Production of Self-Compacting Concrete Containing Limestone Powder with the Effect of Internal and External Salts

by

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LIST OF ABBREVIATIONS

NCCLR	National Centre for Construction Laboratories and Research
SCC	Self-Compacting Concrete
UPV	Ultrasonic Pulse Velocity
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BS	British Standard
CANMET	Canada Centre for Mineral and Energy Technology
CM	Control Mix
CV	Conventional Concrete
EFNARC	European Federation of National Associations Representing for Concrete
EN	European Standard
EPG	The European Project Group
FA	Fly Ash
HVCR	High Volume Cement Replacement
LP	Limestone Powder
OPC	Ordinary Portland Cement
MK	Metakaolin
MPa	Mega Pascal
NVC	Normal Vibrated Concrete

PC	Portland Cement
SP	Super Plasticizer
W/C	Water /Cement ratio
W/P	Water/powder ratio
fcu	Cube Compressive Strength
$fc^{/}$	Cylinder Compressive Strength
C	Cement
P	Powder
S	Sand
L1	Reference mix without internal or external Salts
L2	Mix with internal sulphate 3.4% of sand weight
L3	Mix with internal sulphate 2.3% of sand weight
L4	Mix with internal sulphate 1.3% of sand weight
L5	Mix with internal sulphate 1.2% of sand weight
L6	Mix with external salt $NaCl_2$ (1.4%)
L7	Mix with external salt $NaSO_4$ (0.97 %)
L8	Mix with external salt $MgSO_4$ (0.97%)
L9	Mix with external salt $CaCl_2$ (1.4%)

LIST OF SYMBOLS

%	Percent
$<$	Less than
$>$	Greater than
$\geq$	Greater than or equals to
$\pm$	Plus or minus
°C	Degree Centigrade
µm	Micronmeter
$3CaO.Al_2O_3$	Tricalcium aluminate
$3CaO.Al_2O_3CaCO_3$	Calcium carboaluminate
C_2S	Dicalcium silicate
C_3A	Tetracalcium aluminoferrite
C_3S	Tricalcium silicate
CaO	Calcium oxide
$CaCO_3$	Calcium carbonate
CH	Calcium hydroxide
CO_2	Carbon dioxide
cm^2	Square centimeter
g	Gram
kg	Kilogram
km	Kilometer
L	Liter
mm	Millimeter

m^2	Square meter
m^3	Cubic meter
nm	Nanometer
SiO_2	Silicon dioxide
$CaSO_4$	Calcium sulfate
SO_4	Sulfate

Penghasilan Konkrit Mampatan Sendiri yang Mengandungi Serbuk Batu Kapur dengan Kesan Garam Dalaman dan Luaran

ABSTRAK

Kajian ini bertujuan menyiasat pengaruh perbezaan kandungan sulfat dalaman ($CaSO_4$) dan pengaruh perbezaan garam luaran ke atas sifat konkrit mampatan sendiri dan kesan kandungan garam dalaman dan luaran. Tiga set campuran (No.1), (No.2) dan (No.3) iaitu campuran rujukan, dicampurkan dengan sulfat dalaman dan campuran ini didedahkan kepada garam luaran masing-masing yang direka dengan pembahagian campuran yang sama dan maksimum saiz agregat sebanyak 10mm. Bagi menentukan sifat kebolehpadatan retak sendiri, ujian yang berbeza digunakan seperti Aliran Turunan, Saluran-V, Kotak-L, dan ujian Kotak-U. Ujian ini dijalankan bagi memastikan campuran tersebut menepati keperluan SCC dan menentukan keberkesanan sulfat dalaman ke atas keupayaan pengisian, laluan, dan rintangan pemisahan SCC. Sifat-sifat mekanikal yang dikaji ialah kekuatan mampatan, kekuatan pembelahan, kekuatan lenturan, dan modulus anjalan. Kajian ini disiasat dibawah keberkesanan terhadap serangan garam dan proses pembasahan dan pengeringan. Tambahan pula, kaedah ujian tidak musnah digunakan, yang mana halaju denyutan ultrasonik digunakan untuk menilai ciri-ciri dinamik konkrit. Hasil kajian menunjukkan bahawa tidak mustahil untuk menghasilkan konkrit mampatan sendiri (SCC) daripada bahan tempatan bagi memenuhi kehendak konkrit jenis ini, dan boleh dikatakan bahawa penghasilan konkrit mampatan sendiri ini dipengaruhi oleh serangan garam dan kesannya melalui proses pembasahan dan pengeringan, tetapi disebalik fakta ini, SCC masih mempunyai ciri-ciri yang bagus. Pada 28 hari, kekuatan mampatan untuk semua campuran adalah diantara (23.81 - 44.09) Mpa bagi piawai kiub berukuran 150mm dan (16.56 – 25.95) Mpa untuk silinder 150 x 300mm, kekuatan mampatan pada 60 hari, diantara (23.51 – 36.57) dan (13.24–30.87) MPa bagi kiub dan silinder masing-masing. Daripada keputusan kajian, kekuatan mampatan campuran dengan kandungan garam luaran adalah lebih besar daripada kandungan campuran dengan garam dalaman sulfate untuk 28, 60, 90, 180 dari masing-masing kecuali pada 180 hari campur L5 adalah paling tinggi . Kekuatan pembelahan (ft) untuk sifat konkrit mampatan sendiri menunjukkan kekuatan pembelahan untuk campuran garam luaran adalah lebih tinggi darip[ada keputusan kekuatan pembelahan bagi garam dalaman sulfate. Kekuatan luaran untuk kebolehdapatan retak sendiri menunjukkan pada 28 hari, nilai-nilai kekuatan luaran untuk campuran sulfate dalaman lebih tinggi daripada keputusan kedua – dua garam luaran dan rujukam campuran (LI), manakala pada 60 dan 90 hari keputusan garam dalaman sulfate adalah lebih tinggi daripada garam luaran dan rujukan campur (LI), pada 180 hari keputusan rujukan campur (LI) adalah lebih tinggi. Modulus anjalan untuk keboleh mampatan retak sendiri konkrit menunjukkan pada 28, 60, 90, dan 180 hari modulus anjalan bagi campuran-campuran dengan garam luaran adalah lebih tinggi berbanding dengan keputusan untuk kedua-dua campuran dengan garam dalaman sulfate dan rujukan samput (LI), walaubagaimanapun pada 90 hari, campuran dengan garam dalaman sulfate (L2) adalahpaling tinggi. Nilai halaju denyutan bertambah dengan peringkatan kekuatan mampatan dan penguranagn apabila kekuatan mampatan berkurangan, dimana keputusan pengurangan apabila kekuatan mampatan berkurangan, dimana keputusan halajuj denyutan untuk.

Production of Self-Compacting Concrete Containing Limestone Powder with the Effect of Internal and External Salts

ABSTRACT

This study aims at investigating the influence of different amounts of internal sulphate ($CaSO_4$) and external salts on the properties of Self-Compacting Concrete (SCC). Three sets of mixes (No.1), (No.2) and (No.3) which are reference mix, mixes with internal sulphate and mixes exposed to external salts respectively are designed with the same mix proportion and maximum size of aggregate 10 mm. In order to determine the self-compacting concrete, different tests are adopted such as Slump flow, V-funnel, L-box and U- box test. These tests are carried out to ensure that the mixes satisfy the requirement of SCC and to determine the effect of internal sulfate on the filling ability, passing and segregation resistance of SCC. The mechanical properties studied are the compressive strength, splitting strength, flexural strength, and modulus of elasticity. These tests are to be investigated under the effect of salt attack . Furthermore, a non–destructive test method is used, which is ultrasonic pulse velocity used to assess the dynamic properties of concrete. At age 28 days, compressive strength for all mixes ranges between (23.81-44.09) MPa for standard cubes measuring 150 mm and (16.56-25.95) MPa for cylinders 150x300 mm, the compressive strength at 60 days, ranges between (23.51-36.57) and (13.24-30.87) MPa for cubes and cylinder respectively. It appears from the results that the compressive strength of mixes with external salts is larger than the mixes with internal sulphates for ages 28,60 and 90 respectively except that at age 180 days the mix L5 is the highest. The results of splitting strength (ft) of SCC show clearly that the results of splitting tensile strength for the mixes with external salts are higher than the results of splitting tensile strength for internal sulphates and mix L1. The results of flexural strength (fr) of self-compacting concrete show clearly that at 28 days, the values of flexural strength of mixes with internal sulphates are higher than the results of both external salts and reference mix (L1), while at the ages 60 and 90 days, the results of external salts are higher than the results of internal sulphates and reference mix (L1), at the age 180 days the results of reference mix (L1) are the highest. The results of static modulus of elasticity (E) of self-compacting concrete show clearly that at 28 ,60 and180 days the static modulus of mixes with external salts are higher than the results of both mixes with internal sulphates and reference mix (L1), despite that at age 90 days the mix with internal sulphates(L2) is the highest. The values of pulse velocity increases with the increase in compressive strength and decreases when the compressive strength decreases.

Based on the results obtained from this work, it is clear that it is possible to produce self-compacting concrete (SCC) from local material which satisfies this type of concrete, and it can be stated that the produced self-compacting concrete is affected by salts attack , but despite this fact SCC still has good properties. In this investigation, the self compacting properties were found to be good for cement replacement by limestone powder. Addition of limestone powder increases the compressive strength and increases the sulphates resistance. Quarry dust not only reduces the cost of construction but also the impact on environment by consuming the material generally considered as a waste product with few applications.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Concrete has many qualities which contributed in making it the best commonly used construction material in civil engineering and building, such as cost-effectiveness, versatility, and above all durability. However, the production of concrete causes an environmental and conservation problems owing to its primary component production, which is the Portland cement (PC). This is because PC production is one of the main contributors to the carbon dioxide (CO_2) emissions moreover it consumes large quantities of fossil fuel and natural resources (Meyer, 2009).

Two significant studies carried out around mid 1980s and 1990s resulted in the inventions of self-compacting concrete (SCC) and high volume cement replacement (HVCR) strategy, which produces a major effect on the technique where concrete can be prepared (Okamura & Ouchi, 2003). The reason is that SCC is responsible for a variety of chances to make use of natural and by-product materials as cement substitutes, while the strategy of HVCR not just decreases the use of cement considerably but permits the production of concrete at a low cost as well.

SCC is a creative concrete which fill the formwork due to its capability to flow under its own weight completely, even in the dense reinforcement presence, with no necessity for vibration, while preserving homogeneity (EFNARC, 2002). The self-compacting ability is accomplished by means of large paste volume made possible by mixing cement with mineral additives for instance limestone powder (LP), fly ash (FA), silica fume (SF), ground-granulated blast-furnace slag (GGBS), rice husk ash (RHA), meta-kaolin (MK), etc (Elahi, Basheer, Nanukuttan, & Khan, 2010). Combining mineral additives in SCC turned out to be capable of not merely regulating the cement content but also improving the fresh state properties (Nehdi, Pardhan, & Koshowski, 2004).

The background study determines CO_2 emissions caused by concrete and cement productions as the recent issue is facing construction industry. One method of solving the issue is by substituting cement with byproduct materials such as LP. In this respect, SCC is able to offer varied opportunities to use such materials efficiently. However, the research problems that need to be resolved include SCCs higher material cost compared with traditional concrete, the additives low optimal level of cement replacement with respect to the incorporation of LP in SCC due to supply and properties issue (De Schutter, 2011).

The necessity to move away from the entire dependence on cement in the production of concrete had motivated the studies to employ mineral additives, particularly industrial wastes, as cement replacement materials. Several experts proposed that to enhance the usage of such materials in the production of concrete, concrete must progress. One way in the progression is in the direction of SCC which employs mineral time, cost and quality are the three important factors, which are assumed of significance in construction due to their impact on the industry as a whole.

Any developments, which have positive impact on the factors mentioned above, are always in the interest of civil engineering construction. When these developments have direct, desirable impact on social obligation of the industry, although analysis of pros and cons has to be done, all efforts needed to implement the concept in field of construction are essential (Chen & Liu, 2008). To achieve SCC properties ,the concrete mix should contain lower volume of coarse aggregate (Shankar H. Sanni,2007).SCC requires higher powder content, lesser quantity of coarse aggregate, high range Superplasticizer provide stability and fluidity to the concrete mixes. Substitution of 10% of cement with Quarry limestone powder(QLP) Improved the compressive strength of cement pastes (Burak Felekoglu,2007), which can be accepted as a positive factor in utilization of QLP in self –compacting paste applications.

1.2 Problem Statement

Due to its most major ingredient, Portland cement, concrete industry has suffered from an image of being environmentally unfriendly, because it is associated with high consumption of fossil fuel energy and high emissions of CO_2 into the atmosphere (Glavind, Mathiesen, & Nielsen, 2005). In order to improve its current image, concrete production method may have to progress towards lowering cement usage by replacing with more eco-friendly and cheaper materials such as industrial and agro byproducts. One way leading to this progress is towards second, a new type of concrete that offers wide opportunities to make use of byproduct materials not only to improve its fresh state properties but also to regulate the cement content.

Nevertheless, the problem with SCC is that it is likely more expensive than traditional concrete due to its SP requirement and high paste content. Incorporating mineral additives at their optimal levels, which are between 10-20% mostly (Surabhi, Soman, & Prakash, 2009), is insufficient at any cost increase incurred. Fortunately, most mineral additives have more than one beneficial characteristic which when mixed enable them to produce shared effects that are useful to the SCC, so at the very least they could increase the levels of cement replacement considerably.

The additive of LP in this study is described to be able to decrease cost and environmental load due to cement production and to improve all engineering properties (De Weerdt, 2011). They have a preference to use materials which are easily available and have been effectively used in real structural applications, such as LP, FA and SF and where bulk supply is assured.

1.3 Research Objectives

The objectives of this research are:

1. To produce SCC according to the requirement of the fresh and mechanical properties of concrete.
2. To study the effect of internal and external salts on the properties of SCC.

1.4 Research Significance

The aim in this work is to produce SCC from locally available materials, with an investigation of fresh and mechanical properties, such as compressive strength, splitting tensile strength, modulus of elasticity and flexural strength since the production of this type of concrete is limited and need to be investigated.

In this study, the effect of internal and external salts is investigated. Ordinary Portland cement, normal coarse aggregate, fine aggregate, admixture, and fillers were tested and evaluated. The tests are conducted in order to view the differences in behavior during the fresh state as well as the hardened state of concrete.

1.5 Scope of Study

The scope of this study is to produce SCC characterized to be extremely soft and fluid concrete. This study investigates the influence of using super plasticizer and filler limestone with the concrete mixes to enhance its fresh and mechanical properties. This study investigates the effect of diverse amount of internal sulfate ($CaSO_4$) and external salts on the SCC hardened state properties. Tests on hardened concrete are carried out using destructive and non-destructive methods together with related physical characteristic such as elastic modulus.

1.6 Chapter Organization

The current study includes five chapters which are introduction, literature review, experimental programs, results and discussion, and conclusion and recommendations.

Chapter one contains the background study of the research theme, research problem statement, research objectives, significance, scope, and chapter organization.

Chapter two analyses minor data from former researches and practices related to the bases of this study. In this chapter, the different mineral additives effects for instance fly ash, limestone powder, metakaolin, silica fume and rice husk ash, ground granulated blast furnace slag, etc., on self-compacting concrete fresh and hardened state properties were reviewed.

Chapter three states the SCC ingredients list and define the present research approach. Self-compacting ability of the fresh SCC were tested before the definite production. Afterwards, it was casted into cubic and prismatic molds and water cured for 28, 60, 90 and 180 days. Fresh and engineering properties were achieved by using appropriate test techniques in line with BS or BS EN standards and ASTM.

Chapter four analyzes, reports, discusses and compares main information acquired from the investigational research. Fresh state properties disclose the effects of diverse mineral additives on the requirements of SCC for water, SP and workability levels they produced. Engineering properties comprise mechanical (compressive, flexural strengths, splitting tensile strength and static modulus of elasticity) and physical (ultrasonic pulse velocity).

Chapter five sums up the study results with regard to the fresh and hardened state properties list. Several recommendations made for future study themes that might improve important data for the advance of the current study.