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DEVELOPMENT OF ULTRA HIGH STRENGTH CONCRETE BASED ON LOCALLY AVAILABLE MATERIALS AND SILICA FUME

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DEVELOPMENT OF ULTRA HIGH STRENGTH CONCRETE BASED ON LOCALLY AVAILABLE MATERIALS AND SILICA FUME

NG WAN CHI

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

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ABSTRAK

Keputusan- keputusan ujikaji ke atas menghasilkan konkrit berkekuatan sangat tinggi menggunakan bahan-bahan yang sedia tempatan dan silica fume telah ditunjukkan. Bahan-bahan yang telah digunakan untuk menghasilkan adunan konkrit berkekuatan terlampau tinggi ialah silica fume dan superplasticizer sebagai bahan tambahan untuk membantu konkrit mencapai kekuatan yang diperlukan. Simen digantikan dengan 0%, 10%, 15% dan 20% silica fume. Tempoh ujian akan dijalankan untuk hari ke-28 dan 56 ke dalam tempoh pengawetan. Jumlah keseluruhan simen yang telah dipilih ialah 600 kg/m^3 untuk UHSC. Batu kasar yang telah digunakan adalah 14 mm granite hancur dengan jumlah 60% daripada jumlah keseluruhan batu di dalam konkrit. Nisbah air/bahan pengikat yang telah dipilih ialah 0.21. Ujian-ujian kebolehaliran telah dijalankan untuk mengukur tahap kobolehkerjaan dan juga untuk menentukan dos yang sesuai bagi superplasticizer. Ujian-ujian penurunan telah dilakukan untuk melihat keseragaman campuran konkrit, tetapi bukan untuk mengukur tahap kebolehkerjaan konkrit. Akhir sekali, ujian-ujian mampatan untuk konkrit kiub dan ujian-ujian lenturan untuk konkrit rusuk telah dijalankan untuk menentukan kekuatan mampatan konkrit dan kekuatan lenturan. Keputusan-keputusan ujikaji menunjukkan bahawa setiap nisbah campuran yang telah direkabentuk telah mencapai kekuatan yang diperlukan oleh konkrit berkekuatan tinggi melebihi 100 MPa.

ABSTRACT

The results of an experimental study on developing ultra high strength concrete based on locally available materials and silica fume are presented. Materials used to form ultra high strength concrete mixture were silica fume and superplasticizer as admixture to help the concrete gain the strength needed. The cement was replaced with 0%, 10%, 15% and 20% of silica fume. The hardened concrete properties were tested at the ages of 28 and 56 days. The total cement content selected was 600 kg/m^3 for the UHSC. The coarse aggregate used was 14 mm crushed granite with an amount of 60% by weight of total aggregate in concrete. The water cementitious materials ratio equal to 0.21 was chosen. Flow test were conducted to measure the workability of the concrete and also to determine the suitable dosage of superplasticizer. Slump tests were conducted mainly to see the uniformity of the concrete, but not to measure the workability of the concrete. Finally, the compression tests for concrete cube and flexural tests for the concrete beam were performed to determine the compressive strength and the flexural tensile strength of the concrete. The experimental results show that every of the designed mix proportion has achieved the required strength of ultra high strength concrete of higher than 100 MPa.

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LIST OF ABBREVIATIONS AND NOTATIONS

UHSC	-	Ultra High Strength Concrete
SF	-	Silica Fume
SP	-	Superplasticizer
FA	-	Fly Ash
BS	-	British Standard
ACI	-	American Concrete Institute
ASTM	-	American Society for Testing and Material
SiO_2	-	Silicon Dioxide
$Ca(OH)_2$	-	Calcium Hydroxide
C_3S	-	Tricalcium Aluminate
SSD	-	Saturated Surface Dry
A	-	Ambient
w/c	-	Water cementitious materials ratio
RPC	-	Reactive Powder Concrete

CHAPTER 1

INTRODUCTION

1.1 General

The purpose of this project was to develop Ultra High Strength Concrete (UHSC) based on locally available materials and silica fume (SF) with the addition of chemical admixtures such as superplasticizer (SP). The compressive strength tests will be conduct in order to get the specific strength of UHSC. The main interest of the study was to design the mix proportion of UHSC with different level of cementitious materials contents and different water cementitious materials ratio.

1.2 Background

Over the past year, due to an increase in the number of skyscrapers, there has been a rapid growth of interest in Ultra High Strength Concrete (UHSC). UHSC is also known as reactive powder concrete (RPC), characterized by a very dense structure, high compressive and tensile strength, high durability and large elastic modulus (Perry and Zakariasen. 2009). Due to mechanical properties and benefits of the UHSC such as cost-effective to construct, lasting, easy maintain and competitive in value, UHSC has been widely used in construction of high-rise buildings or skyscrapers such as Petronas Twin Tower, long span prestressed concrete bridge such as Lake Alvord Bridge (Portland Cement Association. 2009), pedestrian bridge in Sherbrooke (Aitcin et al. 1998), offshore structure, Shawnessy Light Rail Transit (LRT) Station (Perry and Zakariasen. 2009), and in similar structure.

The exact definition arbitrary, the term generally refers to concrete having unaxial compressive strength which is 80 MPa or higher (The World Intellectual Property Organization. 2007). Until now, cement that was mixed with admixture such as silica fume, fly ash and fine blast furnace slag powder which are industrial byproducts has been used as a binding material, the addition of high-range water-reducing admixtures or superplasticizer, low water cementitious materials ratio the compressive strength can go up to 100MPa to 200 MPa. However, a process that was applied to produce the concrete having the better performance still in development.

Such concrete can be made using carefully selected but widely available cement, sands and aggregate; certain admixture including high-range water reducing or SP, SF and fly ash (FA); plus very careful quality control during production. In addition to higher strength in compression, most other engineering properties are improved, leading to use of the alternative term high performance concrete. (Ramakrishnan. 1993).

Silica fume (SF) in concrete is a filler, due to its fineness, can fit into spaces between cement grains in a same way than sand fills the spaces between particles of coarse aggregate, (Bache. 1981). It improves the strength of concrete by increasing the fracture toughness of the cement paste-aggregate transition zone. (Detwiler et al. 1989). Another physical effect of silica fume on concrete is the increased internal cohesion of fresh concrete. Because of the very high surface area of the silica fume and the usually very low water content of silica-fume concrete, there will be very little or no bleeding (Detwiler et al. 1989). The optimum SF content ranges between 15% and 22%.

Besides, superplaticizers are essential admixtures for producing ultra high strength concretes. The high concentration of cement particles in the mixing water requires relatively high superplasticizer dosages to completely deflocculate and disperse the suspension of cement particles. It will enhance the fluidity of cementitious systems. Superplaticizers are polymers that can interact physically and chemically with cement particles. The physical interaction occurs when a superplasticizer was used to disperse a non-cementitious fine powder (Gagne et al. 1996). Superplasticizers can be used to decrease the water cementitious materials ratio by reducing the size of voids between the particles, leading to increase in compressive strength of the concrete.

UHSC need to have a low water cementitious materials ratio. The amount of air present in the mortar influences the strength of the concrete later on. According to Rao (2003), the strength deceases as the air content or permeability increase. It indicates that the air content deceases as the SF content increases. As the SF is finer than the cement particles, the finer particles of SF fill the gap between cement particles resulting in impermeable microstructure of the cement paste, which may lead to increase in compressive strength. Therefore, lower water cementitious materials ratio will lower porosity and increase the strength and durability of the UHSC.

1.3 Aim and objectives of study

The aim of the present study was to determine the optimum mix proportion of ultra high strength concrete using locally available materials, that were cementitious materials content, water cementitious materials ratio and the suitability of the dosage of SP.

In accordance with the aim of study, the main objectives were as follows:

- To conduct a series of cube compression test, to determine the compressive strength at concrete age of 28 and 56 days.
- To determine the optimum design mix for ultra high strength concrete.
- To compare the different level of cementitious materials content, water cementitious materials ratio on the compressive strength of ultra high strength concrete.

1.4 Scope of study

This is a lab-based research. Some experimental works will be carried out to determine the properties of the fresh concrete and hardened concrete. The results and data obtained need to achieve the objectives of this research. The general scope of this research focuses on mix design. Trial mix will be prepared to get the optimum mix design for UHSC using locally available materials. The additional materials will be used in this research is SF and superplasticizer. Water cementitious materials ratio will also vary in every mix proportion.

After that, laboratory test will be carried out to study the properties of fresh concrete. Slump test and flow test will be carried out. Then, the specimens will be cured in water at 24 ± 2^{o} C until the time they taken out for testing. The compressive tests will be conducted for testing hardened properties of the specimens at concrete age of 28 and 56 days.

Finally, the laboratory tests results and data obtained will be analyzed. The conclusion and recommendation will be made as the completion of the research.

1.5 Thesis organisation

This thesis was divided into five chapters. Chapter One includes the general introduction of Ultra High Strength Concrete (UHSC) of the study, aim and objectives of this thesis and scope of work. Chapter Two describes the literature review of the development UHSC using silica fume. For Chapter Three, it describes the methodology of producing UHSC in the laboratory. The description of materials used, laboratory work such as mix design or trial mix and types of test for properties of fresh concrete and harden concrete are shown in this chapter. Chapter Four shows the results and data analysis from the laboratory works. All the data or results are analysed in this chapter. From the data or result, some discussion are describes. Finally, Chapter Five concludes the development of UHSC based on locally available materials using silica fume and recommendations for future study are provided.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Strength of concrete is commonly considered the most valuable property of concrete. Strength usually gives an overall picture of the quality of concrete. The maximum strength of concrete used in demanding building and structures has increased steadily from about 40 MPa prior to 1980 to 130 MPa and more in some structures today (Scrivener and Kirkpatrick. 2007). For example, the landmark footbridge in Sherbrooke has been constructed with steel tubes filled with Ultra High Strength Concrete (UHSC) or Ultra High Performance Concrete (UHPC) (Aitcin et al. 1998).

In concrete practice, the strength of concrete is traditionally characterized by the 28 day crushing strength and some other properties of concrete are often referred to the 28 day value (Neville. 2002). For Ultra High Strength Concrete, the late age compression strength is important because of the effect of the mineral admixture (silica fume) on compressive strength at early ages was not significant, even up to 28 days. Compressive strength of UHSC became obvious at late ages which are 56 and 90 days.

Ultra High Strength Concrete has superior properties such as advanced strength, workability, durability and long term stability. Ultra high strength and very good workability can be obtained by a combination of several features. The composition of UHSC includes Portland cement, cementitious materials such as silica fume, crushed quartz, fine sand, coarse aggregate, superplasticizer and water (Skazlic et al, 2006).

This section provides review and study about the new development in UHSC, and is divided into three major parts. The first part discusses about the materials use in the mix proportion UHSC. This part consists of the Portland cement, water and air and aggregates use in the production of UHSC. The second part is the factor affecting the UHSC which include admixtures such as silica fume, superplasticizer and water cementitious materials ratio. The third part includes the trial mixtures in proportioning of UHSC and also provides the examples and results of UHSC and also the summary for the section in the later part.