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A Review on Self-Compacting Concrete and The Effect of Elevated Temperature on Concrete Produced with Rice Husk Ash.

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ABSTRACT: Exposure of concrete to high temperature due to fire outbreaks can lead to damage of concrete structures despite not been a combustible material. Elevated temperature alters physical, chemical and mechanical changes in concrete properties. This paper reviews the effect of elevated temperature on concrete made with rice husk ash and also the properties of rice husk ash in self-compacting concrete. The advantages of using rice husk ash in SCC production over more commonly used materials such as Portland cement are explored. The use of rice husk ash can reduce the environmental impacts of SCC by replacing the primary constituent of cement and allowing for production with significantly lower carbon dioxide emissions and water use. The mechanical properties of SCC produced with rice husk ash are studied, and the results are compared with those of SCC produced with more conventional materials. The influence of various proportions of rice husk ash on the properties of SCC were investigated and discussed. The results of this review suggest that rice husk ash can be easily used in SCC production and offers a number of advantages when compared to other traditional materials.

KEYWORDS*:* Pozzolanic Materials, Rice Husk Ash, Elevated Temperature, Compressive Strength, Flexural Strength and Durability.

I. 1NTRODUCTION

Self-compacting concrete (SCC) is a unique concrete from convectional concrete because it can be laid and compacted due to its own weight without causing any vibration or with minimal vibration (EFNARC, 2002). In addition, SCC has the tendency to segregate and bleed due to its enough cohesive nature. The most influential characteristics of SCC are good passing ability, high flow ability, and high segregation resistance (Lalitha, 2020). Concrete is a construction material that can be exposed to high temperature due to fire outbreak. Its exposure can lead to damage of concrete structures despite not been a combustible material. Elevated temperature alters physical, chemical and mechanical changes in concrete properties. Also, the environmental impact caused by cement is enormous. The production of cement is costly and also consumed higher energy for its production. It causes increase in the extraction of natural resources and release higher CO_2 during the cement production. This has given rise to the search for more efficient and environmental-friendly materials that can replace binders in concrete production. The cement industry accounts for 5 – 8% of CO_2 emission globally and it is regarded as the second largest producer of this greenhouse gas (Scrivener and Kirk, 2007). SO_3 and NO_2 released during manufacture of Portland cement can cause serious environmental impact such as greenhouse effect and acid rain (Dongxu et al, 2000). The cost of cement binder used in concrete works is increasing daily and unaffordable, yet the need for housing and other constructions requiring this material keeps growing with increasing population, thus created a void to be filled by finding alternative binding materials that can be used solely or in partial replacement of cement.

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II. LITERATURE REVIEW

2.1 Pozzolans

Pozzolan is defined as a siliceous or alumino-siliceous material that, in finely divided form and in the presence of moisture, chemically reacts at ordinary room temperature with calcium hydroxide, released by the hydration of Portland cement, to form compounds possessing cementitious properties (Canadian Standard Association, 2000). Pozzolans main function in concrete is to enhance the workability, durability and strength (Olawuyi et al., 2017). American Concrete Institute (2000) categorised Pozzolans into two categories, they are natural or artificial, depending on their source. Natural pozzolans are either raw or calcined natural material-such as ash, shale, or some diatomaceous earth that have pozzolanic properties. Artificial pozzolans are mostly from by-product materials.

2.1.1 Classification of Pozzolans.

Table 1: Requirements of Pozzolana. (ASTM Specification C618-92a, 1994).

Chemical Requirements	Mineral Admixture Class		
	N	F	C
Silicon dioxide, Aluminium dioxide and Iron oxide (SiO_2+Al_2O_3+Fe_2O_3), Minimum %	70	70	50
Sulphur Trioxide (SO_3), Maximum %			
Moisture content, maximum %	4.0	5.0	5.0
Loss on Ignition, maximum %	3.0	3.0	3.0
Available alkalis as Na2O, maximum%	10.0	6.0	6.0
	1.5	1.5	1.5
PHYSICAL REQUIREMENTS			
Fineness, maximum % retained on 325-Mesh (44µm) sieve.	34	34	34

2.1.2 Benefits of Pozzolans

ACI, (2000) said that Pozzolans did not only strengthens the concrete but have the following benefits as well.

(i) Concrete produced from pozzolans are less costly than ordinary Portland cement.
(ii) Concrete produced from pozzolans continues to gain increasing strength with time.
(iii) Pozzolana decreases the permeability of concrete.
(iv) Pozzolana concrete has the ability to resist the attack by aggressive compounds and hence increases concrete durability.
(v) Pozzolans have other benefits such as reduction in shrinkage, low heat production, improve workability of concrete etc.

2.2 Self-Compacting Concrete.

Self-compacting concrete (SCC) is unique from traditional concrete because of its property to be laid and compacted due to its own weight with minimal vibration or no vibration. In addition, SCC has the ability to segregate and bleed due to its enough cohesive nature. The most influential properties of SCC are good passing ability, high flowability, and high segregation resistance (EFNARC, 2002). The addition of pozzolanic materials as a partial replacement to OPC in SCC is an effective way to improve the fresh state and harden properties of concrete. This is due to the fact that calcium hydroxide (Ca $(OH)_2$) produced by cement hydration reacts with pozzolanic materials like rice husk ash (RHA) to produces additional calcium silicate hydrate (C-S-H) gel. The formation of this gel helps to improve the strength and durability of concrete through altering the pore structures of concrete.

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2.2.1 Advantages of SCC Over Conventional Concrete.

EFNARC (2002) stated some of the advantages of using self-compacting concrete, they are:

(i) Improved quality of concrete, faster construction times and overall costs.

(ii) Facilitation of introduction of automation into concrete construction.

(iii) Substantial reduction of environmental noise loading on and around a site.

(iv) Better surface finishes and easier placing.

(v) Improved durability, and reliability of concrete structures.

2.2.2 Workability Properties of SCC

Workability is the ability of a fresh (plastic) concrete mix to fill the form/mould properly with the desired work (vibration) and without reducing the concrete's quality. Slump test is used to measure the workability of a fresh concrete.

Table 2: Test methods for workability properties of SCC (EFNARC. 2002)

Method	Property
Slump-flow by Abrams cone	Filling ability
T50cmslumpflow	Filling ability
J-ring	Passing ability
V-funnel	Filling ability
V-funnel at T5minutes	Segregation resistance
L-box	Passing ability
U-box	Passing ability
Fill-box	Passing ability
GTM screen stability test	Segregation resistance
Orimet	Filling ability

For the initial mix design of SCC all three workability parameters (filling ability, passing ability and segregation resistance) need to be assessed to ensure that all aspects are fulfilled. A full-scale test should be used to verify the self-compacting characteristics of the chosen design for a particular application. For site quality control, two test methods are generally sufficient to monitor production quality. Typical combinations are Slump-flow and V-funnel or Slump-flow and J-ring (EFNARC, 2002).

Table 3: Workability Test (EFNARC, 2002)

Workability Tests	Requirements
Slump flow - Abrams	650 – 800 mm
T 50cm slump flow	2 – 5 sec
J Ring	0 – 10 mm
V Funnel	8 – 12 sec
V Funnel- T 5min	+ 3 sec.
L Box	H2 / H1 = 0,8-1,0
U Box	H2-H1 = 30 mm max
Fill Box	90 – 100 %
Screen Stability	0 – 15 %
Orimet test	0 – 5 sec

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2.3 Rice husk Ash

Rice husk Ash is regarded as super-pozzolana because of the large amount of silicon dioxide which is recommended for use in concrete production. Rice husk ash is one of the promising pozzolanic materials that can be blended with Portland cement for the production of durable and forms a calcium silicate hydrate (CSH) around the cement particles which is highly dense and less porous, and may increase the strength of concrete against cracking. Rice husk ash is a suitable source of pozzolanic material among agricultural waste components and available in large quantities. It improves durability properties of concrete (Abalaka, 2013).

2.3.1 Chemical Properties of Rice Husk Ash.

Table 4. XRF analysis for rice husk ash at 700ºC

Compound	Composition (%)
Al_2O_3	3.22
SiO_2	73.2
Fe_2O_3	1.77
Pb_2O_3	8.75
SO_3	0.15
K_2O	5.67
CaO	4.38
TiO_2	0.24
Cr_2O_3	0.003
MnO	0.67
CuO	0.02
ZnO	0.17
Cl	Nd

Source: Taku (2016).

2.3.2 Mechanical Properties of Concrete Produced with Rice Husk Ash.

Osama et.al (2021) reported the use of Rice Husk Ash (RHA) in the presence and absence of steel fibers in concrete production. The performance of concrete was examined. A total of nine mixes were designed, one control, four were without steel fibers containing only RHA, and the remaining four mixed RHA with steel fibers from 0.5 to 2%. Tests with 5, 10, 15, and 20% percentages of RHA replacing the concrete were targeted. Results were compared with the reference samples. From the results, it was revealed that about 10% of cement might be replaced with Rice Husk Ash mixed in with steel fibers with almost equal compressive strength. The replacement of cement more than 15% with RHA will produce concrete with a low performance in terms of strength and durability.

Seyed and Mojtaba (2017) revealed the benefits resulted from various ratios of rice husk ash (RHA) on concrete indicators through 5 mixture plans with proportions of 5, 10, 15, 20 and 25%. RHA by weight of cement in addition to 10% micro- silica (MS) to be compared with a reference mixture with 100% Portland cement. The results indicated the positive relationship between 15% replacement of RHA with increase in compressive strengths by about 20%. The optimum level of strength and durability properties generally gain with addition up to 20%, beyond that is associated with slight decrease in strength parameters by about 4.5%. The same results obtained for water absorption ratios likely to be unfavorable. Chloride ions penetration increased with increase in cement replacement by about 25% relative to the initial values (about less than one fifth).

Taku (2016) investigated the effect of the calcination temperature of rice husk on the pozzolanic properties of rice husk ash (RHA). Rice husk was collected and washed to remove sand and other impurities using the water beneficiation method and calcined at temperatures of 400, 500, 600, 700and 800°C respectively for three hours. The result of XRF analysis revealed that RHA calcined at temperatures between 400°C and 800°C contains more than 70% silica as stipulated by ASTM C618 for pozzolanas. The silica content though varies slightly with different calcination temperature of the rice husk ash. Calcination removed impurities present in the rice husk. As a whole, calcination improves the silica content of rice husk ash for use as a pozzolan and also removes mineral impurities that may affect the pozzolanic properties of the rice husk ash.

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An investigation by Obam et.al (2011) confirmed that RHA is a pozzolan and acts as a potential cementitious material. The material was mixed with 45 per cent slaked lime. The resultant product 'cement' has a specific gravity of 2.1. The initial and final setting times were found to be 4½ and 76hours respectively. The pozzolanic Activity Index of the ash was determined. It was found to be highly pozzolanic. The average compressive strength was found to be 3.2 N/mm^2 (32.6 kg/cm^2). The optimum water-cement ratio was found to be 0.86.

Dabai (2009) conducted a compressive strength tests on six mortar cubes. Cement was replaced by rice husk ash (RHA) at five levels (0, 10, 20, 30, 40 and 50%). The curing ages of the concrete were 3, 7, 14 and 28 days. The chemical analysis of the rice husk ash showed high amount of silica (68.12%), alumina (1.01%) and oxides such as calcium oxide (1.01%) and iron oxide (0.78%) responsible for strength, soundness and setting of the concrete. It also contained high amount of magnesia (1.31%) which is responsible for the unsoundness. The result of the study indicated that RHA can be used as cement substitute at 10% and 20% replacement and 14 and 28 days curing age.

2.3.2 Effect of Elevated Temperature on RHA-Concrete.

Concrete has the capacity to endure high temperature during fire outbreak due to its low thermal conductivity and high specific heat capacity but it does mean that the fire as well as the high temperatures does not affect the properties of concrete (Arioza, 2007). Exposure of concrete to fire outbreak or high temperature affects the durability of concrete and regarded as one of the most harmful ways that cause permanent damages in structures. It reduces the service life of concrete structure, cause causalities and may affects the construction's sustainability (Aydin 2019).

Mohammed et al., (2021) conducted a research on mechanical properties of self-compacting concrete subjected to elevated temperature. The materials used were cement, rice husk ash, metakaolin, and pulverized burnt bricks. Laboratory tests conducted at the hardened stage were compressive strength, weight loss, and ultrasonic pulse velocity of self-compacting concrete subjected to 200°C, 400°C, 600°C, and 800°C elevated temperatures. At 800ºC elevated temperature, the result of residual compressive strength shows that SCC produced with addition of the ternary blend at 10 % had a higher value of residual compressive strength of 27.3 % over the control specimens. Control specimens were found to have the least values of weight loss in comparison to the self-compacting concrete produced with the addition of the ternary blend. The result of residual UPV shows that self-compacting concrete produced with addition of the ternary blend at 10 % had a higher value of 8.6 % over the control specimens.

Wang (2017) conducted a study on the effect of high temperature on mechanical properties and microstructure of concrete containing rice husk ash. The result showed an improved strength when concrete was mixed with appropriate amount of RHA. At 800ºC the strength was 50% greater than of normal concrete. Thus, rice husk ash can improve the strength and temperature resistance of concrete.

According to Iffat and Bose (2016) revealed that concrete strength, cracking, spalling, moisture content, density of concrete, fire intensity, transverse reinforcement placing, type of aggregates, fibre reinforcement and water-cement ratio can affect the properties of concrete when exposed to fire.

Toumi and Resheidat (2010) identified and quantified surface cracking of concrete heated to different temperatures ranging from 105 to 1250ºC was carried out. The initial surface absorption and total porosity were measured. Crack density was determined using a flatbed scanner and images were treated using paint shop program. The total porosity was obtained using American Society for Testing and Materials (ASTM) methods as reported. The result of the investigation revealed that mechanical properties of concrete were largely affected by temperatures beyond 500°C and were very feeble when temperatures exceeded 1000°C. The surface cracks' density, initial surface absorption and total porosity by boiling methods revealed a rapid indication on concrete durability from the report.

III. CONCLUSION

The following conclusions were drawn from the review:

(1) XRF analysis of RHA showed that RHA calcined at temperatures between 400°C and 800°C contains more than 70% silica as contained in the guideline ASTM C618 for pozzolans.

(2) Concrete containing rice husk ash produced concrete that is economical, durable, workable and effective.

(3) The use of rice husk ash helps to reduce the cost of production of concrete.

(4) RHA blend with cement led to a decrease in the workability of concrete but can be corrected with the additional superplasticizer.

(5) RHA shown much better performance after 90 days of curing.

(6) Exposure of concrete to fire outbreak or high temperature affects the durability of concrete and cause permanent damages in structures. It reduces the service life of concrete.

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(7) Self-compacting concrete is unique from traditional concrete, it can be laid and compacted due to its own weight without causing any vibration but has the tendency to segregate and bleed due to its enough cohesive nature.

(8) The results also showed that substitution of 20% of the cement content by RHA powder induced higher compressive strength and improved of properties related to durability.

(9) The best possible way of disposal of waste material like RHA powder is to use it in concrete, which will reduce environmental disposal burden.

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