PROPERTIES OF SELF-COMPACTING CONCRETE INCORPORATING PALM OIL FUEL ASH

ABDUL HAQ EHSAN

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This project report is dedicated to my parents
for their endless support and encouragement

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ABSTRACT

Self-compacting concrete (SCC) is a concrete which can be placed and compacted under its self-weight with little or no vibration effort, and is at the same time, cohesive enough to be handled without segregation or bleeding. SCC is used to facilitate and ensure proper filling and good structural performance of restricted areas and heavily reinforced structural members. SCC is a flowing concrete with high workability. To achieve flowing concrete low volume of coarse aggregates is used, but the reduction in volume of coarse aggregates require high volume of paste, i.e. cement and fine aggregates, and use of super-plasticizers. Increased volume of cement and addition of super-plasticizer leads to higher cost. The cost of cement can be reduced by using supplementary cementitious materials. One of the potential recycle materials from palm oil industry is palm oil fuel ash (POFA). Palm oil is extracted from the fruit and copra of the palm oil tree. Self-Compacting concrete using POFA has been one of the researching focuses in Malaysia. This study outlines laboratory tests conducted for fresh and hardened properties of SCC incorporating POFA. This study determines the feasibility of replacing cement in SCC with POFA in percentages of 0%, 30% and 60% by weight of cement, with water/binder ratios of 0.40, 0.45 and 0.50. The fresh properties of SCC were tested for filling ability, passing ability and segregation resistance. Slump-flow and Orimet flow time tests were conducted for filling ability, J-ring and L-box tests for passing ability and V-funnel at $T_{5minute}$ for segregation resistance. The hardened properties like compressive strength, split tensile strength, flexural strength and Ultrasonic pulse velocity were determined. Test specimens comprising of cube, cylinder and beams were prepared and tested at 1, 7 and 28 days of curing. The results and observations revealed that high volume POFA can be utilized in the development of SCC in terms of flow and strength gain.

ABSTRAK

Diri pemadatan konkrit (SCC) adalah konkrit yang boleh diletakkan dan dipadatkan di bawah berat badan sendiri dengan sedikit atau tidak ada usaha getaran, dan pada masa yang sama, cukup padu untuk dikendalikan tanpa pengasingan atau pendarahan. SCC digunakan untuk memudahkan dan memastikan pengisian yang betul dan prestasi baik struktur kawasan terhad dan anggota struktur banyak bertetulang. SCC adalah konkrit mengalir dengan kebolehkerjaan yang tinggi. Untuk mencapai mengalir jumlah konkrit rendah agregat kasar digunakan, tetapi pengurangan dalam jumlah agregat kasar memerlukan kelantangan yang tinggi pes, iaitu simen dan batu baur halus, dan penggunaan super-plasticizers. Dagangan meningkat simen dan penambahan super plasticizer membawa kepada kos yang lebih tinggi. Kos simen boleh dikurangkan dengan menggunakan bahan-bahan bersimen tambahan. Salah satu daripada bahan-bahan kitar semula yang berpotensi daripada industri minyak sawit adalah abu bahan api kelapa sawit (POFA). Minyak sawit yang diekstrak daripada buah-buahan dan kelapa kering daripada pokok kelapa sawit. Diri pemadatan konkrit yang menggunakan POFA telah salah satu penyelidikan yang memberi tumpuan di Malaysia. Kajian ini menggariskan ujian makmal dijalankan untuk hartanah segar dan mengeras SCC menggabungkan POFA. Kajian ini menentukan kemungkinan menggantikan simen di SCC dengan POFA dalam peratusan 0%, 30% dan 60% mengikut berat simen, dengan nisbah air / pengikat 0.40, 0.45 dan 0.50. Sifat-sifat segar SCC telah diuji untuk mengisi kemampuan, lulus keupayaan dan rintangan pengasingan. Slump flow dan Orimet flow time aliran telah diadakan untuk mengisi keupayaan, J-Ring dan L-Box untuk lulus ujian kebolehan dan V-Funnel di $T_{5minute}$ untuk rintangan pengasingan. Sifat-sifat keras seperti kekuatan mampatan, kekuatan tegangan berpecah, kekuatan lenturan dan Ultrasonik denyutan halaju ditentukan. Spesimen ujian yang terdiri daripada kiub, silinder dan rasuk telah disediakan dan diuji pada 1, 7 dan 28 hari pengawetan. Keputusan dan pemerhatian mendedahkan bahawa kelantangan yang tinggi POFA boleh digunakan dalam pembangunan SCC dari segi aliran dan kekuatan keuntungan.

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ASTM	-	American Society for Testing and Materials
BS	-	British Standards
EFB	-	Empty fruit bunches
HRWRA	-	High range water reducing
POFA	-	Palm oil fuel ash
SCC	-	Self-Compacting Concrete
SCM	-	Supplementary cementitious material
UPV	-	Ultrasonic pulse velocity
VEA	-	Viscosity enhancing admixtures
VMA	-	Viscosity Modifying Admixture

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Concrete is without any doubt a fascinating building material. In one way, it is very simple and anyone can mix water, cement and aggregates, cast it in moulds of almost any shape and finally obtain an artificial stone with strength. In other way, it is an extremely difficult material: no one completely understands its complex behavior both when fresh and when hardened. This ambiguity makes concrete both the most used building material in the world and a material which creates many problems, when not properly designed or placed.

One of the key issues for traditional concrete is that external energy has to be provided to compact it. This can be obtained on site from vibrating pokers and in factories from vibrating tables or alternative methods. In factories there is more time and proper supervision can be done during the process of vibration but on site the conditions are not the same. The concrete which is not properly vibrated can be harmful to the quality of final structure. The quality of non-vibrated concrete is far lower than its intrinsic quality when properly compacted. This may be in forms of loss in strength and decrease in durability. Decrease in durability can often be much more significant, leading to accelerated degradation process such as reinforcement corrosion, frost damage, sulfate attack etc.

This problem can be overcome by the use of Self Compacting Concrete. The concept of self-compacting concrete came into being in 1980's in japan [1]. The high seismicity of this geographical region requires the use of high levels of steel reinforcement in construction. The use of self-compacting concrete appeared as a solution to improve the filling up of the zones which are not very accessible to conventional methods of concrete compaction. This solution also has the advantage of overcoming the gradual decline in the number of workers qualified to handle and place concrete.

Self-compacting concrete (SCC) is a fluid mixture, which is suitable for placing difficult conditions and also in congested reinforcement, without vibration. In principle, a self- compacting must have a fluidity that allows self-compaction without external energy; remain homogeneous in a form during and after the placing process and flow easily through reinforcement. Self-compacting concrete has recently been used in the pre-cast industry and in some commercial applications. However, the relatively high material cost still hinders the wide spread use of such specialty concrete in various segments of the construction industry, including commercial and residential construction. Compared with conventional concrete of similar mechanical properties, the material cost of self-compacting concrete is more due to the relatively high demand of cementation materials and chemical admixtures including high range water reducing admixtures (HRWRA) and viscosity enhancing admixtures (VEA). SCC targeted for the filling of highly restricted areas and for repair works requires low aggregate volume to facilitate flow among restricted spacing without blockage and ensure the filling of the formwork without consolidation. The incorporation of high volumes of finely ground powder materials is necessary to enhance cohesiveness and increase the paste volume required for successful casting of Self-compacting concrete.

Self-compacting concrete has many advantages over conventional concrete; eliminating the need for vibration; decreasing the construction time and labor cost; reducing the noise pollution; improving the interfacial transitional zone between cement paste and aggregate or reinforcement; decreasing the permeability and improving durability of concrete, and facilitating constructability and ensuring good structural performance.

Proper selection of finely ground materials can enhance the packing density of solid particles and enable the reduction of water or HRWRA demand required to achieve high deformability. It can also reduce viscosity for a given consistency; especially in the case of SCC made with relatively low water/binder ratio. Reducing the free water can decrease the VEA dosage necessary for stability. SCC can also include supplementary cementing material (SCM) mainly to improve the strength and durability of concrete [2]. However, SCM can influence the fresh properties of SCC such as filling ability, passing ability and segregation resistance [3]. Depending on the type and properties of SCM, this effect can be positive or negative for the fresh properties of SCC. The literature review revealed that several SCM's, such as silica fume, ground granulated blast-furnace slag, fly ash and rice husk ash were used to produce SCC with good workability properties, strength and durability [2, 4-6]. Similarly, palm oil fuel ash (POFA) can be used in SCC. Previous studies have been done to produce different SCC mixtures incorporating POFA in the range of 0–15% of cement by weight. The effects of POFA on the filling ability, passing ability and segregation resistance of SCC were examined. It was found that POFA can be used to produce SCC possessing the aforementioned fresh properties within the acceptable ranges [7]. In another study concrete was produced using a particular level of POFA replacement and same or more strength was achieved as compared to OPC concrete. About 30% of cement replacement with POFA showed no significant strength reduction [8].

1.2 Problem Statement

Self-compacting concrete is a flowing concrete with high workability. To achieve flowing concrete low volume of coarse aggregates is used, but the reduction in volume of coarse aggregates require high volume of paste, i.e. cement and fine aggregates, and use of super-plasticizers. Increased volume of cement and addition of super-plasticizer leads to higher cost. The cost of cement can be reduced by using supplementary cementitious materials. Fly ash, silica fumes and Ground blast-furnace slag has been used in SCC. Malaysia has a high production rate of POFA, and previous studies have been conducted using low volume of POFA as supplementary cementitious material in SCC. This study intends to provide fresh and hardened properties of SCC using high volume of POFA, and determining its practicality.

1.3 Objectives

Following are the objectives of study:

i. To determine the fresh properties of self-compacting concrete incorporating palm oil fuel ash.

ii. To investigate the hardened properties of self-compacting concrete incorporating palm oil fuel ash.

iii. To study the effect of different water/binder ratios on fresh and hardened properties of self-compacting concrete incorporating palm oil fuel ash.

1.4 Significance of Study

The advantages of SCC are already recognized by the concrete industry. Design and construction specifications are urgently needed to give designers another option in meeting the demands of high performance concrete in construction. The use of POFA as cement replacement material in SCC will fully utilize the natural resource instead of becoming an industrial waste material. The replacement can reduce the cost of concrete, since the increase in the cost of cement. SCC using POFA has a good potential for greater acceptance and wider applications in civil infrastructure works in Malaysia and other parts of the world.

1.5 Scope of Study

The study is based on laboratory work and it focuses on the use of high volume of Palm oil fuel ash in the development of self-compacting concrete. Percentages of palm oil fuel ash are 0%, 30% and 60% by weight of cement content and water/binder ratio of 0.40, 0.45 and 0.50. Super-plasticizer is added from 2% to 4%. Fresh properties of Self-compacting concrete are examined by Slump-flow test, Orimet test, J-Ring test, L-box and V-funnel at $T_{5minutes}$. Also hardened properties are determined in terms of compressive strength, flexural strength, split tensile strength and ultrasonic pulse velocity test.

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