

1	INTRODUCTION	15
1.1	THE INNOVATION CENTER ICELAND (ICI) AND ICI RHEOCENTER	15
1.2	THE PROJECT	15
1.3	INTRODUCTION TO RHEOLOGY	17
1.3.1	<i>Background and basic terms</i>	17
1.3.2	<i>Fluid types</i>	18
1.3.3	<i>Rheology of fresh concrete and mortar</i>	19
1.4	PREREQUISITES AND LIMITATIONS OF STUDY	21
1.5	REPORT STRUCTURE	21
2.	LITERATURE SURVEY	23
2.1	PURPOSE OF LITERATURE SURVEY	23
2.2	PORTLAND CEMENT	23
2.2.1	<i>Composition of Portland cement</i>	23
2.2.2	<i>Hydration reaction of Portland cement</i>	24
2.2.3	<i>Role of sulfates in cement</i>	33
2.2.4	<i>Role of alkalies in cement</i>	36
2.2.5	<i>Organic compounds used during cement production</i>	37
2.2.6	<i>Effect of chemical admixture on hydration</i>	38
2.3	DISPERSING MECHANISMS IN CEMENTITIOUS SYSTEMS	39
2.3.1	<i>Colloidal particles</i>	39
2.3.2	<i>Electrostatic stabilisation</i>	40
2.3.3	<i>Steric hindrance</i>	41
2.3.4	<i>Adsorption of polymers on cement surface</i>	42
2.4	INTERACTION BETWEEN CEMENT AND ADMIXTURE	43
2.5	CEMENT AND ADMIXTURE CHARACTERISTICS INFLUENCING RHEOLOGY	46
2.6	BRIEF SUMMARY OF LITERATURE SURVEY	47
3.	EXPERIMENTAL	49
3.1	OBJECTIVE AND SCOPE OF RESEARCH	49
3.2	RESEARCH PROGRAM	49
3.3	TEST METHODS	50
3.3.1	<i>ConTec Rheomixer</i>	50
3.3.1.1	<i>Generals about Rheomixer</i>	50
3.3.1.2	<i>Signal logging of Rheomixer</i>	53
3.3.2	<i>Flow calculation for the ConTec Rheomixer</i>	53
3.3.2.1	<i>Background</i>	53
3.3.2.2	<i>The geometry of the ConTec Rheomixer</i>	53
3.3.2.3	<i>Velocity profile</i>	54
3.3.2.4	<i>Torque and shear stress</i>	55
3.3.2.5	<i>Necessary simplifications and assumptions</i>	57
3.3.2.6	<i>The total torque</i>	58
3.3.2.7	<i>Torque as measured by the Rheomixer</i>	58
3.3.2.8	<i>Retrieving the fundamental physical quantities</i>	59
3.3.3	<i>ConTec Viscometer 6</i>	61
3.3.4	<i>ConTec Viscometer 5</i>	62
3.3.5	<i>ConTec Rheometer-4SCC</i>	63
3.3.6	<i>Semi-adiabatic calorimeter</i>	65
3.3.7	<i>Isothermal calorimeter</i>	66
3.3.8	<i>Sympatec HELOS-system for particle size analysis</i>	67

CONTENTS

3.4	MATERIALS	68
3.4.1	<i>Standardized sand according to EN 196-1</i>	68
3.4.2	<i>Cement</i>	69
3.4.3	<i>Water</i>	69
3.4.4	<i>Admixtures</i>	69
3.5	MIX DESIGN OF MORTAR MIXES	71
3.6	MIX DESIGN OF CONCRETE MIXES	71
4.	RESULTS	73
4.1	COUNTRY A.....	73
4.2	COUNTRY B.....	73
4.3	COUNTRY C.....	74
4.4	COUNTRY D.....	76
5.	DISCUSSION	77
5.1	PRELIMINARY INVESTIGATIONS	77
5.1.1	<i>Effect of fluctuations in sieve curve of EN sand on rheology</i>	77
5.1.2	<i>Effect of aging of cement samples on rheology</i>	78
5.1.3	<i>Standard tests versus Rheomixer</i>	80
5.1.4	<i>Isothermal calorimeter versus semi-adiabatic calorimeter</i>	82
5.1.5	<i>Determination of reference system</i>	83
5.1.6	<i>Flow curves obtained by use of Rheomixer and Viscometer 6</i>	85
5.1.7	<i>Performance and characteristics of admixtures used</i>	86
5.1.8	<i>Mortar mini slump versus mortar rheology</i>	88
5.2	MAIN OBJECTIVE	89
5.2.1	<i>Cement production date</i>	89
5.2.1.1	Effect of cement production date on rheology of mortar	89
5.2.1.2	The interval between sampling and its effect on rheology.....	92
5.2.1.3	Repeatability of results in mortar	93
5.2.1.4	Different cement production dates in concrete	95
5.2.1.5	Effect of cement production date on hydration process	99
5.2.1.6	Microstructural investigations on cement by use of ESEM Weimar	101
5.2.1.7	Microstructural investigations on cement by use of SEM Reykjavik	103
5.2.1.8	Hydration process of cements having different rheological properties.....	106
5.2.1.9	Effect of polymer structure on fluctuations in rheology.....	110
5.2.1.10	Total organic carbon (TOC) of cement	112
5.2.2	<i>Granulometry</i>	113
5.2.2.1	Effect of specific surface and particle size distribution.....	113
5.2.2.2	Dynamic particle size distribution during first hour of hydration.....	115
5.2.3	<i>Aluminate phase</i>	118
5.2.3.1	Effect of aluminate phase (modified Taylor-Bogue) on rheology	118
5.2.3.2	Effect of C ₃ A addition on rheology.....	119
5.2.3.3	Mineralogical composition obtained by QXRD (Rietveld).....	120
5.2.4	<i>Alkalies</i>	121
5.2.4.1	Effect of Na ₂ O equivalent of reference cement on rheology.....	121
5.2.4.2	Effect of sodium and potassium hydroxide on rheology	122
5.2.4.3	Effect of sodium and potassium hydroxide on hydration process	127
5.2.5	<i>Sulphates</i>	128
5.2.5.1	Sulphates and their influence on rheology.....	128
5.2.5.2	How various calcium sulphate carriers affect rheology	131
5.2.6	<i>Pore solution analysis on cements differing in rheological properties</i>	134
5.2.7	<i>Adsorption measurements</i>	137

CONTENTS

5.2.8	<i>Grinding aid</i>	138
5.2.8.1	Various grinding aids and their influence on rheology	138
5.2.8.2	Effect of various grinding aids on hydration process.....	140
5.2.8.3	Microstructure of pastes blended with grinding aid.....	141
5.2.9	<i>Brief summary of parameters investigated and how they influence yield stress</i>	146
5.2.10	<i>Some hypothesis</i>	148
6.	<i>FINAL REMARKS</i>	149
	LITERATURE	151
	APPENDIX	163