
5.2 Effect of carbonation on sorption characteristics in blended cement	60
5.3 Effect of carbonation on permeable porosity	65
5.4 Effect of carbonation on air permeability	66
5.5 Depth of Carbonation	70
5.6 Interpretation and summary	73
Chapter 6: Influence of application of waterproofing chemicals on transport properties of low clinker cements	75
6.1 Introduction	75
6.2 Influence of Integral admixtures on sorption characteristics.....	78
6.3 Influence of integral admixtures on porosity.....	85
6.4 Influence of integral admixtures on air permeability	87
6.5 Influence of integral admixtures on water permeation	89
6.6 Influence of surface coating on sorption characteristics	96
6.7 Influence of surface coating on porosity	100
6.8 Influence of surface coating on air permeability	101
6.9 Influence of hydrophobic impregnation on sorption characteristics	104
6.10 Influence of hydrophobic impregnation on porosity	110
6.11 Influence of hydrophobic impregnation on air permeability	111
6.12 Interpretation and summary	115
Chapter 7: Sensitivity of transport properties in low clinker cements treated with waterproofing chemicals upon carbonation process.	117
7.1 Introduction	117
7.2 Influence of Integral admixtures on sorption characteristics.....	119
7.3 Influence of integral admixtures on porosity.....	144
7.4 Influence of integral admixtures on air permeability	145

7.5 Influence of integral admixtures on carbonation depth	147
7.6 Influence of surface coating on sorption characteristics	150
7.7 Influence of surface coating on porosity	162
7.8 Influence of surface coating on air permeability	162
7.9 Influence of surface coating on carbonation depth.....	162
7.10 Influence of hydrophobic impregnation on sorption characteristics	166
7.11 Influence of hydrophobic impregnation on porosity	180
7.12 Influence of hydrophobic impregnation on air permeability	180
7.13 Influence of hydrophobic impregnation on carbonation depth	180
7.14 Summary.....	183
Chapter 8: Discussion of Results	185
8.1 Carbonation of blended cements	185
8.2 Relationship between transport properties before carbonation	188
8.3 Efficacy of waterproofing techniques	191
8.4 Relationship between transport properties after carbonation	194
8.5 Summary.....	198
Chapter 9: Summary and Conclusions.....	200
9.1 Summary.....	200
9.2 Conclusions	200
9.3 Subjects for further study	202
Annexures	203
References.....	216
List of Publications	227
Curriculum Vitae.....	229

List of Figures

Figure 1-1 Research cycle of carbonation and corrosion issue in time ¹⁷	2
Figure 2-1: Scheme of factors affecting the carbonation process ⁵⁵	9
Figure 2-2: Probable durability indicators for different deterioration processes Carbonation-induced Corrosion. ⁵⁶	10
Figure 2-3: Types of Waterproofing Methods. ⁶⁴	12
Figure 2-4: Schematic representation of the different types of surface treatment of concrete. ^{20,62}	12
Figure 2-5: Taxonomy / classification of techniques for protection against ingress. Adapted and organised based on various literature. ^{20,29–31,42,57,59,60,62,64–67}	13
Figure 2-6 General Mechanisms for hydrolysis and polymerization of silane in cement-based materials.	15
Figure 2-7 Reaction on concrete surface treated with a typical silane group. ²⁰	16
Figure 2-8 Hydrophobic effect created by silane treatment.....	16
Figure 2-9 Water absorption in surface impregnated and untreated concrete at different time of water absorption. ⁸⁰	17
Figure 3-1 Particle size distribution of raw materials	23
Figure 3-2: X-ray diffractograms of raw materials with major peaks identified.	29
Figure 3-3 Schematics of the experimental setup for the sorptivity test according to ASTM C1585-2013.....	38
Figure 3-4 Schematic of the oxygen permeability setup, along with compressible collar (All dimensions in mm) ^{107,108}	42
Figure 3-5 Systematic representation of the research methodology	45
Figure 4-1 Comparison of individual TPs for control specimens at 0.4 vs 0.5 w/b ratio.	49
Figure 4-2 Comparison of Transport Properties (TPs) for control specimens at 0.4 and 0.5 w/b.....	50
Figure 4-3 Correlation of TPs of control specimens based on normalised [A] value for 0.4 vs 0.5 w/b ratio.	53
Figure 4-4 Experimental results for different transport properties at 0.4 w/b ratio.	54
Figure 4-5 Experimental results for different transport properties at 0.5 w/b ratio.	55
Figure 5-1 Comparison of individual transport properties for control specimens NC vs C at 0.4 w/b ratio	61

Figure 5-2 Comparison of individual transport properties for control specimens NC vs C at 0.5 w/b ratio	65
Figure 5-3 Influence of water-cement ratio in carbonated control specimens.....	68
Figure 5-4 Influence of carbonation on transport properties for blended cements.....	69
Figure 5-5 Sensitivity analysis [C_{values}] for all transport properties of various blends substituted with varied percentage of mineral additives SCMs at 0.4 <i>Left {A}</i> and 0.5 <i>Right{B}</i> w/b ratios.	70
Figure 6-1: Comparative plots based on normalized D-value with transport properties and Cement types - Control vs. IWA 1-5 at 0.4 w/b ratio.	80
Figure 6-2: Comparative plots based on normalized D-value with transport properties and Cement types - Control vs. IWA 1-5 at 0.5 w/b ratio.	81
Figure 6-3: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment IWA 1	91
Figure 6-4: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment IWA 2.....	92
Figure 6-5: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment IWA 3.....	93
Figure 6-6: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment IWA 4.....	94
Figure 6-7: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment IWA 5.....	95
Figure 6-8: Comparative plots based on normalized D-value with transport properties and Cement types - Control vs. SC 1-3 at 0.4 w/b ratio.	98
Figure 6-9: Comparative plots based on normalized D-value with transport properties and Cement types - Control vs. SC 1-3 at 0.5 w/b ratio.	99
Figure 6-10: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment SC 1	102
Figure 6-11: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment SC 2.....	103
Figure 6-12: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment SC 3.....	104
Figure 6-13: Comparative plots based on normalized D-value with transport properties and Cement types - Control vs. HI 1-4 at 0.4 w/b ratio.....	107

Figure 6-14: Comparative plots based on normalized D-value with transport properties and Cement types - Control vs. HI 1-4 at 0.5 w/b ratio.....	108
Figure 6-15: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment HI 1.....	112
Figure 6-16: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment HI 2.....	113
Figure 6-17: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment HI 3.....	114
Figure 6-18: Comparative plots based on normalized D-value with individual transport properties at 0.4 vs. 0.5 w/b ratios – Treatment HI 4.....	115
Figure 7.1: Comparison of integral WP admixtures for all transport properties using normalized E-values at 0.4 w/b ratio	121
Figure 7.2: Comparison of integral WP admixtures for all transport properties using normalized E-values at 0.5 w/b ratio	122
Figure 7.3: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for crystalline IWA1 admixture.	123
Figure 7.4: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for crystalline IWA2 admixture.	124
Figure 7.5: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for crystalline IWA4 admixture.	125
Figure 7.6: Comparison of integral WP admixtures for all transport properties using normalized F-values at 0.4 w/b ratio.....	126
Figure 7.7: Comparison of integral WP admixtures for all transport properties using normalized F-values at 0.5 w/b ratio.....	127
Figure 7.8: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for crystalline IWA1 admixture.	128
Figure 7.9: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for crystalline IWA2 admixture.	129
Figure 7.10: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for crystalline IWA4 admixture.	130
Figure 7.11: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for hydrophobic IWA3 admixture.	135
Figure 7.12: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for hydrophobic IWA5 admixture.	136

Figure 7.13: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for hydrophobic IWA3 admixture.....	137
Figure 7.14: Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for hydrophobic IWA5 admixture.....	138
Figure 7.15: Comparison graph of measured carbonation depth for each cement type and different integral crystalline and hydrophobic admixtures at 0.4 w/b.	148
Figure 7-16: Comparison graph of measured carbonation depth for each cement type and different integral crystalline and hydrophobic admixtures at 0.5 w/b.	149
Figure 7-17 Comparison of surface coating for all transport properties using normalized E-values at 0.4 w/b ratio.	151
Figure 7-18 Comparison of surface coating for all transport properties using normalized E-values at 0.5 w/b ratio.	152
Figure 7-19 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for SC1 cementitious surface coating.	153
Figure 7-20 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for SC2 cementitious surface coating.	154
Figure 7-21 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for SC3 cementitious surface coating.	155
Figure 7-22 Comparison of surface coating for all transport properties using normalized F-values at 0.4 w/b ratio.	157
Figure 7-23 Comparison of surface coating for all transport properties using normalized F-values at 0.5 w/b ratio.	158
Figure 7-24 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for SC1 cementitious surface coating.	159
Figure 7-25 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for SC2 cementitious surface coating.	160
Figure 7-26 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for SC3 cementitious surface coating.	161
Figure 7.27: Comparison graph of measured carbonation depth for each cement type and different cementitious surface coatings at 0.4 w/b.....	164
Figure 7.28: Comparison graph of measured carbonation depth for each cement type and different cementitious surface coatings at 0.5 w/b.....	165
Figure 7.29: Comparison of various hydrophobic impregnation compounds for all transport properties using normalized E-values at 0.4 w/b ratio.....	167

Figure 7.30: Comparison of various hydrophobic impregnation compounds for all transport properties using normalized E-values at 0.5 w/b ratio.....	168
Figure 7-31 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for HI1-hydrophobic impregnation.....	169
Figure 7-32 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for HI2-hydrophobic impregnation.....	170
Figure 7-33 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for HI3-hydrophobic impregnation.....	171
Figure 7-34 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized E-values for HI4-hydrophobic impregnation.....	172
Figure 7-35 Comparison of surface coating for all transport properties using normalized F-values at 0.4 w/b ratio.	174
Figure 7-36 Comparison of surface coating for all transport properties using normalized F-values at 0.5 w/b ratio.	175
Figure 7-37 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for HI1-hydrophobic impregnation.	176
Figure 7-38 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for HI2-hydrophobic impregnation.	177
Figure 7-39 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for HI3-hydrophobic impregnation.	178
Figure 7-40 Comparison between 0.4 & 0.5 w/b ratio for all transport properties using normalized F-values for HI4-hydrophobic impregnation.	179
Figure 7.41: Comparison graph of measured carbonation depth for each cement type and different hydrophobic impregnation coating at 0.4 w/b.....	182
Figure 7.42: Comparison graph of measured carbonation depth for each cement type and different hydrophobic impregnation coating at 0.5 w/b.....	183
Figure 8-1 Plot showing the relationship in terms of variation of carbonation coefficient with diffusion coefficient and reserve alkalinity using equation 8-1.....	186
Figure 8-2 The plot demonstrates the relationship of the calculated carbonation coefficient based on diffusion coefficient using OPT values after carbonation	187
Figure 8-4 The plot shows a comparison between water and gas transport rates under pressure in various mortars specimens.....	189
Figure 8-5 A comparison between the rates of water permeation under pressure and capillary water sorption in all mortar samples at different w/b ratio.	190

Figure 8-5 A comparison between the rates of water permeation under pressure and capillary water sorption in carbonated mortar samples at different w/b ratio.	191
Figure 8-7 A comparative plot of various datasets showing reduction in water and gas transport rates under pressure with reduced permeable pore volume post carbonation	192
Figure 8-8 Shows a comparison plot between reduced initial sorption and permeable pore volume of mortar samples treated with integral crystalline waterproofing chemical - IWA4	193
Figure 8-9 Shows a comparison plot between reduced initial sorption and permeable pore volume of mortar sample treated with integral hydrophobic chemical – [IWA5].....	194
Figure 8-10 The plot shows the variation between initial sorption and gas permeability in all control mortar samples after carbonation.	195
Figure 8-11 The plot shows the increase in rate of gas permeability after carbonation for mortar samples both treated integrally with two different waterproofing chemicals – integral crystalline [IWA4] and integral hydrophobic admixture [IWA5].	196
Figure 8-12 The plot shows the decrease in rate of water sorption after carbonation for mortar samples both treated integrally with two different waterproofing chemicals – integral crystalline [IWA4] and integral hydrophobic admixture [IWA5].	197
Figure 8-13 The plot shows the decrease in rate of water sorption after carbonation for mortar samples treated with same chemical but with different Techniques – hydrophobic impregnation [HI4] and integral hydrophobic admixture [IWA5].	198
Annex 6-1: Experimental results bar charts for all transport properties - Control vs. IWA [1 to 5] at 0.4 w/b ratio – non-carbonated.	204
Annex 6-2: Experimental results bar charts for all transport properties - Control vs. IWA [1 to 5] at 0.5 w/b ratio – non-carbonated.	205
Annex 6-3: Experimental results bar charts for all transport properties - Control vs. SC [1 to 3] at 0.4 w/b ratio – non-carbonated.	206
Annex 6-4: Experimental results bar charts for all transport properties - Control vs. SC [1 to 3] at 0.5 w/b ratio – non-carbonated.	207
Annex 6-5: Experimental results bar charts for all transport properties - Control vs. HI [1 to 4] at 0.4 w/b ratio – non-carbonated.	208
Annex 6-6: Experimental results bar charts for all transport properties - Control vs. HI [1 to 4] at 0.5 w/b ratio – non-carbonated.	209
Annex 7-1: Experimental results bar charts for all transport properties - Control vs. IWA [1 to 5] at 0.4 w/b ratio – Carbonated.....	210

Annex 7-2: Experimental results bar charts for all transport properties - Control vs. IWA [1 to 5] at 0.5 w/b ratio – Carbonated.....	211
Annex 7-3: Experimental results bar charts for all transport properties - Control vs. SC [1 to 3] at 0.4 w/b ratio – Carbonated.....	212
Annex 7-4: Experimental results bar charts for all transport properties - Control vs. SC [1 to 3] at 0.5 w/b ratio – Carbonated.....	213
Annex 7-5: Experimental results bar charts for all transport properties - Control vs. HI [1 to 4] at 0.4 w/b ratio – Carbonated.....	214
Annex 7-6: Experimental results bar charts for all transport properties - Control vs. HI [1 to 4] at 0.5 w/b ratio – Carbonated.....	215

List of Tables

Table 2-1: Densities of the phases that take part in SCMs reaction. ³⁸	7
Table 3-1 Specific gravity of raw materials.....	22
Table 3-2 Experimental parameters for particle size analysis	22
Table 3-3 Summary of Particle size analysis - results	23
Table 3-4 Physical testing results of OPC-43 compared with IS guidelines.	24
Table 3-5 Result of XRF-based chemical composition of raw materials (% weight) normalised with respective LOI.....	25
Table 3-6 Reactivity indices with equation and literature recommendation for GGBFS (slag)	26
Table 3-7 Result summary of lime reactivity test for different SCMs	26
Table 3-8 Phase composition and amorphous content of OPC and various pozzolans in weight percentage	28
Table 3-9 Amorphous silica and alumina (% weight)	29
Table 3-10 List of various IWAs with brief descriptions and dosage	32
Table 3-11 List of surface coating chemicals showing the description and mixing ratio.....	33
Table 3-12 Description of chemicals used for hydrophobic impregnation.....	34
Table 3-13 Blend Design – Details of constituents % replacement, notation, and clinker factor	34
Table 3-14 Experimental parameters and variables for the research	35
Table 3-15 List of equations for calculation of permeable pore space in the concrete according to ASTM C 642-13.....	40
Table 8-1: Calculated values of reserve alkalinity for various cement blends at two w/b ratios.	185