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Experimental Evaluation of Eco-friendly Light Weight Concrete with Optimal Level of Rice Husk Ash Replacement

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Abstract

Concrete is a versatile and cost-effective building material whose properties are influenced by age, curing condition, and installation. A number of studies deduced that there should be an association of benefits encouraged the use of partial replacements of cement seems to improve strength and durability properties of concrete. This paper presents a framework for feasibility assessment and determination of optimum percentage of rice husk ash (RHA) replacement. Five mix plans with RHA replacing ratio of 0-20% and constant micro- silica value by 10% were prepared. Tests results indicated that compressive strength increased by 20% with an increase in RHA up to 15%. The similar trend was observed in mix designs made of cement replaced by RHA up to 20% in water absorption coefficient measurement. Higher chloride ion penetration was observed in mix designs containing 25% RHA compared to that of conventional concrete. Mixes developed a slightly higher impact resistance than the control mix.

Keywords: Rice Husk Ash; Micro-Silica; Lightweight Concrete; Compressive and Durability Properties.

1. Introduction

Today, construction industry encountered host of problems mostly concerned with associated environmental warnings, disposal of wastes, and depletion of natural resources. There has been a nominal decrease in the availability of quality natural aggregates especially in the last 15 years has compelled authorities in some countries to put a series of restrictions on natural aggregates extraction and utilization [1]. A significant amount of carbon dioxide (CO2) and other greenhouse gases (GHGs) release into the atmosphere by the production of Ordinary Portland Cement [2]. It is estimated that approximately one ton of carbon dioxide is generated in production of one ton Portland cement [3, 4]. The maintenance and improvement of living conditions requires a particular focus on ecology and environmental protection worldwide [5].

Over the last twenty years, the observed values of by-products have encouraged a number of researches concerned substituent materials to have a cleaner production. Eco-friendly materials using renewable and local resources are in full development [6]. These include industrial (steel slag, copper slag, waste iron, fly ash, lime stone, pond ash, etc.) and agricultural by products (hemp shives, flax, reed, expanded cork, natural wood, rice husk ash, etc.). The waste utilized as cement replacement include minerals derived from other production processes. Cement replacement materials include

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Meta kaolin (china clay), brick powder, stone dust, industrial wastes (i.e. Fly ash, silica fume, blast furnace slag, etc.), and agricultural wastes (i.e. Rice husk ash, wheat straw ash, hazel nutshell and sugarcane bagasse ash, etc.) [7, 8]. Pozzolans are either natural or artificial and have little or no cementitious value by itself [9], led to improved workability, resistance to sulphate attack, thermal cracking, ultimate strength and durability, and decreased permeability [10].

Burning rice husk leads to the production of ash which is burned or excreted in open land as waste and is becoming increasingly an environmental burden. It is estimated that about 120 million tons of RHA in produced across the globe [11], while 25% of theses RH is converted to RHA by burning in to boiler [12]. The quality of the rice husk ash lies on some factors as burning temperature, duration of burning, air supply requirement during burning, the cooling rate, and the grinding time [13].

Muhammad Shoaib Ismail et al, in early works associated with feasibility assessment and analysis of bagasse ash application reviewed 3rd, 7th, 28th and 150th specimens containing 10 to 30% RHA as a partial replacement of cement on compressive and split tensile strengths. The strength of samples lacking any RHA were obtained over 70 MPa [14]. In another study Martinera et al. studied the effect of various waste ashes as Pozzolans in lime-pozzolanic binders [15]. This material usually poses a disposal problem in sugar factories [16]. Kartini, stated that replacing rice husk ash instead of ordinary Portland cement led improving in strength and durability of concrete [17]. Kumar and Gupta reported that the cement-stabilized mix with optimum percentage of RHA and pond ash can be successfully used as fillers in geotechnical matters [18]. D. Bui, J. Hu indicated that rice husk ash as a pozzolanic reactive material can be used to improve the microscopic structure of transfer surface area between the cement pastes and aggregate [19]. Coutinho reported that adding rice husk ash to concrete examples reduces capillary water absorption [20]. In addition to confirm this view, Chindaprasirt reported that chloride ion penetration depth can be decreased by RHA incorporation in the samples [21]. The use of locally available RHA, and cement can provide sustainability for the local construction industry [22]. Pozzolanic potential, strength development of mortars and concrete, efficiency factors, chloride penetration were tested by Antiohos, S. K., et al, revealed the importance of the binary action of RHA in producing competitive blended cement and concrete [23, 24]. Properties of concrete with different percentages of RHA (10% and 20% by weight) were investigated by Mohammad Badrul Ahsanet al, also fresh concrete properties (slump, unit weight, air entrainment etc.) as well as mechanical properties (compressive, tensile, flexural strength) of hardened concrete were determined. The maximum compressive strength obtained by 10% RHA-modified concrete was 56% of that of the control specimen, and tensile and flexural strengths achieved by 10% replacement level were 76% and 96%, respectively, of those of the control samples[25]. The experimental results of nanostructure estimation of mortar containing RHA indicated that, with the increase of RHA dosages of samples, the volume fraction of high-density calcium-silicate-hydrate (HD C-S-H) in porosity and hydration product phases increases [26].

Our present area of research is to evaluate the suitability of concrete containing locally available RHA as a partial replacement of cement, by weight following some experimental backgrounds besides the perfect estimations by replacement that were made in percentages of 0-20%. The compressive strength, water permeability, chloride ion penetration, impact resistance, and tensile strength were assessed experimentally. All of the test results were evaluated to achieve the optimum level of RHA replacement.

Figure 1. Rice husk ash

2. Experimental Procedure

2.1. Materials

Materials used in this research include cement; light weight gravel (Qorveh pumice), sand, super plasticizer, rice husk ash and micro-silica.

2.1.1. Cement

Ordinary Portland cement (OPC) is denoted as the most common type of cement using nowadays in construction of roads, docks, bridges and so on, may be hardened both in the air or underwater conditions, then by increasing strength over time. The cement used in this study is sulphate-resistant cement type II with medium heat of hydration, its physical properties and chemical composition are represented in the following tables:

Table 1. Physical properties of cement used in this study

Property	Density (g /cm^3)	Specific surface Blaine (cm^2/g)	compressive strength at 28 day (MPa)	Stacking density (g/cm^3)
Content	3.14	3460	41.2	1.17

Table 2. Chemical analysis of cement

Constituent oxides of cement	Cao	Al_2O_3	Fe_2O_3	Sio_2	Mgo	SO_3	Na_2O+K_2O	LOI
Portland cement type II	63.61	4.5	3.19	21.2	2.05	2.86	1.09	1.5

Cement and RHA particle sizes are shown in Figure 2. As it is clear in the figure, both two materials are similar in size.

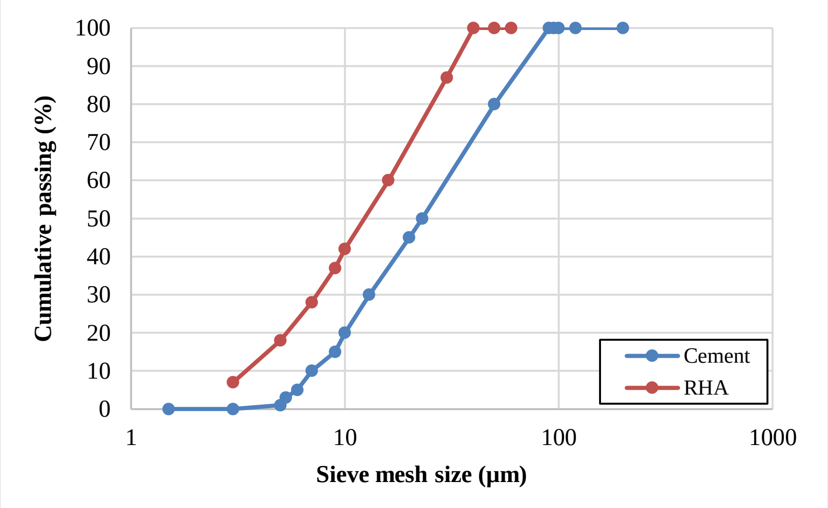


Figure 2. Particle size distribution of cement and rice husk ash

2.1.2. Micro-Silica

Silica fume, also known as micro silica, is an amorphous (non-crystalline) polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles. Silica fume is an ultrafine airborne material with spherical particles about 0.1 μm and is approximately 100 times smaller than the average cement particle [27].

Many investigations have been undertaken to establish the major role of micro-silica in producing concrete resistant by following standard regulations and theses highlight the important factor of considering mineral additives. Generally, micro-silica is a sub-material in the production of silicon, particularly ferrosilicon alloy i.e., is a by-product of electric arc furnaces during the production of ferrosilicon alloys. This highly pozzolanic material contains more than 90% silica, including non-crystalline state and extremely fine particles in the range of 0.1 diameter of average micron, with highly potential for cement replacement. Small particle size per unit mass made it resistance 2 to 4 times more than that of cement. Reduction of total amount of cementitious materials containing micro-silica to achieve a certain resistance will in turn reduces the concrete forming heat.

Table 3. Chemical composition and physical properties of micro silica

Sio2	**Mgo**	**Cao**	**K2O**	**AL_2O_3**	**Fe_2O_3**	**Density (kg/m^3)**	**Aggregate size (µm)**
96.6	0.71	0.26	0.21	1.32	0.89	550-650	0.45-0.6

2.1.3. Rice Husk Ash

Rice husk ash is an agricultural waste obtained from burning rice husk under controlled temperature below $800\ ^{\circ}C$, to produce the average amount of 25% ash which includes 85% to 90% silica non crystalline, and 5% aluminium oxide all makes it very pozzolanic. It was reported that for about $1000\ kg$ of milled rice, $55\ kg$ of rice husk ash was found to be produced. The apparent density of rice husk concrete is about $600\ kg/m^3$ or higher, depending on the proportion of husks, cement and the degree of compaction [5].

In India, the largest producer country of rice, approximately annually 20 million tons of rice husk ash is produced [28]. In some countries, rice may be considered as one of the dominant agricultural products, while open heap burning is not acceptable on environmental grounds, and the majority of husk is currently going into landfills [29]. Huge amount of lands has been allocated to rice planting in Iran. Therefore, recycling the large amount of remained rice hulls has become a burden led to host of problems in these areas. For the present study, rice husk was provided from the city of Lenjan located in Isfahan, and then it was burned inside the furnace at $600\ ^{\circ}C$ for 1h, as it can be seen in Figure 1. The results of X-ray fluorescence (XRF) analysis testing of these samples are presented in Table 4. compared to the same results obtained by Ramezanianpour et al, [30] which is shown in Table 5.

Table 6. is the representation of standard chemical requirements of pozzolanic materials.

Table 4. XRF test results

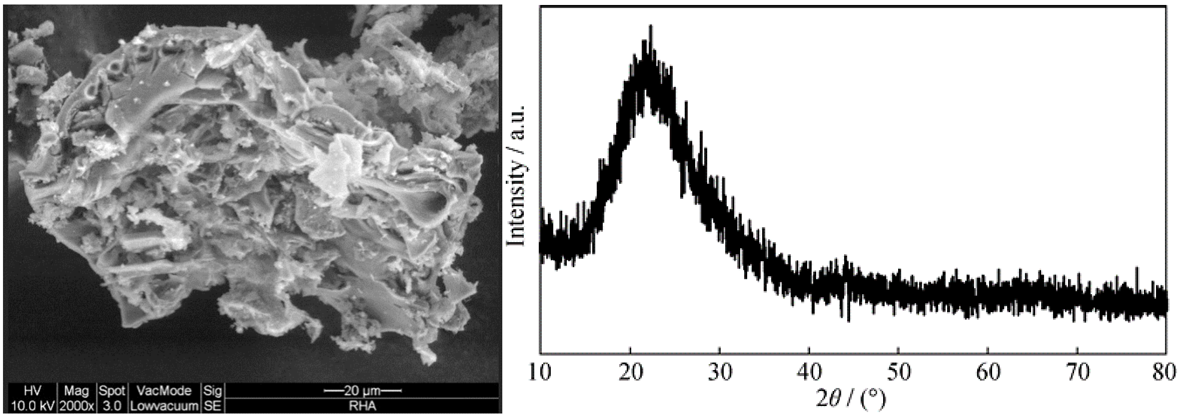
Compounds	Na_2O	Cao	K_2O	Fe_2O_3	Sio_2	Al_2O_3	Mgo	SO_3	P_2O_5	Tio_2	LOI
Percentage	0.08	0.61	1.32	0.13	86.73	0.04	0.39	0.35	0.54	0.01	9.76

Table 5. Results of XRF on rice husk ash samples and cement [30]

		550 c	600 c	650 c	700 c	750 c	Cement type II
		6O Minutes					
ELEMENTS	Sio_2	75.22	80.55	89.61	89.93	93.11	21.5
	Al_2O_3	0.05	0.02	0.04	0.06	0.08	6.1
	Fe_2O_3	0.14	0.24	0.22	0.11	0.27	3.19
	Cao	0.57	0.59	0.91	0.88	0.67	65.9
	SC_3	0.37	0.34	0.15	0.14	0.11	2.5
	Mgo	0.36	0.39	0.42	0.39	0.44	2
	Na_2O	0.07	0.06	0.07	0.09	0.06	0.2
	K2O	1.47	1.65	1.58	1.48	1.69	0.4
	P_2O_5	0.51	0.44	0.41	0.55	0.63	0.23
	Tio_2	0.01	0.02	0.02	0.02	0.02	0.04
	LOI	21.01	15.33	5.91	6.01	2.67	1.35

Table 6. Standard chemical requirements of ASTM 618 for Pozzolans [31]

Chemical properties	Results of tests on rice husk ash	Standard requirements
Maximum of SO_3 %	0.35	4%
Maximum humidity (%)	0.29	3%
Minimum of (SIo_2+Al_2O_3+Fe_2O_3) (%)	86.9	70%
Maximum weight fraction by become ash%	5.4	6%



(a) (b)

Figure 3. a) SEM image of RHA [32]; b) XRD pattern of RHA at 500°C (500RHA) [33]

2.1.4. Pumice

This grey and black stone generated by weathering of accumulated volcanic ash after reaching the earth's surface coincide with expansion of bubbles by steam and gases to be contained, form a coarse and porous granular light weight material with very high strength. Variability of pumice particles size placed in the range of dust particles to large pieces, each with specified applications. Using this material in prefabricated concretes greatly reduces building total weight, and therefore iron and concrete mass, demolishes extent, and physical damage occur in earthquakes. A series of properties as low specific gravity, high compressive strength, elastic constants and resistance in action of fire are among the most contributing factors of pumice incorporation in concrete structures, prefabricated components and light filling.

Table 7. Properties of aggregates used in this study

					Water absorption (mass ratio)				
Type	**Aggregates**	**Form/ Plan**	**Production Method**	**Raw Materials**	**24 H**	**60 Min**	**30 Min**	**Bulk Density**	**Granular Density**
Natural	Pumice	Irregular	Mechanical	Pumice	20-40	20-30	10-20	500-800	900-1900

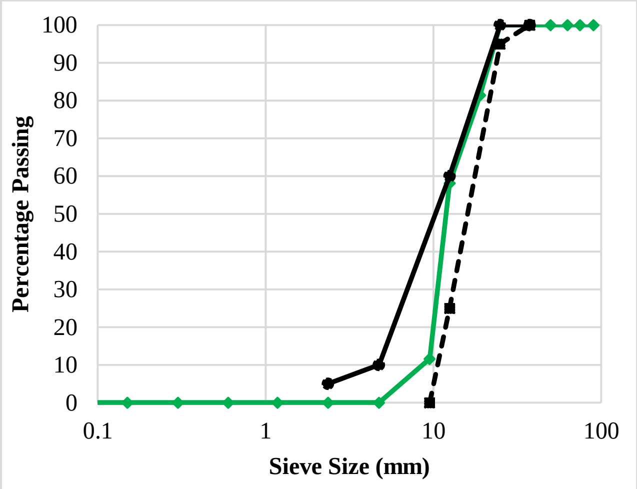


Figure 4. Particle size distribution of pumice aggregates (gravel)

2.1.5. Super Plasticizer

Superplasticizers typically offer more surface areas in contact with water and better cement hydration in long term services possibly increase resistance of concrete compared to the same w/c ratio containment without any additives. Considering durability, water-reducing additives restrain concrete to be permeated with fluids and solutions. It has been established that providing high plasticity and initial and final strengths are advantages of plasticizers involved in prefabricated concretes. In this respect plasticizers mainly function as:

1) Water reducing from 18 to 20%, even potential reduction up to 40%,

2) Creation high slump, flowing and instant self-levelling.

2.1.6. Sand

Locally available washed river sand with particle size of $0-5\ mm$ and specific gravity equal to $2545\ Kg/m^3$ was provided from Isfahan Sofeh (a place near Isfahan) mine. The sand grains hinder the coarser aggregates from sinking and thus prevent sedimentation [34].

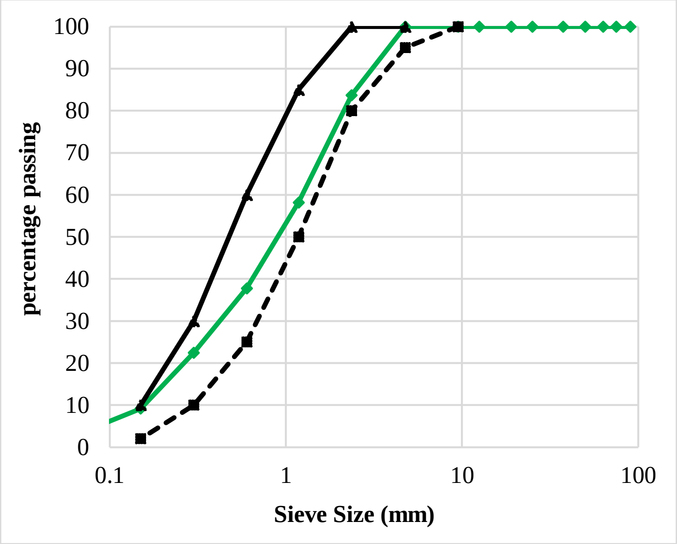


Figure 5. Particle size distribution of sand aggregates

3. Mix Design

Based on aforementioned studies, five mix plans were made with constant w/c ratio of 0.38 and 10% micro- silica powder in which a portion of cement was replaced by RHA in weight ratios of 0%, 5%, 10% and 25% in which OPC was replaced partially by weight with RHA, and a reference mix lacking RHA. Mix designs are shown in Table 8.

Table 8. Mix design (Kg/m^2)

Mix design	W/c ratio	RHA*	Cement	Percentage of Micro-silica	Water	Gravel-Pumice Max 19 mm	Ordinary Sand	Super plasticizer
CTL	0.38	0	450	10	190	340	500	15
RHA 5%		5	427.5					
RHA 10%		10	405					
RHA 15%		15	382.5					
RHA 20%		20	360					
RHA 25%		25	337.5					

* RHA: rice husk ash, CTL: control

A series of cube specimens from each mix design of dimensions $10 \times 10 \times 10\ mm$ were prepared. The first sets of specimens were cured separately at 7 and 28 days to measure the compressive strength, two specimens were employed for 24 h water absorption evaluation, and two tests were conducted for chloride ions penetration detection. Another parameter to be tested was the tensile strength (Brazilian or split test) using two cylindrical samples of $15 \times 30\ cm$ size that were cured at 28 d.

The experimental methods used here to determine concrete properties are shown in Table 9. The hardened density was evaluated in accordance with ASTM C642-13. The 7th, and 28th day specimens were evaluated to have the compressive strength, splitting tensile strength and impact resistance. Water absorption coefficient and accelerated chloride ion penetration test (RCPT) were determined based on the provisions of ASTM C642-13and ASTM C1202, respectively [35-39].

Table 9. Standard codes to determine concrete properties

Target properties	Method
Hardened density	ASTM C642-13
Compressive strength	ASTM C39/C39M-14
Splitting tensile strength	ASTM C496/C496M-11
Flexural strength	ASTM C78/C78M-10
Water absorption	ASTM C642-13
Accelerated chloride ion penetration test (RCPT)	ASTM C1202
impact resistance test	ASTM G544

Figure 6. Experimental samples

3.1. Compressive Strength Test and Average Density in a State of Saturated Surface Dry (S.S.D)

Sample size is of factors for changing the compressive strength, i.e. compressive strength of a 28th d cylindrical sample was found to achieve 80% of that of a sample by 150 mm size and 83% of that of a cube specimen by 200 mm size. While, the compressive strength of both light weight concrete samples was almost the same. Specimens once demoulded were immersed in cold water tank, then placed under the hydraulic jack., while a controlled load (up to 3 MPa/s) was applied on specimens using a hydraulic jack (a standard press machine (ELE hydraulic jack -ADR-Auto V2.0 2000 standard compression) to determine the specific gravity and short-term water absorption coefficient. It should be noted that density of concrete is strongly affected by the specific gravity of ingredients; therefore, incorporation of lighter materials leads to reduction in specific weight of concrete. Structural lightweight concrete is a term used to describe concrete with a density less than 2000 kg/m^3, and compressive strength of more than 17 MPa [40].

In another study, the compressive strength of 28th and 91th d mixes containing RHA were higher than that of the reference mix lacking any RHA, maybe due to high reactivity of this pozzolanic waste [18]. It was proved that longer curing (at 28–91 days) may be the reason of higher compressive strength values in the mixtures investigated [42]. In the case of the compressive strength and chloride ingress determination, standard practice of curing for 28 d was found to be adequate. It was found that curing period up to 90 days assumed to be beneficial only in case of improving the resistance to water absorption [43].

W. Chalee a, et al., stated that corrosion resistance of concrete after 5-year exposure in a marine environment indicated that concrete containing RHA gained strength faster than type I Portland cement concretes align with lack of strength loss in RHA concrete [44].

Table 10. compressive strength test results

Characteristic of design	7-day compressive strength	28-day compressive strength	Average density S.S.D*
CTL	35.03	50.78	1964
RHA 5%	38.27	55.47	1947
RHA 10%	36.55	54.56	1932
RHA 15%	39.41	57.10	1930
RHA 20%	41.67	60.36	1913
RHA 25%	38.65	56.84	1889

* S.S.D: Saturated Surface Dry

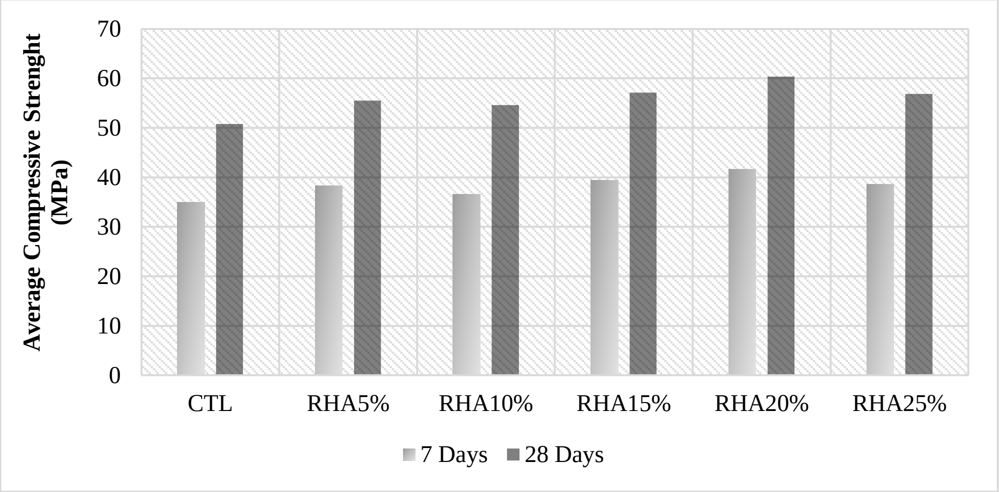


Figure 7. The results of compressive strength test (MPa)

The results indicated that increase in RHA up to 5% instead of cement by weight led to increase in the compressive strength achieved by approximately about 9% of those of the control sample at 7 and 28th d of curing. It was indicated that strength of 10% RHA modified concrete reduced with an ascending rate. The highest strength was observed in mix designs made of a substitution of cement partially by weight with 20% RHA. Optimum percentage replacement was obtained with 20% RHA.

3.2. Tensile Strength

Measurement of the tensile strength is conducted in two ways:

1) By measuring the tensile strength of pure tension

2) By measuring the tensile strength under strain due to bending

The first mode of tensile strength measurement normally used in evaluation of pure tensile strength indirectly led to underestimation of strength when lateral pressure- induced is measured on cylindrical samples using a hydraulic jack until the failure point. This test normally is denoted the Cylinder splitting test or Brazilian tests. Simple standard test methods were found to experimentally measure the tensile strength of concrete in strain due to bending mode. For this purpose, a simple concrete beam of $50 \times 10 \times 10\ cm$ size was placed on two supports with two identical loads were imposed in one-third distance from the end of the support beam, until the initiation of cracking. The strength of concrete in the latter is less important.

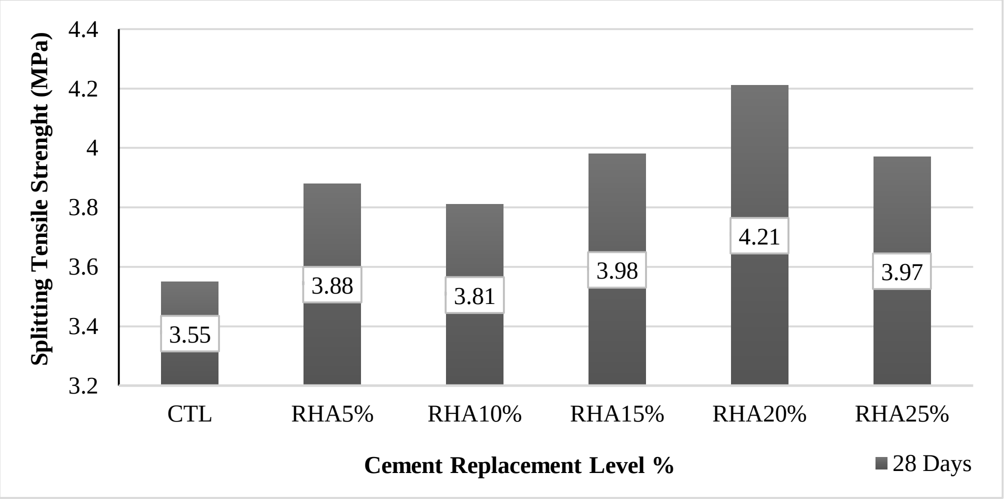


Figure 8. The results of indirect tensile strength test (MPa)

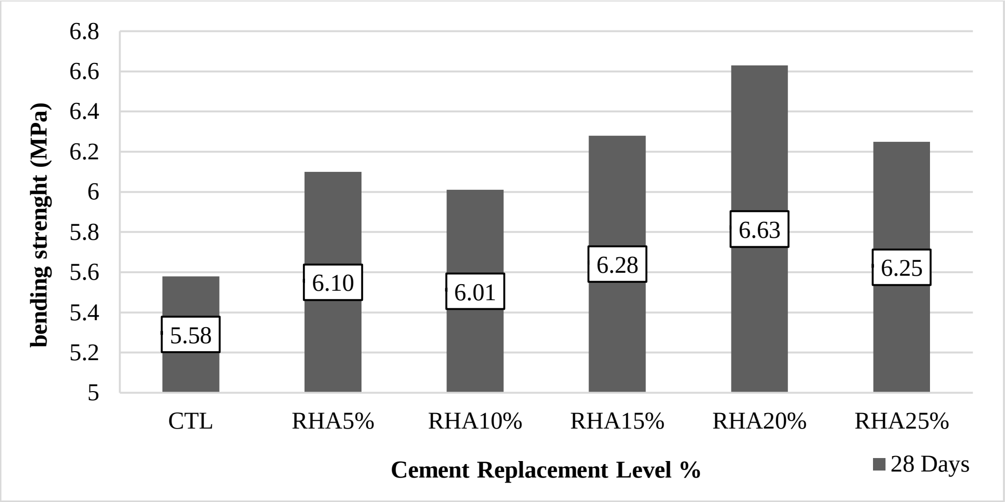


Figure 9. Test results of bending tensile strength (MPa)

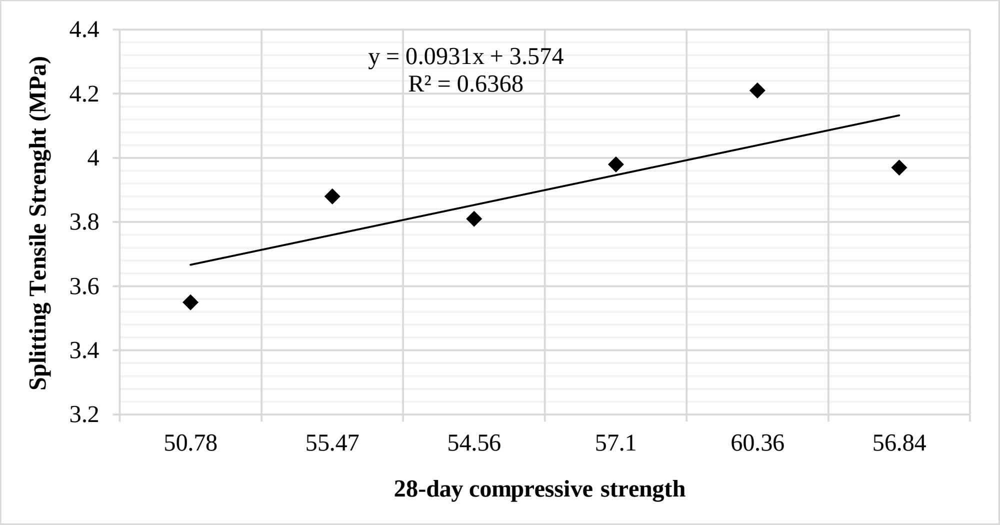


Figure 10. Correlation between 28 d compressive strength and splitting tensile strength (MPa)

The lowest compressive strength led to the lowest tensile strength gained by 5% RHA- modified samples by $3.55\ MPa$ at 28th day. The maximum compressive strength and tensile strength were observed in mix design made of cement containing 20% RHA reached by 60.36 and 4.21, respectively. It can be concluded that, RHA replacing ratio up to 20% was acceptable, beyond that was associated with a descending rate of strength gained.

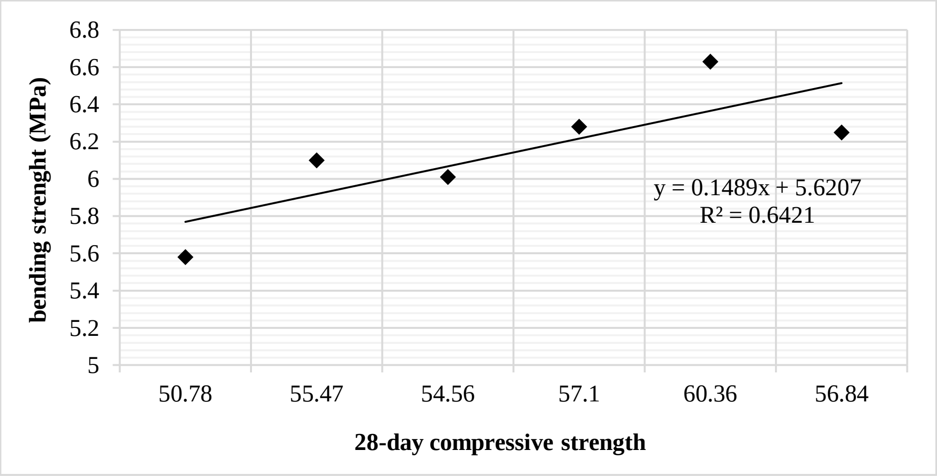


Figure11. Correlation between 28 d compressive strength and bending strength

Test performed in accordance with standard test methods indicated that tensile strength increased with 5% RHA due to pure tension and bending reached by 109% of those of the reference sample with a descending rate. Conversely, tensile strength decreased slightly with an increase in RHA by 10% in early ages. The minimum tensile strength was observed with 20% RHA as a partial replacement of cement, as it can be seen in figures 7 and 8. It can be concluded that there should be a positive relation between tensile strength and the compressive strength, means to increase in the compressive strength leads to increase in the tensile strength accordingly.

3.3. Water Absorption Test

Samples were designed to develop 28-day water absorption. Once the specimens were demoulded they were transferred in to an oven at 105 $°C$, then immersed in water for 24 h and weighted precisely to determine the saturation weight. Water absorption coefficient can be defined by the following equation:

$$\text{Water Absorption } (\%) = \frac{W_2 - W_1}{W_1} \times 100 \tag{1}$$

The result of this equation relatively indicates the concrete quality in contact with unbound environmental conditions. Concrete sample exposed to desiccation lacking residual water or continuous saturation proved to be more resistant in different weathering conditions.

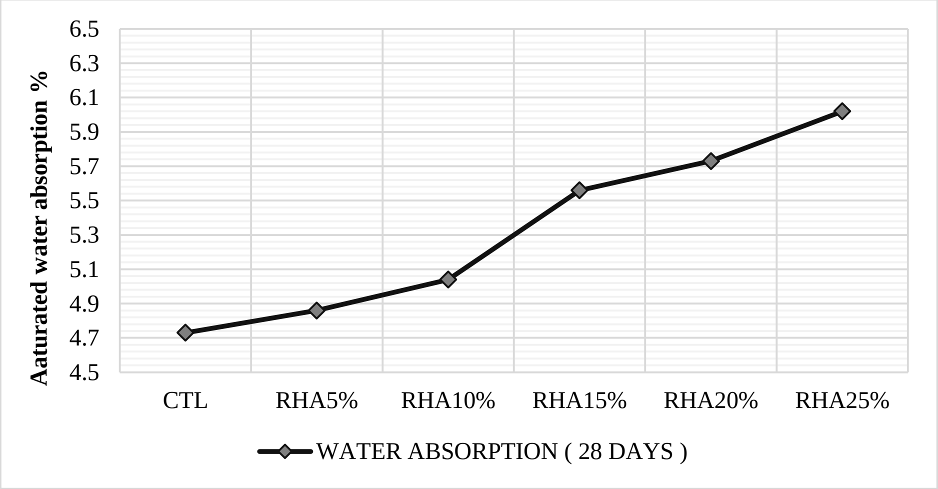


Figure 12. Results of short-term water absorption of different samples

General ways of water absorption tests are as follows [45]:

- The sample should be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22 and 32 ^{o}C.
- After immersion, the entrapped air should be removed by lifting the basket and allowing it to drop 25 times in 25 seconds. The basket and sample should remain immersed for a period of 24 + $^{1}/_{2}$ hours, Afterwards [46].
- The basket and aggregates should then be removed from the water, allowed to drain for a few minutes, after which the aggregates should be gently emptied from the basket on to one of the dry clothes and gently surface-dried with the cloth, transferring it to a second dry cloth when the first would remove no further moisture [47]. The aggregates should be spread on the second cloth and exposed to the atmosphere away from direct sunlight till it appears to be completely surface-dry. The aggregates should be weighed (Weight 'A').
- The aggregates should then be placed in an oven at a temperature of 100 to 110 ^{o}C for 24 hrs. It should then be removed from the oven, cooled and weighed (Weight 'B').

Cement type, the water/binder ratio, the degree of hydration and incorporation of minerals and chemical activators significantly influence the pore structure, microstructure of the paste and the transition zone between paste-aggregates [48, 49] also durability.

Inclusion of RHA reduced the pores in all mixes. Divya Chopra reported that porosity decreased with increase with age assumed to be caused by high rate of hydration with time, in which the mix containing 15% RHA had the lowest porosity [50]. The increase in water absorption with an increase in RHA replacement values was attributed to higher water absorption of pumice aggregates, low ability of RHA to fill the pores in the transition zone, high porosity due to long term pozzolanic reactions resulting from the lower reactivity between Pozzolans and Ca(CH) produced in hydration phases and lack of adhesive-bond cement creation (cement jell).

3.4. Accelerated Chloride Ion Penetration Test (RCPT)

Chloride penetration in the concrete can be attributed to electrochemical processes of cylindrical samples. The samples were placed in a 3 % (or 1.5%) NACL-solution, while the distance between the surface of the water/salt-solution and the top of the specimen may reach to 20 mm. The test setup is presented in Figure 13. The electrical current through the system is automatically recorded. Therefore, the voltage drop over a 1 Ohm reference resistance is measured and converted to a current: $V = R.I = 1.I$ according to Ohm's law [51].

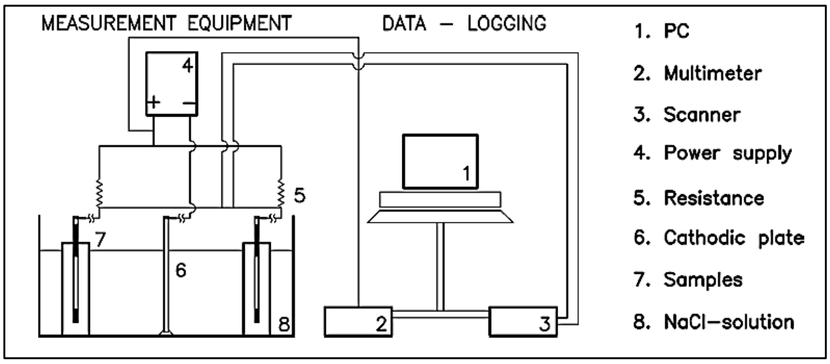


Figure 13. Schematic plan of the test setup of the accelerated CPT-test [51]

Chloride ion penetration is a term used to describe suction and diffusion phenomenon with time assumed to be shortened aimed to reach control and design. So a number of accelerated chloride penetration test methods have been proposed since early works in literature [29-30].

Ingress of chlorides or specific and unique destroyers in to concrete is the main reason of deterioration of concrete structures in many parts of the world [52]. Chloride ions originated from different sources as contaminated materials, soils, de-icing salts and exposure to sea water. Diffusion, hydrostatic pressure, and capillary absorption are the means by which chloride ions can penetrate concrete [53]. Concentration of free chloride ions in concrete pore solution seems to be the main factor chloride- induced corrosion. In Figure 14, total amount of electrical charges measured for mix plans with different percentage replacements in Coulomb is represented. Both rapid chloride permeability test (RCPT) as described in ASTM C1202-17 and diffusion test on the same mixes allowing the results to be known more reliable in terms of the relationship between the diffusion coefficients, indicate reduction of charge passed through the specimens with increase in RHA content [40]. RCPT is a well – established method to provide quick comparative tests on different concrete mixes, and hydrophobic factors using diffusion coefficient and chloride penetration times. In this test, the total amount of charge passed through a concrete cube sample under 60 V was measured for 6 h. To ensure saturation, all samples were placed in an mmhg1 vacuum chamber. Accordance to Kartini, increased replacement of RHA may be resulted in less charge passed values, which reduces along with increase in curing period. So, more replacement of RHA leads to less percentage of chloride ions penetration [17].

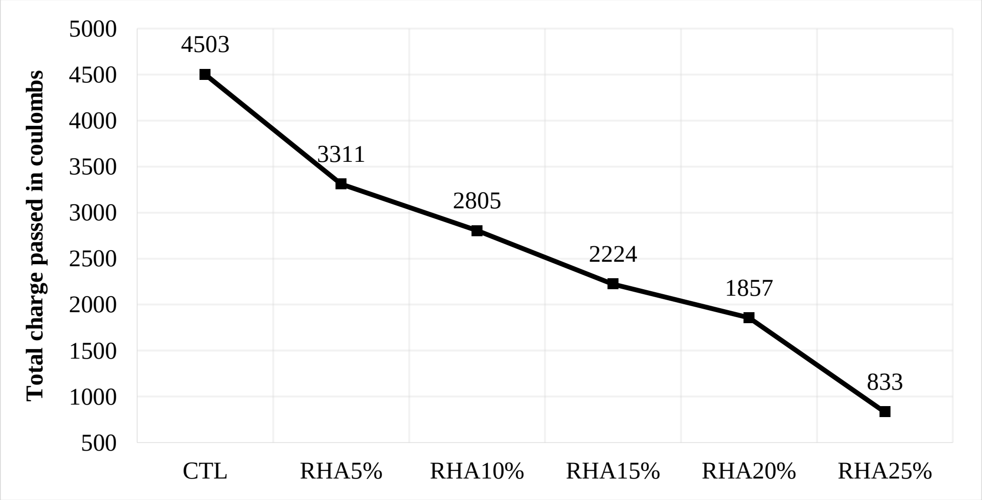


Figure 14. Results of chloride ions accelerated penetration test (Coulombs)

The more cement was replaced with RHA by weight, the less was the charge passed in all series in agreement with the ascending rate of chloride ions ingress accordingly. According to standard of passing electric flux (Coulomb) of light weight concrete, the amount of charge passed in all series of mixes was medium range, in average. It is expected that higher ratios of RHA addition lends increased loss in chloride ions ingress.

3.5. Impact Resistance Test

Impact testing aimed with measuring partial or total material's ability to resist impacts or high-rate loadings before approaching returned conditions to establish functionality, safety and liability of a material for a specified structural application. Impact resistance is one of the most difficult parameters to quantify. It involves Charpy and IZOD Specimen configurations. The Charpy Impact Test can be operated using instrumented machines with the ability of measuring less than 1 foot-pound to 300 foot-pounds, at temperatures variations ranging from $-320\ °F$ to more than 2000°F. Specimen types in impact tests often include notch constructions as V-Notch, U-Notch, Key-Hole Notch, Un-notched and ISO (DIN) V-Notch, with different abilities of impact testing of specimens even down to ¼ size.

To the author's knowledge there may not be a clear relationship between impact resistance and the compressive strength. The most familiar method is falling weight test under iterative impacts. Simple to conduct is the main reason of its widespread usage. For this to occur, the number of beats from the initial cracks (on the surface of the specimen) to crack occurrence by width of 2.5 cm was recorded, all based on ASTM G544 impact resistance tests [38].

Table 11. Impact resistance results of samples

Mix design	Concrete specific gravity Kg/m^3	Impact resistance First crack/ final failure	Compressive strength (MPa)		Age (days)
CTL	1964	13	25	50.78	28
RHA5%	1947	17	31	55.47	28
RHA10%	1932	14	27	54.56	28
RHA15%	1930	22	44	57.10	28
RHA20%	1913	27	49	60.36	28
RHA25%	1889	18	36	56.84	28

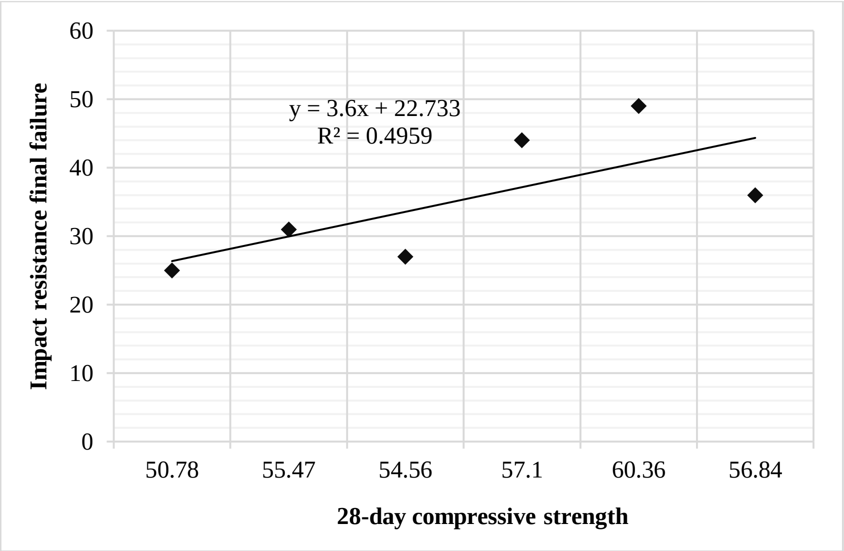


Figure 15. Correlation between the compressive strength and impact resistance

It was observed that impact resistance increased up to 24% with increase in percentage level of RHA up to 5%. Samples with 10% replacement demonstrated a slight reduction in impact resistance. It was found that within 15-20% percentage replacement, values of impact resistance were comparable to that for the reference sample, therefore impact resistance reached by 76% and 96% of those of the reference sample, respectively. The highest values of impact resistance were observed in 20% RHA- modified samples reached by approximately about 196% of those of the reference sample. There was found a linear relation between the compressive strength and impact resistance of the samples that can be observed in Figure 12. The enhanced compressive strength led to increased impact resistance. The lowest compressive strength gained by the control specimen led to the lowest impact resistance gained by 25 MPa. The maximum compressive strength and impact resistance gained by 40% RHA- modified concrete was 60.36 and 49 MPa, respectively. The optimum percentage replacement was observed in 20% RHA- modified samples.

4. Conclusion

There exists a huge potential of feasibility of utilizing different by-products as partial replacement of cement to attain improved mechanical properties, also environmental benefits, cost reduction and cleaner production of green products. A number of by-products generally improve strength attributes of by-products substitutes concretes compared to control sample lacking any supplementary material. These wastes seem to have the property to improve strength and durability characteristics of concretes. Literature review points out the need to provide a framework of additional experimental efforts aimed with the real assessment of optimum percentage replacement and disadvantages of RHA with age. It was concluded that the optimum performance obtained with replacement level of 20%. The following conclusion can be drawn from the experimental tests:

- Light weight concrete is a term used to materialize concrete incorporated with either natural lightweight aggregates such as pumice, scoria, volcanic cinders, diatomite or artificial aggregates as expanded clays, slates, slag, etc. Such low-density aggregates seem well suited to improved environmental and economic impacts.
- The lowest workability of mix designs made of cement was observed at 25% replacement with RHA.
- Inclusion of 15% RHA into concrete as a partial replacement of cement led to a decrease in permeability.
- It can be established from related studies that partial substitution for cement can be made with RHA as an agricultural waste and micro-silica can open up new ways to achieve eco-friendly green concrete products.
- The amount of silica added into concrete is tantamount to the performance of RHA that may be attributed largely to the existence of amorphous silica by 85% to 95% in RHA composition, by weight whose reactivity largely lies on the burning process led to increased surface area of transition zone between the microscopic structure of cement paste and aggregate in the high-performance concrete.
- It was found that percentage replacement of RHA by 25% led to enhanced strength approximately reached by 38% and 56% at 7 and 28 d of curing, respectively with a descending rate in higher replacements due to reduced hydration and cement weight. Therefore, there was found a linear relation between percentage replacement of RHA and modified microstructure of transition zone in hardened state. Pozzolanic particles react with calcium hydroxide to form C-S-H gel to impede transportation of soluble compounds into surface led to increase cement density up to 15%. The same trend was observed for the bending strength most increased up to 15% RHA replacement level.

5. References

[1] Rashad, Alaa M. "A preliminary study on the effect of fine aggregate replacement with metakaolin on strength and abrasion resistance of concrete." Construction and Building Materials 44 (2013): 487-495.

[2] V. M. Malhotra, “Role of supplementary cementing materials and superplasticizers in reducing greenhouse gas emissions,” in Proceedings of ICFRC International Conference on Fiber Composites, High-Performance Concrete, and Smart Materials, 2004, pp. 489–499.

[3] G. C. Cordeiro, R. D. Toledo Filho, L. M. Tavares, and E. de M. R. Fairbairn, “Ultrafine grinding of sugar cane bagasse ash for application as pozzolanic admixture in concrete,” Cem. Concr. Res., vol. 39, no. 2, pp. 110–115, 2009.

[4] Mehta, P. Kumar, and Helena Meryman. "Tools for reducing carbon emissions due to cement consumption." Structure 1, no. 1 (2009): 11-15.

[5] Claudiu, A. C. I. U., and Nicoleta COBIRZAN. "Use of Agricultural Products and Waste in the Building Materials Industry." Proenvironment Promediu 6, no. 15 (2013).

[6] A. M.-A. Bilba K, “Silane treatment of bagasse fiber for reinforcement of cementitious composites,” Compos A Appl Sci Manuf, vol. 39, pp. 1488–95, 2008.

[7] A. Tiwari, S. Singh, and R. Nagar, “Feasibility assessment for partial replacement of fine aggregate to attain cleaner production perspective in concrete: A review,” Journal of Cleaner Production, vol. 135. pp. 490–507, 2016.

[8] Shahnaz, Akhtar, Phool Shahzadi, Adan Mujahid, Muhammad Saadet Khan, Ammarah Abbass, and Ammarah Kanwal. "Utilization of bio materials as pozzolanic material for partial replacement of cement." (2016): 85-91.

[9] Sharif, Burhan, Rafia Firdous, and Muhammad Akram Tahir. "Development of Local Bagasse Ash as Pozzolanic Material for Use in Concrete." Pakistan Journal of Engineering and Applied Sciences (2016): 39-45.

[10] Alp, I., H. Deveci, Y. H. Süngün, A. O. Yilmaz, A. Kesimal, and E. Yilmaz. "Pozzolanic characteristics of a natural raw material

for use in blended cements." Iranian Journal of Science and Technology 33, no. B4 (2009): 291.

[11] Giddel, M. R., and A. P. Jivan. "Waste to wealth, potential of rice husk in India a literature review." In International conference on cleaner technologies and environmental Management PEC, Pondicherry, India, vol. 2, pp. 4-6. 2007.

[12] Kumar, S., P. Sangwan, R. Mor V. Dhankhar, and S. Bidra. "Utilization of rice husk and their ash: A review." Res. J. Chem. Env. Sci 1, no. 5 (2013): 126-129.

[13] A. Z. Hansen H., "Ecobuild – Environmentally friendly construction and building,." Project co - ordinator Horsens Polytechnic, Denmark, 2001.

[14] Ismail, Muhammad Shoaib, and A. M. Waliuddin. "Effect of rice husk ash on high strength concrete." Construction and Building Materials 10, no. 7 (1996): 521-526.

[15] J. Martirena Hernández, B. Middendorf, M. Gehrke, and H. Budelmann, "Use of wastes of the sugar industry as pozzolana in lime-pozzolana binders: study of the reaction," Cem. Concr. Res., vol. 28, no. 11, pp. 1525–1536, 1998.

[16] Mu'Azu, Mohammed Abdullahi. "Influence of compactive effort on Bagasse ash with cement treated lateritic soil." Leonardo Electronic Journal of Practices and Technologies 10, no. 1 (2007): 79-92.

[17] K. Kartini, "Rice Husk Ash- Pozzolanic Material for Sustainability," Int. J. Appl. Sci. Technol., vol. 1, no. 6, 2011.

[18] Gupta, Deepak, and Arvind Kumar. "Strength Characterization of Cement Stabilized and Fiber Reinforced Clay–Pond Ash Mixes." International Journal of Geosynthetics and Ground Engineering 2, no. 4 (2016): 32..

[19] J. H. and P. D. D. Bui, "Particle Size Effect on the Strength of Rice Husk Ash Blended Gap-Graded Port- land Cement Concrete," Cem. Concr. Compos., vol. 27, no. 3, pp. 357–366, 2005.

[20] J. Sousa Coutinho, "The combined benefits of CPF and RHA in improving the durability of concrete structures," Cem. Concr. Compos., vol. 25, no. 1, pp. 51–59, 2003.

[21] P. Chindaprasirt, T. Chareerat, and V. Sirivivatnanon, "Workability and strength of coarse high calcium fly ash geopolymer," Cem. Concr. Compos., vol. 29, no. 3, pp. 224–229, 2007.

[22] Gupta, Deepak, and Arvind Kumar. "Performance evaluation of cement-stabilized pond ash-rice husk ash-clay mixture as a highway construction material." Journal of Rock Mechanics and Geotechnical Engineering 9, no. 1 (2017): 159-169.

[23] S. K. Antiohos, V. G. Papadakis, and S. Tsimas, "Rice husk ash (RHA) effectiveness in cement and concrete as a function of reactive silica and fineness," Cem. Concr. Res., vol. 61–62, pp. 20–27, 2014.

[24] R. K. Sandhu and R. Siddique, "Influence of rice husk ash (RHA) on the properties of self-compacting concrete: A review," Construction and Building Materials, vol. 153. pp. 751–764, 2017.

[25] Z. H. Ahsan, Mohammad Badrul, "Use of Rice Husk Ash (RHA) as a Sustainable Cementitious Material for Concrete Construction," in In International Congress and Exhibition" Sustainable Civil Infrastructures: Innovative Infrastructure Geotechnology, 2017, pp. 197–210.

[26] He, Zhihai, Chunxiang Qian, Shigui Du, Man Huang, and Menglu Xia. "Nanoindentation characteristics of cement paste and interfacial transition zone in mortar with rice husk ash." Journal of Wuhan University of Technology-Mater. Sci. Ed. 32, no. 2 (2017): 417-421.

[27] V. Ajay and C. Rajeev, "Effect of Micro Silica on The Strength of Concrete with Ordinary Portland Cement," Research Journal of Engineering Sciences . ISSN Sept. Res. J. Engineering Sci, vol. 1, no. 3. pp. 2278–9472, 2012.

[28] N. P. Singhania, "rice husk ash," Inst. Concr. Technol., vol. 55, 2004.

[29] S. Ramesh and S. Kavitha, "Experimental study on the behaviour of cement concrete with rice husk ash (RHA)," Int. J. Eng. Appl. Sci., vol. 6, no. 2, 2015.

[30] G. A. A. A. Ramezanianpour, M. Mahdi khani, "The Effect of Rice Husk Ash on Mechanical Properties and Durability of Sustainable Concretes," Int. J. Civ. Eng., vol. 7, no. 2, 2009.

[31] S. S. for C. F. A. and R. or C. N. P. for U. in Concrete, "24ASTM C618. 2004," in Annual Book of ASTM Standards., 2004.

[32] K. H. M. Kah Yen FOONG, U. Johnson ALENGARAM†‡, Mohd Zamin JUMAAT, "Enhancement of the mechanical properties of lightweight oil palm shell concrete using rice husk ash and manufactured sand," J. Zhejiang Univ. A (Applied Phys. Eng., vol. 16, no. 1, pp. 59–69, 2016.

[33] L. A. Bui, C. Chen, C. Hwang, and W. Wu, "Effect of silica forms in rice husk ash on the properties of concrete," Int. J. Miner. Metall. Mater., vol. 19, no. 3, pp. 252–258, 2012.

[34] H. S. Müller and M. Haist, "New Types of High Performance Concretes – Potentials for Innovations in Concrete Construction,"

in Innovative Materials and Techniques in Concrete Construction, 2012, pp. 43–58.

[35] A. C642-13, “Standard Test Method for Density, Absorption, and Voids in Hardened Concrete. American Society for Testing and Materials.” ASTM International, West Conshohocken, PA, 2013.

[36] A. S. C39/C39M-14, “Standard Test Method for Compressive Strength of Cylindrical Test Specimens.” ASTM International, West Conshohocken, PA, 2014.

[37] A. S. T. M. Norma, “C496/C496M-11, Standard test method for splitting tensile strength of cylindrical concrete specimens.” ASTM International, West Conshohocken, PA, pp. 469–90, 2004.

[38] A. G544, “design considrations for steel fiber reinforced concrete,” ACI Struct. J., vol. 85, no. 5, pp. 536–580, 1988.

[39] S. T. M. for E. I. of C. A. to R. C. I. Penetration, “ASTM C1202 - 17.” ASTM International, West Conshohocken, PA, 2011.

[40] U. S. ASTM Publication, “ASTM Standard C1202, “Standard Test Method for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration.” 2007.

[41] U. S. ASTM Publication, “ASTM C330- Specification for Lightweight Aggregates for Structural Concret.” 2009.

[42] T. F. H. A.L.G. Gastaldini , G.C. Isaia, A.P. Saciloto, F. Missau, “Influence of curing time on the chloride penetration resistance of concrete containing rice husk ash: A technical and economical feasibility study,” Cem. Concr. Compos., vol. 32, pp. 783–793, 2010.

[43] K. T. K. Ganesan a, K. Rajagopal a, “Rice husk ash blended cement: Assessment of optimal level of replacement for strength and permeability properties of concrete,” Constr. Build. Mater., vol. 22, pp. 1675–1683, 2008.

[44] C. J. W. Chalee a, T. Sasakul b, P. Suwanmaneechot c, “Utilization of rice husk–bark ash to improve the corrosion resistance of concrete under 5-year exposure in a marine environment,” Cem. Concr. Compos., vol. 37, pp. 47–53, 2013.

[45] R. Jones, “The ultrasonic testing of concrete,” Ultrasonics, vol. 1, no. 2, pp. 78–82, 1963.

[46] S. Kumar, handbook of material testing. Indian railways institute of civil engineering, 2006.

[47] Sharma, Narendra Kumar, Praveen Kumar, Sanjeev Kumar, Blessen Skariah Thomas, and Ramesh Chandra Gupta. "Properties of concrete containing polished granite waste as partial substitution of coarse aggregate." Construction and Building Materials 151 (2017): 158-163.

[48] P.-C. Aïtcin, “Concreto de Alto Desempenho,” CONCRETO ALTO DESEMPENHO EM Ambient. COM BAIXAS Temp., p. 667, 2000.

[49] R. Polat, M. M. Yadollahi, A. E. Sagsoz, and S. Arasan, “The Correlation between Aggregate Shape and Compressive Strength of Concrete,” Int. J. Struct. Civ. Eng. Res., vol. 2, no. 3, pp. 62–80, 2013.

[50] Chopra, Divya, and Rafat Siddique. "Strength, permeability and microstructure of self-compacting concrete containing rice husk ash." Biosystems Engineering 130 (2015): 72-80.

[51] A. P. & D. Van Gemert, “Evaluation Of Accelerated Chloride Ion Diffusion Test And Applicability Of Fick’s Second Law,” 9DBMC, pp. 1–10, 2002.

[52] A. Michel, B. J. Pease, A. Peterová, M. R. Geiker, H. Stang, and A. E. A. Thybo, “Penetration of corrosion products and corrosion-induced cracking in reinforced cementitious materials: Experimental investigations and numerical simulations,” Cem. Concr. Compos., vol. 47, pp. 75–86, 2014.

[53] L. Hussein and L. Amleh, “Structural behavior of ultra-high performance fiber reinforced concrete-normal strength concrete or high strength concrete composite members,” Constr. Build. Mater, vol. 93, pp. 1105–1116, 2015.