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DEVELOPMENT OF ULTRA HIGH STRENGTH CONCRETE BASED ON LOCALLY AVAILABLE MATERIALS AND FLY ASH

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DEVELOPMENT OF ULTRA HIGH STRENGTH CONCRETE BASED ON LOCALLY AVAILABLE MATERIALS AND FLY ASH

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This project is submitted in partial fulfillment of
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To my beloved family and friends

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ABSTRACT

Ultra High Strength Concrete (UHSC) is a concrete with a very high strength, high durability, large elastic modulus and very densed structure. It is widely used in construction of skyscrapers such as Petronas Twin Tower, Shawnessy Light Rail Transit (LRT) Station and Seonyu footbridge. The concrete with very high strength has low water binder ratio, high cement content mixed with chemical product such as fly ash, optimum aggregates size and addition of superplasticizer. This thesis presents the results of an experimental study on the ultra high strength concrete using local available materials. This study focuses on the fresh and hardened properties of concrete which are slump, flow, compressive strength and flexural tensile strength of the concrete containing different percentages of fly ash, water binder ratio and superplasticizer dosage. The properties of aggregates, cement and fly ash were also determined. The cement was replaced with 0%, 15%, 20% and 25% of fly ash. The hardened concrete properties were tested at the ages of 28 and 56 days. Results show that the workability, compressive strength and flexural tensile strength increase with the increase in percentage of replacement of fly ash for the concrete. The concrete with water binder ratio of 0.24, 20% of fly ash replacement and 3% superplasticizer has highest compressive and flexural tensile strength at 56 days, which are 114.5 MPa and 13.30 MPa respectively.

ABSTRAK

Kekuatan Konkrit Ultra Tinggi (UHSC) adalah konkrit dengan kekuatan yang sangat tinggi, ketelapan tinggi, modulus elastic yang besar dan struktur yang padat. Ia banyak digunakan dalam pembinaan bangunan pencakar langit seperti Petronas Twin Tower, Light Rail Transit (LRT) Stesen, Shawnessy dan jambatan di Seonyu. Konkrit dengan kekuatan yang sangat tinggi mempunyai nisbah pengikat air yang rendah, kandungan simen bercampur dengan produk kimia seperti fly ash yang tinggi, saiz agregat optimum dan penambahan superpemplastikan. Tesis ini mengajikan hasil kajian eksperimental tentang UHSC dengan menggunakan bahan-bahan yang sedia tempatan. Kajian ini akan focus tentang ciri-ciri basah dan keras konkrit dengan seperti kemerosotan, aliran, kekuatan mampatan dan kekuatan lenturan yang mengadungi peratusan fly ash, nisbah simen-air dan dosis superpemplastikan yang berbeza. Ciri-ciri agregat, simen dan fly ash juga akan dilakukan. Simen digantikan dengan 0%, 15%, 20% dan 25% of fly ash. Tempoh ujian akan dijalankan untuk hari ke-28 dan 56 ke dalam tempoh pengawetan. Keputusan experiment menunjukkan bahawa kebolehkerjaan, kekuatan mampatan dan kekuatan lenturan dengan peningkatan peratusan penggantian fly ash dalam konkrit. Air binder nisbah 0.24 dan 20% fly ash pengganti mempunyai kekuatan mampatan dan kekuatan lenturan yang tertinggi dalam 56 hari, iaitu 114.5 MPa dan 13.30 MPa.

CONTENTS

		PAGE
DEDICATION		i
ACKNOWLEDGEMENTS		ii
ABSTRACT		iii
ABSTRAK		iv
CONTENTS		v
LIST OF TABLES		ix
LIST OF FIGURES		xi
LIST OF ABBREVIATIONS AND NOTATIONS		xiii
CHAPTER 1	**INTRODUCTION**	
	1.1 General	1
	1.2 Aim and objectives	3
	1.3 Problem statement	4
	1.4 Scope of work	5
	1.5 Thesis organization	5
CHAPTER 2	**LITERATURE REVIEW**	
	2.1 General	7
	2.2 Factor affecting properties of UHSC	10
	2.2.1 Fly ash	10
	2.2.2 Water reducing admixture	12
	2.2.3 Water binder ratio	15

2.2.4 Portland cement 18

2.2.5 Coarse aggregate 20

2.3 Mix proportion 23

2.3.1 Material used 23

2.3.2 Concrete mixtures 25

2.3.3 Properties of UHSC 26

2.4 Sequence of mixing 28

2.5 Summary 29

CHAPTER 3 METHODOLOGY

3.1 General 30

3.2 Material used 31

3.2.1 Fly ash 32

3.2.2 Superplasticizer 33

3.2.3 Portland cement 33

3.2.4 Other materials 34

3.3 Material properties test 34

3.3.1 Test for coarse aggregate 35

3.3.1.1 Sieve analysis 36

3.3.1.2 Specific gravity and absorption test 37

3.3.2 Test for fine aggregate 38

3.3.2.1 Sieve analysis 38

3.3.2.2 Specific gravity and water absorption test 39

3.3.3 Test for fly ash 40

3.4 Mix design 41

3.4.1 Mixing procedure 43

3.4.2 Casting 44

3.4.3 Curing 45

3.5 Concrete testing 46

3.5.1 Properties of fresh concrete 46

3.5.1.1 Flow test 46

3.5.1.2 Slump test 48

3.5.2 Properties of hardened concrete 50

3.5.2.1 Compression test 50

3.5.2.2 Flexural tensile test 51

3.6 Schedule 53

CHAPTER 4 RESULTS, ANALYSIS AND DISCUSSION

4.1 General 54

4.2 Properties of aggregates 54

4.2.1 Sieve Analysis 54

4.2.2 Specific gravity and absorption test 59

4.3 Properties of fly ash 60

4.4 Mix proportions for UHSC 61

4.5 Properties of fresh concrete 62

4.5.1 Slump test 62

4.5.2 Flow test 64

4.6 Properties of hardened concrete 65

4.6.1 Compression test 65

4.6.2 Flexural tensile test 70

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 General 74

5.2 Conclusions 74

5.3 Recommendations 75

References 77

Appendix 81

LIST OF TABLES

Table		Page
2.1	Properties of fly ash	12
2.2	Approximate range of water reduction effectiveness	13
2.3	Effects of cements on concrete properties	19
2.4	Properties of fresh self-compacting UHSC	21
2.5	Properties of cement and fly ash	24
2.6	Properties of aggregates	25
2.7	Proportioning of concrete mixtures	26
2.8	Compressive strength of the concrete mixes	27
2.9	Porosity of concrete	28
3.1	Aggregates properties test	35
3.2	Proportioning of concrete mixtures	41
3.3	Trial mix	42
4.1	Sieve analysis for coarse aggregate	56
4.2	Sieve analysis for fine aggregate	58
4.3	Specific gravity and water absorption of coarse aggregate	60
4.4	Specific gravity and water absorption of fine aggregate	60
4.5	Specific gravity of fly ash	61
4.6	Mix proportion for UHSC with FA	61

4.7	Slump of concrete specimens	63
4.8	Flow of concrete specimens	64
4.9	Compressive strength of concrete specimens	67
4.10	Flexural strength of concrete specimens	71
4.11	Ratio of flexural strength to compressive strength	71

LIST OF FIGURES

Figure		Page
2.1	Component volume fractions in HSC, SCC, UHSC and RPC	8
2.2	The influence of w/P ratio and P/S on the flowing ability of fresh UHSC	17
2.3	The influence of w/P and Q/P (Q= Crushed quartz*)* on compressive strength	17
2.4	The influence of w/P and Q/P on flexural strength	18
2.5	Effect of type of cement on compressive strength	20
2.6	Autogenous shrinkage of UHSC with and without coarse aggregate	22
2.7	Sequence of mixing	29
3.1	Stages of thesis	31
3.2	Fly ash	32
3.3	Sieving machine	37
3.4	Wire- mesh basket	38
3.5	Apparatus for pycnometer test	40
3.6	Concrete mixer	43
3.7	100mm x 100mm x 100mm cube mould	44
3.8	100mm x 100mm x 500 mm prism mould	45
3.9	Curing tank	46
3.10	Apparatus for flow test	47

3.11	ELE mortar mixer	48
3.12	Slump cone	49
3.13	ELE ADR2000 compression testing machine	51
3.14	Flexural tensile testing machine	52
4.1	Grading curve for coarse aggregate	57
4.2	Grading curve for fine aggregate	59
4.3	Slump test	63
4.4	Flow test	65
4.5	Comparison of compressive strength in different percentage of FA replacement	68
4.6	Comparison of compressive strength in different w/b ratio	68
4.7	Compressive test	69
4.8	Failure pattern of concrete failing below 100 MPa	69
4.9	Failure pattern of concrete failing above 100 MPa	69
4.10	Comparison of flexural strength	72
4.11	Flexural test	72
4.12	Failure pattern of concrete prism	73

LIST OF ABBREVIATIONS

AND NOTATIONS

ABBREVIATIONS	FULL NAME
UHSC	ULTRA HIGH STRENGTH CONCRETE
HSC	HIGH STRENGTH CONCRETE
NSC	NORMAL STRENGTH CONCRETE
SCC	SELF COMPACTING CONCRETE
RPC	REACTIVE POWDER CONCRETE
FA	FLY ASH
SF	SILICA FUME
SP	SUPERPLASTICIZER
CMS	CAHAYA MATA SARAWAK Sdn. Bhd.
w/b ratio	WATER BINDER RATIO

CHAPTER 1

INTRODUCTION

1.1 General

Concrete is generally defined as weak in tension, porous and brittle when compared with steel. However, advancement in cement and concrete science result in the development of new cementitous products that can be made as strong as steel materials. One of the aspects is ultra high strength in concrete leading to a material defined as Ultra High Strength Concrete (UHSC). UHSC is also known as reactive powder concrete (RPC), characterised by a very densed structure, high compressive and tensile strength, high durability and large elastic modulus. Due to these properties, UHSC has been used in the construction of skyscrapers, pedestrian bridges and highway bridges such as Petronas Twin Tower, Shawnessy Light Rail Transit (LRT) Station, Seonyu footbridge and landmark footbridge in Sherbrooke (Aitcin et al, 1998).

Generally, UHSC has compressive strength of 80MPa or higher. Nevertheless, when high cement content mixed with silica fume (SF), fly ash (FA) or blast furnace slag and optimum aggregates size (maximum size of 10mm), low water binder ratio (w/b ratio) and addition of high-range water-reducing admixtures or Superplasticizer

(SP), the compressive strength of UHSC can achieve 200MPa and flexural strength up to 50MPa.

In concrete practice, the strength of concrete is traditionally characterized by the 28 days value and some other properties of concrete are often referred to the 28 days strength (Neville, 2002). However, for UHSC, the late age compressive strength was important because of the effect of the mineral admixture (such as FA). Compressive strength of UHSC became obvious at late ages which are 56 and 90 days.

Mixing FA is also an effective way to increase the strength of the concrete. FA is a pozzolonic material which finely divided mineral residue produced from the combustion of ground or powdered coal in electric generating plant. FA will limit the heat of hydration and useful in filling voids in concrete due to it finer than cement particle. It also will improve the properties of the fresh concrete as well as the hardened concrete. There are two types of FA: Class C and Class F. Class F FA is a low calcium material and usually derived from the burning of anthracite or bituminous coal and Class C FA usually derived from the burning of lignite or sub bituminous coal (ASTM C 618).

Besides, the concrete can achieve high compressive strength by the addition of water reducing admixtures or SP. Water reducing admixtures or SP can be used to alter the attraction forces between the cement particles, enhance the fluidity of cementitous systems, better dispersing the cement particles, and reducing the size of

these voids. While SPs can be used to decrease the water binder ratio, in turn increasing the compressive strength of the concrete.

UHSC generally need to have a low w/b ratio. If natural pozzolans are used in the mix (such as FA) then the ratio becomes a water-cementitious material ratio (cementitious material = Portland cement + pozzolonic material). Lower w/b ratio has lower porosity and higher strength and durability can be obtained, provided proper compaction occurs.

The demand of UHSC is steadily rising in the construction market. The advantages of using this type of concrete are now well established and frequently cited in the literature. High durability and low porosity of UHSC may decrease maintenance cost and a longer service life. If the UHSC is reinforced with fibers, the structural elements may have a high tensile and bending strength and do not generally require reinforcement even when used for construction of bridges and buildings. So, designers can design various shape and size for the structural elements Furthermore, the size of a girder can also be reduced, loading to reduction in dead load approximately 30% to 50% as compared to normal concrete. This property is beneficial to construction of skyscrapers, highly- tensioned bridges and other mega structures.

1.2 Aim and objectives

The main aim of this study is to develop UHSC using locally available materials and FA. The objectives to achieve this aim are as follows:

i. Develop UHSC with compressive strength over 100MPa at concrete age of 56 days.
ii. Determine the optimum design mix for UHSC.
iii. Determine the right sequence of mixing for UHSC.
iv. Determine the properties of fresh UHSC.
v. Determine the properties of harden UHSC.

1.3 Problem statement

Nowadays, construction industry plays an important role in economic development. Clients required their building, skyscrapers, highways and bridges to have long term service life, economical, durable, less maintenance, workable, time saving etc. Therefore, UHSC had been explored in order to produce high quality in construction.

Many researches on UHSC had been developed and investigated (Poon et al., 2000). UHSC does not only produce high strength and durability for the concrete, but it is also economical. One of the results show that the additional chemical product (such as FA) to replace cement and liquid admixture (such as SP) to replace water content may increase the strength of the concrete (Poon et al., 2000).

Therefore, it is important to know how these chemical admixtures may affect the properties of the concrete. This study focuses on the effect of compressive strength in UHSC with the different mix proportion (different percentage of admixture replaced into cement and water content).

1.4 Scope of work

This study is based on laboratory work. Some experimental works were carried out to obtain the required data needed to achieve the objectives of this study. The general scope of this study is mix design. Trial mixes were prepared to get the optimum mix design for UHSC using locally available materials. The additional material were used in this study are Class F FA and SP. Water binder ratio was varied in every mix proportion.

After that, laboratory work was carried out to determine the properties of fresh UHSC. Slump test and flow test were carried out in fresh UHSC. Then, the specimens were cured in water at 24° C until the time they are taken out for testing. The tests for hardened properties of the specimens were conducted at concrete age of 28 and 56 days.

Finally, the laboratory tests results and data obtained were analysed. The conclusion and recommendation were made as the completion of the research.

1.5 Thesis organization

This study was divided into five chapters. Chapter one included the general introduction of UHSC, aim and objectives of this study, problem statement and scope of work. Chapter two described about the literature review of the development UHSC based on locally available materials. For the chapter three, it was described the methodology of producing UHSC. The description of material used, laboratory

work such as mix design or trial mix and types of test for properties of fresh concrete and harden concrete had been carried out in this chapter. Chapter four was the results and data analysis from the laboratory works. All the data or results were analysed in this chapter. From the data or result, some discussion and problem statement were carried out. Finally, chapter five was concluded the development of UHSC and recommendation for future study.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Ultra High Strength Concrete is a new class of concrete that has been developed in recent decade. Ultra High Strength Concrete has superior properties such as advanced strength, workability, durability and long term stability. When compared with the compressive strength with different types of concrete, UHSC have a compressive strength of at least 100MPa, high strength concrete (HSC) with a compressive strength up to 80MPa and normal strength concrete (NSC) with a compressive strength less than 50MPa. Ultra High Strength Concrete also has considerably improved tensile strength and stiffness compared to other concrete types. Different types of concrete have different components. Figure 2.1 shows the component volume fraction in HSC, self compacting concrete (SCC), UHSC and RPC. The composition of UHSC includes Portland cement, cementitious material such as FA, crushed quartz, fine sand, coarse aggregate, SP and water (Skazlic et al., 2006).