Self Compacting Concrete from Uncontrolled Burning of Rice Husk & Blended Fine Aggregate

Muhammad Ekhlasur Rahman*
School of Engineering & Science
Curtin University Sarawak, Malaysia
merahman@curtin.edu.com

Agus Setyo Muntohar
Department of Civil Engineering
Universitas Muhammadiyah Yogyakarta

Vikram Pakrashi
Department of Civil and Environmental Engineering,
School of Engineering, University College Cork, Cork, Ireland
v.pakrashi@ucc.ie
Brabha Hari Nagaratnam
School of Engineering & Science
Curtin University Sarawak, Malaysia

Sujan Debnath
School of Engineering & Science
Curtin University Sarawak, Malaysia

* Corresponding Author
School of Engineering & Science
Curtin University Sarawak,
CDT 250 98009, Miri, Malaysia
Email: merahman@curtin.edu.com
Mobile: +60128451750

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% & 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.

Keywords: Rice Husk Ash (RHA), Self Compacting Concrete (SCC), Sustainability, Fresh State Properties, Hardened State Properties, Uncontrolled Burning

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, 2, 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 [4,5,6]. 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, 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 SCC reduced the porosity of concrete and hence improved resistance to corrosion, freeze thaw cycles and sulphate attack. Studies on hardened state properties of RHA [8] indicated that 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 strength increase through the use of RHA [9, 10, 11], use in High Performance Concrete (HPC) [12], contribution of RHA on properties of mortar and concrete [13], effect of RHA on average particle size, shrinkage [14], durability and corrosion resistance [15]. 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. This paper presents experimental studies onRHA 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 [16] was used in the concrete as cementitious material. The particle 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 75µm 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%.

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

LOI	2.5	N.A

2.3 Coarse Aggregate

10mm nominal size crushed quartzite was used as the coarse aggregate in this research. The coarse aggregate was composed of particles within the range of 5mm to 10mm. Sieve analysis of a 2000 gram sample indicated that the entire sample (100%) passed through a 9.5mm sieve while only 5% passed a 4.75mm sieve (i.e. 95% retained on 4.75mm sieve). This conforms with the 10mm single sized aggregate requirements in AS 2758.1 [17]. The gradation of coarse aggregate is presented in Table 2.

TABLE 2
COARSE AGGREGATE (CA) GRADATION

Sieve Size (mm)	% Finer	AS 2758.1 Requirements
9.5	100	85 - 100
4.75	5	0 - 20
2.36	0	0 - 5

2.4 Fine Aggregate

AS 2758.1-1998 [17] categorizes aggregates with particles finer than 4.75mm as fine aggregates (FA) for concrete mix design. After several mix trials using several proportions of fine aggregates with several gradations, it was decided that this research would utilize two types of fine aggregates. One category was chosen such that nominal size was 5.0mm while all the particles were coarser than 600μm (crushed quartzite). The other category had a nominal size of 600μm (uncrushed river sand) while sieve analysis indicated the presence of even micro-fines to a small extent (particles of size less than 75μm). The gradations of the two categories chosen as fine aggregates of both types are presented in Table 3 and Table 4 respectively.

TABLE 3

RIVER SAND GRADATION

Sieve Size (μm)	% Finer	AS 2758.1 Requirements
600	100	15 -100
300	58	5-50
150	10	0 -20

TABLE 4

CRUSHED QUARTZITE GRADATION

Sieve Size	% Finer	AS 2758.1 Requirements
4.75mm	99	90 -100
2.36mm	50	60 -100
1.18mm	20	30 -100
600μm	2	15 - 80

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.

TABLE 5

Aggregate Characteristics Summary

	Material Type	Size Range	Fineness Modulus	Water Absorption	Specific Gravity	Sample

Fine Aggregate	Uncrushed River Sand	0.0µm to 600µm	1.32 (low)	1.10%	2.64	
	Crushed Quartzite	600µm to 5.0mm	4.29 (high)	1.30%	2.67	
Coarse Aggregate	Crushed Quartzite	5.0mm to 10.0mm		1.40%	2.62	

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 (up to 30% depending on dosage) admixture is Sikament®-NN and conforms to the requirements of ASTM C494 Type F [18] while the chemical base of the dark brown liquid is Naphthalene Formaldehyde Sulphonate. The use of admixture is advocated along with the application of the use of RHA from uncontrolled burning to enhance the workability and the reduction of water requirement. Such admixtures used during normal production of concrete and consequently the use of RHA can be effective in reducing the cost.

3. Details of Experimentation

3.1 Mix Proportions

Four concrete mixes were designed and the dosage of RHA are limited to 0%, 20%, 30% and 40% respectively by the mass of the total cementitious material.. Crushed quartzite was mixed with river sand to increase the fineness modulus of fine aggregates. The fineness modulus of river sand was 1.32 and the maximum size of the coarse aggregate was limited to 10mm. The mix proportions of RHA based SCC are summarized in Table 6.

TABLE 6
Mix Proportions of RHA based SCC

Materials	Cement kg/m^3	RHA kg/m^3	Water kg/m^3	w/p	sp %	River sand kg/m^3	Crushed quartzite kg/m^3	Coarse aggregate kg/m^3
Mix 1	540	0	205	0.38	1.8	230	630	690
Mix 2	400	100	250	0.5	3.5	150	700	700
Mix 3	350	150	250	0.5	3.5	150	700	700
Mix 4	300	200	250	0.5	3.5	94	756	700

3.2 Sample Preparation

The mixer used was a 0.5m^3 capacity forced action cylindrical pan mixer with a vertical axis of rotation. For optimal mixing outcomes a specific procedure was chosen from a number of different methods of mixing. The procedure most suited to the experiments involved putting all the aggregates into the pan and running the mixer for around 1 minute. Following this run, RHA powder was added and the mixer was run for approximately another 1 minute. Next, about 60% of the required water was added slowly (poured towards, but not too close to the outer wall of the pan) and mixer was run again for around 1 to 1.5 minutes. Once this mixing was carried out, 30% of the water and 90% of the super-plasticizer was mixed in a bucket and then added slowly to the pan before running it for about 3 to 3.5 minutes. The super-plasticizer was found out to be most effective when added with water). The consistency and the flow of the resulting mixes were observed and the remaining 10% of water and 10% of super-plasticizer (mixed together) were used to adjust the mix. This step was found out to be especially helpful due to the changes in water and super plasticizer demand as RHA content was increased. The step took about 40 to 50 seconds. The resulting mixture was then allowed to rest for not less than 2.5 minutes (for air dissipation), and remixed for 20 to 30 seconds, after which all the fresh state tests were carried out. With increasing the RHA content in the mix, the need to follow this procedure was obvious since the mixture tended to be more sticky and sudden addition of water lead to complete failures in terms of achieving the desired SCC.

3.3 Testing of Samples

3.3.1 Fresh State Properties

SCC must satisfy three fresh concrete properties including the filling ability, the passing ability and the adequate segregation resistance. For determining the filling ability, slump flow and V-funnel tests were carried out. The passing ability was determined through J-ring test while the segregation resistance was determined through sieve segregation tests. The performance criteria for fresh state concrete properties of SCC are presented in Table 8 [4, 5, 8].

TABLE 8
PERFORMANCE CRITERIA FOR FRESH STATE SCC [4,5,8]

Test Method	Property	Criterion
Slump flow	Filling ability	550-850mm
V-funnel	Filling ability	6-12s
J-ring	Passing ability	0-10mm
Sieve segregation	Segregation resistance	≤ 18%

The slump flow indicates the ability to completely fill all areas and corners of the formwork into which it is placed. It measures the average diameter from two perpendicular directions of the mass of the concrete after taking out the standard slump cone. V-funnel test was carried out to determine the stability of SCC mixes which determine the flow time. J-ring test (Figure1) was carried out to determine passing ability of the SCC through congested reinforcement without separation of the constituents or blocking. This test measures the difference in height between the concrete inside the bars and that just outside the bars. Sieve segregation test was carried out to determine the resistance to segregation of SCC to retain the coarse components of the mix in suspension in order to maintain a homogeneous material.

Fig. 1 J-Ring sample

3.3.2 Hardened State Properties:

The hardened state properties of the concrete include strengths in compression and tension properties. Cylindrical specimens were tested to failure to determine hardened state properties like compressive strength and splitting tensile strength at 3, 7, and 28 days respectively using Universal Testing Machine. Adequate strength in compression and tension establishes the uses of RHA based SCC from uncontrolled burning for the production of normal strength concrete.

4. Results and Discussions

4.1 Fresh State Properties

The results of the slump flow, V-funnel, J-ring and Sieve segregation test for the fresh state properties of RHA based self compacting concrete are presented in Table 9. For Mix 1, the slump flow diameter is 630mm, V-funnel flow time is 5.9s, the difference in height in J-ring is 5.2m and the segregation ratio is 8.2%. For Mix 2, the slump flow diameter is 660mm, V-funnel flow time is 6.6s, the difference in height in J-ring is 3.7mm and the segregation ratio is 0.04%.

For Mix 3, the slump flow diameter is 670mm, V-funnel flow time is 6.3s, the difference in height in J-ring is 3.5mm and the segregation ratio is 0.09%.For Mix 4, the slump flow diameter is 580mm, V-funnel flow time is 7.0s, the difference in height in J-ring is 4.4mm and the segregation ratio is 0.2%.

Slump flow test was carried out to investigate the filling ability of normal strength SCC. The standard range of slump flow diameter is 550 to 850mm. If the slump flow (SF) value is higher than 750mm, the viscosity will be lower and the greater its ability to fill formwork under its own weight however concrete might segregate. If the slump flow (SF) value is lower than 500mm, the viscosity will be higher and greater its chance to make blockage in congested reinforcement. All the results from this study fall within the middle range, which indicates an excellent filling ability of normal strength SCC.

V-funnel test was also carried out in addition to the slump flow test to investigate the filling ability of normal strength SCC. The standard range of V-funnel flow time is 6-12s as per EFNARC [4]. This test measures the ease of flow of the concrete. The longer flow times indicate lower flowability and shorter flow times indicate greater flowability. The results from this study are higher than the minimum standard value of 6s and lower than the maximum standard value of 10s.

J-ring test was carried out to investigate passing ability of the normal strength SCC. This test measures the difference in height between the concrete inside the bars and that just outside the bars. The standard range of difference in concrete height between the concrete inside and outside the bars is 0-10mm. The greater the difference in height, the passing ability of the concrete is low and the lower the difference in height; the passing ability of the concrete is high. All the results from this research work are less than 10, which indicate a good passing ability of RHA based normal strength SCC.

The sieve segregation resistance test was carried out to investigate the resistance of normal strength self-compacting concrete to segregation. The standard limiting value for sieve segregation resistance test is less than 18%. As per EFNAC, if the result is higher than 15%, the viscosity will be lower, the concrete might segregate. The results from this research work are less than 15%, which indicate that RHA based normal strength SCC is a good resistance to segregation [4,5].

It is noted from these experiments on the fresh state properties that the RHA based SCC from uncontrolled burning satisfies all the criteria of the fresh state properties of SCC including filling ability, passing ability and segregation resistance. Consequently, the material has good potential as a cement replacement in the production of SCC.

TABLE 9
FRESH STATE PROPERTIES OF RHA BASED SCC

Test Method	Mix 1	Mix 2	Mix 3	Mix 4
Slump flow, mm	630	660	670	580
V-funnel, s	5.9	6.6	6.3	7
J-ring, mm	5.2	3.7	3.5	4.4
Sieve segregation, %	8.2	0.04	0.09	0.2

4.2 Hardened State Properties

4.2.1 Compressive Strength

The compressive strength of RHA based SCC are evaluated at 3, 7 & 28 days and the results are presented in Table 11. The percentage of RHA content in the Mix1, Mix2, Mix3 and Mix4 are 0, 20, 30 and 40 respectively. It can be seen from the Table 11 that the compressive strength decreased with increasing of RHA content. Previous studies [2, 9, 19] showed that the 28 days compressive strength decreased with increasing of RHA content. It is due to the fact that the amount of RHA present in the mix is higher than the amount required and due to the leached out extra silica. This extra silica replaces part of the cementitious material and does not contribute to compressive strength [19]. Compressive strength of RHA based SCC along with the results obtained from similar studies carried out on fly ash based SCC are presented in Figure 2. It can also be observed from the Figure 2 that the compressive strength decreased with increasing of fly ash content. Studies [20] also showed that the compressive strength decreased with increasing of FA content. At an early stage, the rate of gain of strength of RHA based SCC was higher due to presence of higher percentage of silica in RHA. The higher percentage of silica helps the pozzolanic reactions occur at early ages [21]. However, the rate of gain of strength was lower after 7 days. In general RHA based SCC yielded higher strength than similar studies carried out on FA results. However, the 28 day strengths of Mix2 (Fly Ash) are higher than RHA based SCC, an obvious reason of which is not apparent Generally, the strength gain of RHA is consistently more rapid than the FA based SCC and the maximum compressive strength is reached quite early.

TABLE 11
COMPRESSIVE STRENGTH OF SCC
Compressive Strength, MPa

RHA Based SCC				
Days	Mix1	Mix2	Mix3	Mix4
3	28.2	26.1	23.4	20.9

7	32.8	37.2	35.1	28.1
28	48.5	42.9	40.9	33.5

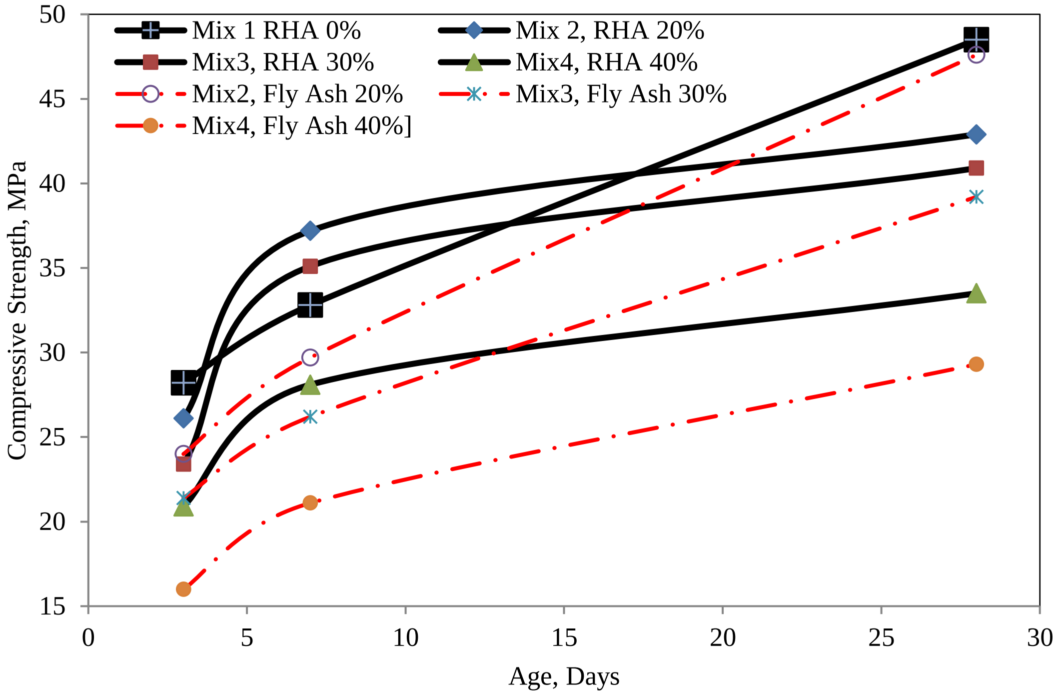

Figure.2. Compressive strength of SCC mixes

4.2.2 Splitting tensile strength

The splitting tensile strength test results of RHA based SCC are presented in Table 12. The percentage of RHA content in the Mix1, Mix2, Mix3 and Mix4 are 0, 20, 30 and 40 respectively. It can be seen from the Table 12 that the splitting tensile strength decreased the same as the compressive strength with the increasing of RHA content. This relationship between the compressive strength and the splitting tensile strength of RHA based SCC is presented in Figure 3. The fingings correspond to some previous studies[22-25]. The correlation between the splitting tensile strength and compressive strength are presented in Table 13. It can be seen from Figure 3 that the splitting tensile strength increases with increasing the compressive strength. The splitting tensile strength of SCC based on RHA was 8-12% of compressive strength. It can also be observed in Figure 3 that the splitting tensile strength of SCC are higher than the normal vibrating concrete due to uniform compaction of SCC under its own weight without any types of internal and external vibrator and without segregation and bleeding. Felekoglu et al [22] also found that the splitting tensile strength of SCC is higher than the normal vibrating concrete.

TABLE 12
SPLITTING TENSILE STRENGTH OF SCC

Splitting Tensile Strength, MPa				
RHA Based SCC				
Days	Mix1	Mix2	Mix3	Mix4
28	5.1	5.1	4.3	2.8

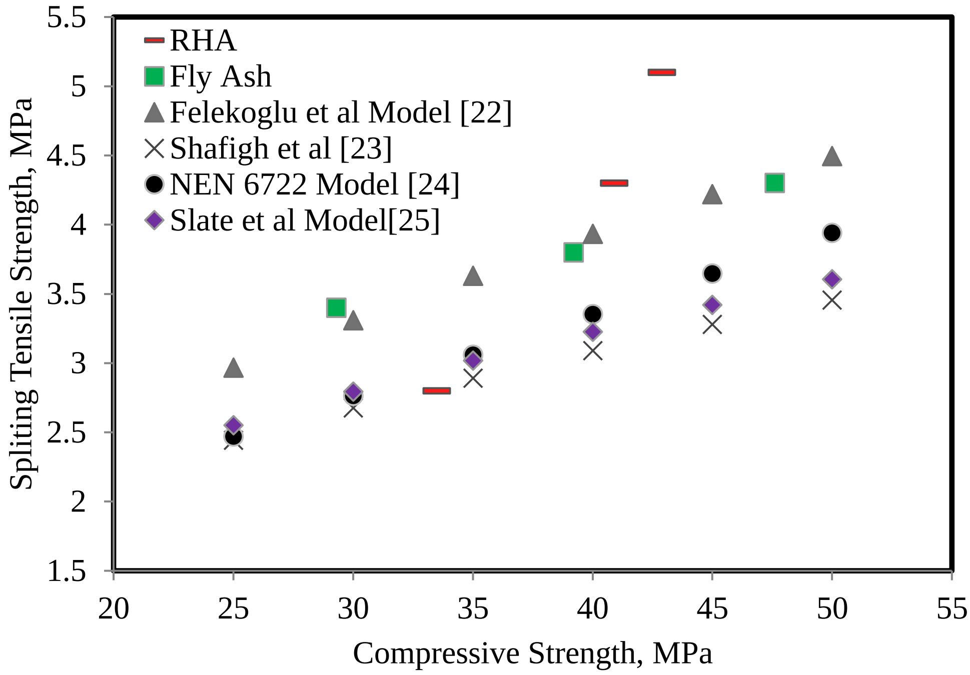

Figure.3. Relationship between 28-days compressive and splitting tensile strength

TABLE 13
Equations for Splitting Tensile Strength

RHA based SCC [Experimental]	$0.0007(f_c)^{2.3437}$
Studies based on FA	$0.676(f_c)^{0.4759}$
Felekoglu et al Model [30]	$0.4887(f_c)^{0.5}$
Shafigh et al. Model [31]	$0.43(f_c)^{0..6}$
NEN 6722 Model [32]	$1N/mm^2 + 0.05 f_c$
Slate et al Model [31, 33]	$0.51(f_c)^{0..5}$

4.2.3 Water Absorption Test

The water absorption test results of RHA based SCC are presented in Table 14. The percentage of RHA content in the Mix1, Mix2, Mix3 and Mix4 are 0, 20, 30 and 40 respectively. It can be seen from the Table 14 that the water absorption of the SCC increased with the increasing of the content of RHA. Previous studies [26] showed that the water absorption level increased with increasing of RHA content in concrete. RHA is finer than cement and and it is also hygroscopic in nature. The total binder surface area increased with increasing the RHA content in SCC and thus the water absorption level of concrete also increased [26].

TABLE 14
Water Absorption, (%)

RHA Based SCC				
Days	Mix1	Mix2	Mix3	Mix 4
28	6.2	7.7	8.9	10.5

4.3 Materials & Carbon Footprint

Significant amounts of virgin materials including limestone and clay besides energy are consumed to produce cement and 1.5 ton of virgin materials are needed to produce one ton of cement [27]. Cement production industries are liable for more or less 7% of the world's carbon dioxide discharge and to produce one tone of cement approximately one ton of CO_2 is released in the atmosphere [27, 28]. RHA is a by-product of paddy which can be abundantly found over a very large region of the world and is a contributor to air, river, sea and groundwater pollution. This study shows that RHA has good potential as a cement replacement up to 40% in normal strength self compacting concrete production. Every year significant amount RHA from uncontrolled burning is produced by villagers in developing countries. 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 and consequently reduce carbon footprint.

5. Conclusions

- Concrete blended with RHA obtained from uncontrolled burning is able to produce normal strength self compacting concrete with incorporating up to 40% RHA as supplementary of cementing material and blended fine aggregate without compromising the fresh state properties.
- The ranges of slump flow diameter for all the mixes are 580 to 670 mm indicating an excellent filling ability of SCC.
- The V-funnel flow time ranges are 6.3 to 7s indicating also an excellent filling ability of SCC.
- The ranges of difference in height between the concrete inside the bars and that just outside the bars are 3.5 to 4.4 mm indicating a good passing ability of SCC.

- The sieve segregation resistance value falls in the range of 0.04 to 0.2% indicating a good resistance to segregation of SCC.
- Compressive strength and splitting tensile strength decreased with increasing of RHA content. It is due to the fact that the amount of RHA present in the mix is higher than the amount required and due to the leached out extra silica. This extra silica replaces part of the cementitious material and does not contribute to compressive strength.
- With increasing the RHA content in the mix, the mixture tended to be more sticky and especially sudden addition of water lead to complete failures in terms of achieving the desired SCC.
- The splitting tensile strength of SCC based on RHA was 8-12% of compressive strength respectively which satisfies the correlation between tensile strength and compressive strength of concrete.
- The splitting tensile strength of SCC is higher than the normal vibrating concrete due to better homogeneous mixture of SCC.
- The water absorption level increased with increasing of RHA content as it is hygroscopic in nature.

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Reference

[1] Goodier C.I., (2003), “Development of self-compacting concrete”, ICE Journal: Structures & Buildings, Vol. 156, pp-405- 414.

[2] Ahmadi M. A., Alidoust O., Sadrinejad I., & Nayeri M., (2007), “Development of Mechanical Properties of Self Compacting Concrete Contain Rice Husk Ash” World Academy of Science, Engineering and Technology, Issue 34, pp. 168-171.

[3] Memon S.A., Shaikh M. A, & Akbar H., (2011), “Utilization of Rice Husk Ash as viscosity modifying agent in Self Compacting Concrete”, Construction and Building Materials, Vol. 25, pp. 1044-1048.

[4] EFNARC (2002), specifications and guidelines for self compacting concrete.

[5] The European Guidelines for Self-Compacting Concrete; Specification, Production and Use (2005)

[6] Okamura H. & Ouchi M., (2003), “self compacting concrete”, Journal of Advanced Concrete Technology, Vol. 1, pp 5-15.

[7] Safiuddin M., West J.S., & Soudki K.A., (2008), “Durability Performance of Self-consolidating Concrete”, Journal of Applied Sciences Research, Vol. 4, pp 1834-1840.

[8] Safiuddin M., West J.S., & Soudki K.A., (2010), “Hardened properties of self – consolidating high performance concrete including rice husk ash”, Cement & Concrete Composites, Vol. 32, pp 708-717.

[9] de Sensale G.R., (2006), "Strength development of concrete with rice-husk Ash", Cement and Concrete Composites, Vol. 28, pp 158-160.

[10] Ahmadi M.A., Alidoust A., Sadrinejad I., & Nayeri, N., (2007), "Development of Mechanical Properties of Self Compacting Rice Husk Ash", World Academy of Science, Engineering and Technology, Vol. 34, pp 168-171.

[11] Habee b G.A., & Mahmud H.B., (2009),"Experimental Investigation on the Mechanical Properties of Grade 40 Concrete Incorporating Rice Husk Ash (RHA), 7th APSEC & 2nd EACEF Joint Conference, Langkawi, Malaysia.

[12] Salas A., Delvasto S., de Gutierrez R.B., & Lange D., (2009), "Comparison of two Processes of Treating Rice Husk Ash for use in High Performance Concrete", Cememt and Concrete Research, Vol. 39, pp 773-778.

[13] Givi A.N., Rashid S.A., Aziz F.N.A., & Salleh M.A.M., (2010), "Contribution of Rice Husk Ash to the Properties of Mortar and Concrete: A Review", Journal of American Science, Vol. 6(3), pp 157-165.

[14] Habeeb G.A., & Fayyadh, M.M., (2009), "Rice Husk Ash Concrete: the Effect of RHA Average Particle Size on Mechanical Properties and Drying Shrinkage", Australian Journal of Basic and Applied Sciences, Vol. 3(3), pp1616-1622.

[15] Abu Bakar B.H., Putrajaya R., & Abdulaziz H., (2010), "Malaysian Rice Husk Ash – Improving the Durability and Corrosion Resistance of Concrete: Pre-review", Concrete Research Letters, Vol. 1(1), pp 6-13.

[16] ASTM C150, (2009), "Standard Specification for Portland Cement".

[17] AS 2758.1-1998 Aggregates and rock for engineering purposes- Concrete aggregates

[18] ASTM C494 / C494M - 11 "Standard Specification for Chemical Admixtures for Concrete."

[19] Al-Khalaf, Moayad N, and Hana A. Yousift. (1984), Use of Rice Husk Ash in Concrete. The International Journal of Cement Composites and Lightweight Concrete 6(4), pp 241-248.

[20] Siddique R., (2011), "Properties of self compacting concrete containing class F fly ash", Materials and Design, Vol.32, pp 1501-1507.

[21] Alireza N. G., Suraya A. R., Farah N., & Mohamad A. M. S., (2010), "Contribution of Rice Husk Ash to the Properties of Mortar and Cobcrete: A Review", Journal of Americal Science, Vol. 6(3), pp 157-165.

[22] Felekoglu B., Turkel S. & Baradan B., (2007), "Effect of water/cement ratio on the fresh and hardened properties of self-compacting concrete", Building and Environment Vol. 42, pp 1795–1802.

[23] Shafigh P., Jumaat M. Z., Mahmud H. B., & Abd Hamid N. A., (2012), "Lightweight concrete made from crushed oil palm shell: Tensile strength and effect of initial curing on compressive strength", Vol. 27, pp 252–258.

[24] Browers H.J.H. & Radix H.J., (2005), "Self-compacting concrete: theoretical and experimental study", Vol. 35, pp-2116-2136.

[25] Slate F. O., Nilson A.H, S. Martinez, (1986), "Mechanical properties of high strength lightweight concrete", AC1 Journal Proceeding 83 (4), pp 606-613.

[26] Ganesan, K, K. Rajagopal, and K. Thangavel. (2008), "Rice Husk Ash Blended Cement: Assessment of Optimal Level of Replacement for Strength and Permeability Properties of Concrete." Construction and Building Materials 22, pp. 1657-1683.

[27] Fredrik B, (1999), "Concret Technology and Sustanailble Develoipment", Symposium on Concrete Technology for Sustainable Development, Vancouver, Canada.

[28] Juan C., Breixo G., Juan L. D., Salvador G. M., & Hortensia G. L., (2011), "Calculation of the corporate carbon footprint of the cement industry by the application of MC3 methodology", Ecological Indicators, Vol. 11, pp. 1526–1540.