Materials and Design 55 (2014) 410–415

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Self compacting concrete from uncontrolled burning of rice husk and blended fine aggregate

M.E. Rahman [a,*], A.S. Muntohar [b], V. Pakrashi [c], B.H. Nagaratnam [a], D. Sujan [a]

[a] School of Engineering and Science, Curtin University Sarawak, Malaysia
[b] Department of Civil Engineering, Universitas Muhammadiyah Yogyakarta, Indonesia
[c] School of Engineering, University College Cork, Cork, Ireland

ARTICLE INFO

Article history:
Received 3 June 2013
Accepted 2 October 2013
Available online 10 October 2013

Keywords:
Rice husk ash
Self compacting concrete
Sustainability
Fresh state properties
Hardened state properties
Uncontrolled burning

ABSTRACT

This paper presents an experimental study on the development of normal strength Self compacting concrete (SCC) from uncontrolled burning of rice husk ash (RHA) as a partial replacement to cement and blended fine aggregate whilst maintaining satisfactory properties of SCC. Experiments on the fresh and hardened state properties have been carried out on RHA based SCC from uncontrolled burning. The dosages of RHA are limited to 0%, 20%, 30% and 40% by mass of the total cementitious material in the concrete. The experiments on fresh state properties investigate the filling ability, the passing ability and the segregation resistance of concrete. The experiments on hardened state properties investigate the compressive and the splitting tensile strengths. The water absorption level of the concrete with changing RHA levels has also been monitored. The experimental studies indicate that RHA based SCC developed from uncontrolled burning has a significant potential for use when normal strength is desired.

1. Introduction

Concrete is one of the most important materials for a very wide range of construction work. Generally, concrete is compacted by a vibrator or a steel bar after placing it inside the formwork to remove the entrapped air and it becomes a dense and homogeneous material. Compaction is very important to produce good concrete with desired strength and durability.

Self compacting concrete (SCC) is competent to flow, fill all areas and corners of the formwork even in the presence of congested reinforcement. It compacts under its own weight without segregation and bleeding and does not require any type of internal or external vibrator. Self compacting concrete must satisfy three fresh concrete properties related to the filling ability, the passing ability and the adequate segregation resistance [1–3].

The prototype of SCC was first developed in Japan in 1988 in order to make sure durable and safe concrete structures by changing the concept of concrete production and construction process. Significant research and development work into SCC are now being conducted nearly all over the world [4–6]. SCC seems to have a number of benefits in terms of economical, environmental, mechanical strength and durability aspects over Normally Vibrated Concrete (NVC) construction. As SCC does not require internal or external compaction, it reduces the segregation of coarse aggregate from cement paste leading to less porous zones between aggregate and cement paste. This reduction in porous zones may be related to durability properties [3,4].

SCC requires a significant decrease of coarse aggregate and an increase of cement content to maintain its fresh state properties and homogeneity. High cement content generally increases overall concrete production cost and also generates high heat during the chemical reactions as well as increasing creep and shrinkage problems. Consequently, significant quantities of pozzolanic material including Fly Ash (FA), rice husk ash (RHA), silica fume, Ground Granulated Blastfurnace Slag (GGBS), etc. are frequently used to replace cement to improve the fresh state properties of concrete, to control the generation of heat and to reduce the creep and shrinkage problems [4,5].

An increasing focus of the society towards sustainability has led to a significant increase in the use of different types of waste materials including RHA, tires, Oil Palm Shell (OPS) and FA. Intelligent reuse of materials is directly related to the necessity arising from the environmental effects of waste. The reuse of waste materials in concrete is an attempt to address a part of these problems by introducing sustainable materials in the construction industry. Concrete is the second most used material in the construction industry after water. As a result, the environmental impact, including the carbon footprint of concrete, is severe.

RHA, a by-product of paddy, can be abundantly found over a very large region of the world and is a contributor to air, river,

* Corresponding author. Address: CDT 250 98009 Miri, Sarawak, Malaysia. Tel.: +60 85 443939x3816.
E-mail address: merahman@curtin.edu.my (M.E. Rahman).

0261-3069/$ - see front matter
http://dx.doi.org/10.1016/j.matdes.2013.10.007

sea and groundwater pollution. Reuse of RHA in concrete attempts to address a part of the environmental problems. To establish the credibility of the use of such materials, experimental studies are important to demonstrate the efficiency of RHA blended concrete in terms of a number of traditional performance measures of standard concrete in terms of construction usage. Consequently, it is very important to study the physical and chemical properties of RHA and fresh state properties and hardened state properties of RHA based self compacting concrete extensively.

Diverse studies have been carried out on high strength conventional SCC and FA based SCC in both fresh and hardened states and a limited number of studies also exist on RHA based normal strength SCC. Fresh state properties of RHA based SCC along with cost analysis have been carried out before [3] where the dosage of RHA was limited to 5–10% by mass of the total cementitious material. RHA based SCC was observed to be more cost effective than Ordinary Portland Cement (OPC) based SCC. Mechanical properties of RHA based SCC have also been investigated [2] where the dosage of RHA was limited to 10–20% by mass of the total cementitious material. It was found that the RHA based SCC yielded higher results than the OPC based self compacted concrete in terms of strength at an age of 60 days. Durability performance of SCC has been investigated by researchers as well [7] and it has been reported that the porosity of SCC is generally lower than that of normal concrete and hence improved resistance to corrosion, freeze thaw cycles and sulphate attack. Hardened state properties of RHA based SCC have been studied [8] where the dosage of RHA is limited to 0–30% by mass of the total cementitious material. It was found that the hardened state properties improved with the increasing of RHA content. Some investigations have been reported relating to the increase of strength and durability properties of concrete through the use of RHA [9–14].

The availability of a significant amount of RHA is through uncontrolled burning. Considering the fact that a very significant amount of concrete construction in the developing regions around the world is associated with the use of normal strength concrete, there seems to be a potential of using RHA from uncontrolled burning to produce normal strength concrete with adequate fresh and hardened state properties. There does not seem to be extensive research work present on RHA based normal strength SCC from uncontrolled burning. A significant amount of RHA from uncontrolled burning is generated every year in many developing countries. Such RHA contains around 90% SiO_2 and due to this high percentage of SiO_2 in RHA, it works as a pozzolanic material. Therefore it is very important to utilize in concrete and also to study RHA based normal strength self compacting concrete by examining its hardened state properties. The uses of normal strength concrete in Malaysia and in many developing nations associate with a very high share of all of the concrete construction. The application of uncontrolled burning RHA as pozzolanic material in normal strength SCC in Malaysian construction industry and similar developing nations is not usual and there is a general lack of technical knowledge and guidance in this regard.

These paper present experimental studies on RHA based normal strength SCC from uncontrolled burning with blended fine aggregates in relation to the adequacy of achieving fresh and hardened state properties. Filling ability, passing ability and segregation resistance were tested for fresh state while the compressive and the splitting tensile strength were tested for hardened state. Additionally, a water absorption test and a comparison with FA based SCC are carried out in this paper with respect to RHA based SCC from uncontrolled burning. The study demonstrates the possibility of use of RHA based SCC from uncontrolled burning as a sustainable building method for the development of normal strength concrete.

2. Details on materials for testing

2.1. Cement

Ordinary Portland Cement (OPC) grade 42.5 based on ASTM: C150/C150 M-12 was used in the concrete as cementitious material. The density of the cement is 2950 kg/m^3.

2.2. RHA

RHA obtained through uncontrolled burning was used in this study. The RHA was collected from a village (Kota-Kinabalo) in Sabah, Malaysia. The RHA was sieved by a 75 μm sieve to remove large particles and was then grinded to obtain fine powder. The chemical composition of the RHA was determined using XRF (X-ray Fluorescence). The results of the chemical composition of cement are presented in Table 1. The amount of SiO_2 in the RHA is observed to be 94.8%.

2.3. Coarse aggregate

10 mm nominal size crushed quartzite was used as the coarse aggregate in this research. The coarse aggregate was composed of particles within the range of 5 –10 mm. Sieve analysis of a 2000 g sample indicated that the entire sample (100%) passed through a 9.5 mm sieve while only 5% passed a 4.75 mm sieve (i.e. 95% retained on 4.75 mm sieve). This conforms with the 10 mm single sized aggregate requirements in AS: 2758.1 [15]. The gradation of coarse aggregate is presented in Table 2.

2.4. Fine aggregate

AS: 2758.1 [15] categorize aggregates with particles finer than 4.75 mm as fine aggregates (FA) for concrete mix design. In this research programme two categories of fine aggregates was used. One category was chosen such that nominal size was 4.75 mm while all the particles were coarser than 600 μm (crushed quartzite). The other category had a nominal size of 600 μm (uncrushed river sand) while sieve analysis indicated the presence of even microfines to a small extent (particles of size less than 75 μm). The gradations of the two categories chosen as fine aggregates of both types are presented in Table 3 and Table 4 respectively.

The fineness modulus of river sand is rather small (1.32), indicating a very fine overall particle size. Very often, the desired value for fine aggregates is 2.5 or above. Hence it is necessary to use a coarser fine aggregate in the mix. The fineness modulus of crushed quartzite is 4.29. The aggregate characteristics summary is presented in Table 5.

2.5. Admixture

The super-plasticizer used in this research was supplied by Sika Kimia Sdn Bhd. The trade name of the high range water reducing

Table 1
Chemical composition of cement, RHA.

Compound	Cement (%)	RHA (%)
SiO_2	20	94.8
CaO	63.2	1.41
Fe_2O_3	3.3	1.61
K_2O	N.A	1.33
TiO_2	N.A	0.17
MnO	N.A	0.28
CuO	N.A	0.04