Available online at www.CivileJournal.org

Civil Engineering Journal

Vol. 5, No. 1, January, 2019

Green and Sustainable Concrete – The Potential Utilization of Rice Husk Ash and Egg Shells

Ashfaque Ahmed Jhatial [a,b*], Wan Inn Goh [a], Kim Hung Mo [c], Samiullah Sohu [d], Imtiaz Ali Bhatti [a]

[a] *Jamilus Research Center, Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.*

[b] *Department of Civil Engineering, Mehran University of Engineering and Technology, Shaheed Zulfiqar Ali Bhutto Campus, Khairpur Mirs', Sindh, Pakistan*

[c] *Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia.*

[d] *Department of Civil Engineering, Quaid-e-Awam University College of Engineering, Scienc and Technology, Larkano, Sindh, Pakistan.*

Received 05 September 2018; Accepted 15 December 2018

Abstract

Concrete which is widely used material in the construction industry, has a carbon footprint. Approximately 10% of global Carbon Dioxide (CO_2) gas is emitted during the production of cement which is vital ingredient of concrete. The increase in production of cement affects global warming and climate change. Therefore, many have attempts have been made to develop green and sustainable concrete by utilizing different waste materials. With the utilization of waste materials as cement replacement, the CO_2 gas emissions can be reduced as well as resolve the environmental issues that the inhabitants face during the disposal of such waste materials. This paper reviews the potential and innovative utilization of Rice Husk Ash (RHA) and Eggshells as partial cement replacement to develop green concrete. RHA which is rich in silica and eggshells contain identical amount of calcium oxide as cement, when finely grinded and used together as partial cement replacement, can trigger a pozzolanic reaction, in which silica reacts with calcium oxide resulting in the formation of calcium silicates which are responsible for achieving higher strengths.

Keywords: Sustainable Concrete; Solid Waste Management (SWM); Hazardous Wastes; Supplementary Cementitious Materials (SCMs); Pozzolanic Activity.

1. Introduction

Concrete is the single most widely used building material in the world and is continuously being used to construct various infrastructures. Its ability to resist freezing, chemical resistance, workability, durability and flexibility [1] are what makes concrete so demanding. Concrete has been utilized in countless architectural eyesores. But despite having many advantages, concrete's environmental credentials have come under scrutiny, due to it being unsustainable.

Concrete is made up of four main ingredients, cement, fine aggregates (sand), coarse aggregates and water. Out of which, cement is the most vital ingredient of concrete which acts as a binder and glues all other ingredients. With the growing demand of concrete in construction of infrastructures across the world, the production of cement has also increased. The cement industry has been reported to contribute approximately 8% to 10% of anthropogenic global

* Corresponding author: ashfaqueahmed@muetkhp.edu.pk

http://dx.doi.org/10.28991/cej-2019-03091226

Carbon Dioxide (CO_2) gas emissions [2]. The CO_2 is one of the greenhouse gases which are one of the main causes of global warming and climate change.

Apart from the emission of CO_2, the production of cement also requires natural resources such as calcium, silica and alumina which are extracted from natural resources. The growing demand of concrete indicates that the production of cement will not slowdown in near future, in fact, it has been gradually increasing over the years, thus contributing to depletion of natural resources. Therefore, with the rise in temperatures, increasing CO_2 gas emissions and depletion of natural resources, the construction industry has diverted its focus to develop green and sustainable concrete.

1.1. Green and Sustainable Concrete

With the increasing environmental challenges, it has become paramount that green and sustainable materials be researched for a wider range of applications to offer feasible alternatives alongside conventional materials. Green concrete has nothing to do with its color [3]. Green concrete is a concrete which utilizes waste materials as at least one of its ingredients, or its production process does not lead to environmental destruction [4]. Green concrete, however, should not compromise on the strength and performance while utilizing the waste materials. Manufacturing methods and process, life cycle sustainability impacts and amount of cement replaced are the key factors which are used to identify weather a concrete is green or not [2]. Though green concrete follows reduce, reuse and recycle techniques, the main aim behind the development of green concrete is to reduce the CO_2 gas emissions, to limit the use of natural resources and the use of waste materials in concrete, which otherwise are disposed-off, costing money for the disposal and causing environmental pollution. One potential way to utilize waste materials to develop green concrete is to use waste materials as partial cement replacement. Most of the waste materials have the ability to enhance the properties of concrete while simultaneously reducing the cement content in concrete.

Rapid industrialization and urbanization have occurred to accommodate the growing demands of the people [5], agricultural/industrial waste byproducts are generated in abundance across the world. Though the quantity and type of waste materials may vary from country to country, but almost all such waste materials end up being dumped in the landfill sites without proper treatment or re-use. The continuous dumping has caused the number of landfill sites to increase significantly and due to the increased awareness of environment and scarcity of land, the solid waste management (SWM) has become major environmental challenge for developing as well as developed countries. Many waste materials such as construction and demolition (C&D) waste, Rice Husk Ash (RHA), eggshells, Palm Oil Fuel Ash (POFA) and Coal Bottom Ash (CBA) are produced on large scale causing environmental issues regarding their disposal. Most of these wastes that are generated in abundance are pozzolanic in nature. Pozzolanic materials are those materials which contain significant amount of silica or alumina in their composition. These materials react with $Ca(OH)_2$ when water is present to produce a new reaction product which exhibits similar binding characteristics [6-8] as cement. The type of cement, ratio of cement hydration and the percentage of pozzolans used decrease the amount of $Ca(OH)_2$ which is produced during the cement hydration. Therefore, not all $Ca(OH)_2$ that is produced during cement hydration is available or free to react with pozzolans [9-10]. RHA and eggshells are two of the most produced waste products in the world. This paper reviews the potential utilization of RHA and eggshells in concrete to develop a green and sustainable concrete which can resolve the environmental issues faced during the disposal of such waste materials as well as reduction of CO_2 gas emissions.

2. Rice Husk Ash (RHA)

Rice has become staple food for over half of the world's population [11]. Rice is a seed of semi-aquatic grass species. A total of 22 species of rice exist, out of which *Oryza sativa* and *Oryza glaberrima* are the only two species which are important for human consumption. *Oryza sativa* was first grown and cultivated in South and Southeast Asia between 8,000 to 15,000 years ago, while *Oryza glaberrima* is believed to be the domesticated version of the wild *Oryza barthii* species of rice approximately 3,000 years ago in the floodplains of Niger River in Africa [11]. Today, except the Antarctica, rice is being cultivated in every continent. Paddy rice is the end-product of the harvesting and threshing of rice grains. It has been reported that approximately 600 million tons of rice paddy is produced annually [12] and is expected to increase significantly in the future. On average, paddy rice produces 25% husk, 10% bran and germ, and 65% white rice [13]. Rice mills generate 20% rice husk from every paddy ton, which is then used as fuel in the boiler to produce electricity for the mill. Approximately 25% of the rice husk is converted into solid waste known as RHA [14], both Rice Husk and RHA are shown in Figure 1. Being a waste product produced by the rice mills, it has very little to none commercial value, thus is disposed causing health issues to the inhabitants nearby.

RHA is an agro-industrial by-product which is being generated in abundance. Due to high surface area and pozzolanic in nature, RHA has the potential to be effectively used as supplementary cementitious material (SCM). Properties and characteristics of any material resemble closely to the parent material's properties and characteristics and the methods and techniques of its production. This is also the case of RHA. RHA is produced by burning rice husk either in open field or under controlled incineration conditions. Poor quality RHA containing high carbon content is produced if rice husk is burnt in open field and produce air pollution, thus it is avoided. The high carbon content will adversely affect performance of concrete and results in development of a structure of highly crystalline form which is of low reactivity [15]. Amorphous form of silica based RHA is produced when rice husk is burnt through controlled incineration conditions in which temperature and duration is controlled. It is obvious that there exists various techniques and methods to produce RHA, however the controlled incinerating significantly produces high quality RHA which contains amorphous form that can allow it to be used for structural concrete.

Figure 1. Sample of Rice Husk and Rice Husk Ash [16]

The chemical composition of RHA as obtained by various researchers is shown in Table 1. It can be observed that though duration, temperature and method have significant influence on the chemical composition of RHA, yet all the researchers have reported that RHA has very high silica content above 70%. The amount of silica is the measure of reactivity of RHA, in other words, silica is compound that has been found to be responsible for strength in concrete [17].

Table 1. Chemical Composition of RHA

Chemical Elements	[18]	[19]	[20]	[21]	[22]
SiO_2	87.2%	87.08%	85.76%	89.90%	77.19%
Al_2O_3	0.15%	0.01%	0.25%	0.46%	6.19%
Fe_2O_3	0.16%	0.11%	1.15%	0.47%	3.65%
CaO	0.55%	0.70%	0.74%	1.01%	2.88%
MgO	0.35%	0.42%	0.81%	0.79%	1.45%
Na_2O	-	0.18%	-	-	-
SO_3	0.24%	-	0.31%	-	-
P_2O_5	-	-	-	2.45%	-
K_2O	-	1.40%	-	4.50%	1.82%

RHA has the highest silica content from all the plant residue and due to the high amount of silica, RHA is a confirmed pozzolanic material [23-25]. Pozzolanic properties allows the material to be used as a cementitious material when finely grinded, consume calcium hydroxide [$Ca(OH)_2$] at ordinary temperatures in the presence of water. The reaction involving silica and $Ca(OH)_2$ leads to strength gain. But ordinary Portland cement has limited extra $Ca(OH)_2$ that RHA may consume, thus providing higher strength till certain level. Utilization of RHA as partial cement replacement will help in achieving greener and economical concrete as it will reduce the cement content, ultimately reducing the cost of construction. Furthermore, use of RHA results in environmental benefit as lesser quantity of it would have to be land-filled, leading to reduction in environmental pollution.

Pozzolanic activity of cement is enhanced when RHA is used, this is due to the large quantity of Silica and to the surface area governed by the porous structures of the particle [26]. According to Tangchirapat et al. [27], the fineness of cement has influence on the strength of concrete, therefore when RHA is finely grinded, it enhances the reactivity thus allowing the concrete to gain significant strength. Chao-Lung et al. [28], investigated the effect of RHA on the strength and durability characteristics of concrete. Three different percentages of RHA (10%, 20% and 30%) were used to replace cement. To improve the pozzolanic reactivity of RHA, it was ground for 1 hour. The results indicated that up to 20% of ground RHA could be utilized as cement replacement without negatively impacting the strength or the durability properties of concrete.

Kishore et al. [29], also studied the strength characteristics of high strength RHA concrete, cement was partially replaced in M40 and M50 grade concrete from 0% to 15% with an increment of 5%. The compressive strength was determined at 7, 28 and 56 days curing regime, while the tensile and flexural strengths were tested at 28 days curing. The results showed that with the replacement of cement with RHA led to decrease in strength, though it improved the workability. The optimum replacement was determined to be 10% for both the grades of concrete. Kachwala et al. [30], replaced ordinary Portland cement with RHA from 0% to 25% and studied its effect on the compressive strength of concrete. It was found that with the increase in replacement of cement with RHA the strength decreased. This may be due to the fact that RHA used in this study was passed through only 600 µm sieve, thus, not producing enough pozzolanic reactivity.

Rahim et al. [31], studied the properties of concrete when cement was substituted with different percentages of RHA (0%, 5%, 15% and 25%). The RHA obtained were burnt at 650ºC such that the colour of RHA turns into grey or white. RHA was then sieved through 63 µm before being used as cement replacement. Based upon the results it was concluded that increase in RHA content decreased the workability of concrete. The optimum percentage of replacement was determined to be 5%. Apart from being used as cement replacement, RHA has also been utilized as fine aggregate replacement to reduce the use of natural resources such as sand [32]. The percentage replacement by weight and volume was utilized ranging from 0% to 25% with an increment of 5% in M15 grade concrete. From the investigation it was determined that 5% of RHA showed close compressive strength compared to the control sample with no RHA when it is replaced by volume. Thus, it was recommended that when RHA is involved, it should be replaced per volume and not by weight.

From the previous researches [27-32] it has been proven that RHA can successfully partially replace cement 5% to 20% by weight without any loss in strength. The content of replacement varies due to many factors such as water/cement ratio and grinding of RHA which have significant influence on the strength parameters of concrete. The further increase in RHA content reduces the strength due to during pozzolanic reaction which is triggered by silica when water is added, $Ca(OH)_2$ is consumed. Since RHA has very high silica content, requires as much $Ca(OH)_2$ to develop calcium-silicate-hydride (C-S-H) gels. Cement does not have much free calcium oxide (CaO), therefore this restricts the pozzolanic reaction. It is proposed that another material which is rich in CaO be added along with RHA, the extra CaO provided by such material can be consumed during pozzolanic reaction in turn enhancing the properties of concrete. Eggshell is one such material that has abundance of CaO and can potentially be utilized along with RHA.

3. Eggshell Powder (ESP)

Eggs being a cheap source of nutrition for human being a cheap source of nutrition [33] for human beings is consumed in large quantities around the world, it has been reported that 2.8 million eggs are consumed on daily basis in Malaysia [34] and due to this, large quantity of bio-waste is generated. Eggshells constitutes only approximately 11% of the total weight of egg [35], but it contains high content of Calcium Carbonate ($CaCO_3$) which amounts to 93.70% [36].

Eggshell is typically considered as waste and thrown away. If it is kept for long time in the garbage it creates some allergies and undesirable smell which can cause irritation [36]. It is evident from the chemical composition as shown in Table 2, that eggshells powder (ESP) contains almost similar amount of CaO as cement. Due to its almost identical chemical composition to cement, many researchers have tried to utilize eggshells as cement replacement and study its effects on the properties of concrete.

Parthasarathi et al. [37], studied the effect of ESP in addition with silica fume. ESP substituted cement by 5%, 10% and 15% in addition with silica fume (SF) by 2.5%, 5% and 7.5% by weight of cement. The eggshells were grinded and sieved through 90 µm sieve. It was observed that up to 15% ESP achieved higher compressive, tensile and flexural strength. 5% replacement achieved the highest strength. Addition of silica fume also improves the strength, but it is inexpensive, point of view only the ESP replacement is enough for getting higher strength. Ansari et al. [38], underwent a study in which the cement was replaced by eggshells which were grinded into powder and sieved through 75 µm sieve. The percentage of replacement was 10%, 15% and 20%. Based upon the results, it was determined that 15% replacement achieved increased 7 days compressive strength as compared to control sample. Thus, proving that ESP can be used as cement replacement material.

Table 2. Chemical Composition of ESP and OPC

Constituents	ESP			OPC		
	[39]	[40]	[41]	[37]	[39]	[40]
CaO	63.8%	60.1%	64.34%	50.7%	47.9%	52.1%
SiO_2	21.4%	21.8%	19.90%	0.09%	0.11%	0.08%
Al_2O_3	5.1%	6.6%	4.30%	0.03%	-	0.03%
MgO	0.36%	2.1%	2.04%	0.01%	-	0.01%
Na_2O	0.14%	0.4%	0.31%	0.19%	0.14%	0.15%
SO_3	3.38%	2.2%	2.88%	0.57%	0.38%	0.62%
P_2O_5	---	---	0.13%	0.24%	-	---
K_2O	1.88%	0.4%	1.05%	--	--	--
Fe_2O_3	2.6%	4.1%	4.24%	0.02%	Traces	0.02%

Tan et al. [42], studied the effect on the compressive strength of eggshell concrete when different curing methods are utilized. The cement was replaced with eggshells by 5%, 10%, 15% and 20%. While two different cuing methods, one consisting of fully water curing while the other was open-air curing. In both the curing methods, 15% eggshell replacement was determined to be optimum at which the concrete achieved the highest strength compared to the concrete with no replacement. Further increase beyond 15% replacement resulted in significant loss of strength. The eggshells were grinded and passed through 45 µm sieve in this study. Like RHA, eggshells have also been utilized as fine aggregates replacement. An experimental study was conducted by Karthick et al. [43], on the potential usage of eggshells as partial sand replacement up to 50%. It was determined that with 20% replacement, the compressive strength was at par with the control sample. It was also observed that with the increase in the eggshells the tensile and flexural strength of concrete decreased.

4. Recent Trends in Combined Utilization of RHA and ESP in Concrete

Due to RHA's pozzolanic nature and lack of calcium, researchers have attempted to utilize egg shells in addition with RHA as cement replacement in concrete. Asman et al. [26], carried out a study to determine the optimum percentage of eggshell ash (ESA) and RHA as partial cement replacement. The eggshell ash was used 2%, 4% and 6% while 8%, 6% and 4% of RHA was utilized. The combined total replacement was 10%. Both concrete A (2% RHA + 8 ESA) and Concrete B (4% RHA + 6% ESA) achieved lower compressive strength then the normal concrete. But concrete C (6% RHA + 4% ESA) gained higher strength. All concrete with RHA and eggshell ash achieved lower flexural strength compared to normal concrete. Thus, proving that it is possible to use both waste materials together and substitute the cement.

Another experimental investigation was carried out on the combined utilization of RHA and ESP as partial cement replacement [44]. RHA and ESP were first individually used to replace cement, and then combinedly. The results obtained from the experimental work is shown in Table 3. Based upon the results shown in Table 3, it can be said that individual utilization of RHA as cement replacement losses strength when content of RHA is increased. Interestingly, small amount of ESP (Mx4 and Mx5) used as partial cement replacement enhanced the compressive strength such that it was 17.42% higher than control, though other strengths were slightly lower than the control sample. The combined utilization of RHA and ESP improved strength. Mx6 mix which contained 15% RHA and 5% ESP recorded the highest compressive strength of 38.67 MPa which was 22.72% higher than control sample at 28 days curing, though the tensile and flexural strengths for this mix were slightly lower than the control sample, it was still in acceptable range. Thus, proving that RHA and ESP are compatible, combined utilization can enhance the strength of concrete while simultaneously reducing the cement content.

Table 3. Mechanical properties of concrete incorporating RHA and ESP [44].

Mix Name	RHA (%)	ESP (%)	Cement (%)	Compressive Strength (MPa)		Tensile Strength (MPa)		Flexural Strength (MPa)	
				7 days	28 days	7 days	28 days	7 days	28 days
Mx0	0	0	100	24.23	31.51	2.92	3.9	4.8	6.32
Mx1	10	0	90	27.6	29.3	2.1	2.52	1.85	2.53
Mx2	15	0	85	14.4	17.6	1.8	2.11	1.1	1.94
Mx3	0	4	96	19.5	36.2	2.11	3.14	3.15	4.6
Mx4	0	5	95	19.3	37	2.13	3.24	3.23	4.78
Mx5	10	4	86	18.01	35.21	4.5	5.7	4.9	6.4

5. Conclusion

Rapid urbanization and industrialization have increased the generation of waste materials, which has put unnecessary burden on the country's economy which has to dispose these materials into landfills. The disposal of such waste materials not only occupies land causing scarcity of land, but also increases health-related issues for the surrounding residents, which has focused researchers to find alternative to disposing these waste materials. One potential alternative and sustainable solution to dumping of waste materials is the utilization of these waste materials in the production of concrete which not only will result in the efficient solid waste management while simultaneously help reduce the dependency and use of cement in its production. Though many researchers have studied the potential of using individual agricultural and food ash wastes as partial cement replacement in concrete, there is lack of study on the combined utilization of such wastes. Most of these wastes that are generated in abundance are pozzolanic in nature.

According to Massazza [45], 22% of $Ca(OH)_2$ is available and this amount can be used up by the pozzolans. Pozzolan materials, which have low calcium/silica ratio, enhance the hydration reaction for the formation of C-S-H gels thus improving the mechanical strength of high-performance concrete when calcium is added to it [8, 46]. Therefore, RHA, a highly reactive pozzolan material with very low calcium/silica ratio, when substituted along with a calcium rich material can enhance the properties of concrete at the same time also reducing the amount of cement used, thus reducing the emission of CO_2. Eggshell which has identical amount of calcium can provide extra $Ca(OH)_2$ that pozzolans require and produce higher strengths. Past researches have proven that both waste materials can be used, but extensive research is required to understand the effect of combined use of RHA and eggshells as cement replacement on the strength performance of concrete. The potential reduction on the dependency on cement to achieve higher strengths in concrete with the utilization of RHA and eggshells can lead to development of green and sustainable concrete, while also resolving the environmental issues that these waste materials have.

6. Funding

The authors would like to thank the Universiti Tun Hussein Onn Malaysia (UTHM) which provided the financial support for this project under Tier 1 grant (Vot-H122).

7. Conflicts of Interest

The authors declare no conflict of interest.

8. References

[1] Jhatial, A. A., Sohu, S., Bhatti, N. K., Lakhiar M. T. and Oad, R. “Effect of steel fibres on the compressive and flexural strength of concrete.” International Journal of Advanced and Applied Sciences, vol. 5, issue 10, (2018): 16 – 21. doi:10.21833/ijaas.2018.10.003.

[2] Suhendro, B. “Toward green concrete for better sustainable environment.” Procedia Engineering. 95, (2014): 305–320. doi:10.1016/j.proeng.2014.12.190.

[3] Baikerikar, A. “A Review on Green Concrete.” Journal of Emerging Technologies Innovative Research, vol. 1, issue 6, (2014):472-474.

[4] Obla, K. H. “What is Green Concrete?” The Indian Concrete Journal, (2009): 26 – 28.

[5] Jhatial, A. A., Inn, G. W., Mohamad, N., Alengaram, U. J., Mo, K. H. and Abdullah, R. “Influence of polypropylene fibres on the tensile strength and thermal properties of various densities of foamed concrete.” IOP Conference Series: Materials Science and Engineering, vol. 271, no. 1, (2017): 1 – 7. doi: 10.1088/1757-899X/271/1/012058.

[6] Dembovska, L., Bajarea, D., Pundieneb, I. and Vitolaa, L. “Effect of Pozzolanic Additives on the Strength Development of High Performance Concrete.” Procedia Engineering, vol. 172, (2017): 202 – 210. doi:10.1016/j.proeng.2017.02.050.

[7] Martinez-Ramirez, S., Blanco-Varela, M. T., Erena, I. and Gener, M. “Pozzolanic reactivity of zeolitic rocks from different Cuban deposits: characterisation of reaction products.” Applied Clay Science, vol. 32, (2006): 40 – 52. doi:10.1016/j.clay.2005.12.001.

[8] Martens, G., Snellings, R., van Balen, K., Bicer-Simsir, B., Verlooy, P. and Elsen, J. “Pozzolanic reactions of common natural zeolites with lime and parameters affecting their reactivity.” Cement and Concrete Research, vol. 39, (2009): 233 – 240. doi:10.1016/j.cemconres.2008.11.008.

[9] Toropovs, N., Bajare, D., Sahmenko, G., Krage, L. and Korjakins, A. “The formation of microstructure in high strength concrete containing micro and nanosilica. Key Engineering Materials, vol. 604, (2014): 83 – 86. doi:10.4028/www.scientific.net/KEM.604.83.

[10] Popovic, S. “Strength and Related Properties of Concrete: A Quantitative Approach” John Wiley and Sons, Inc, New York (1998).

[11] Muthayya, S., Sugimoto, J. D., Montgomery, S. and Maberly, G. F. “An overview of global rice production, supply, trade, and consumption.” Annals of the New York Academy of Sciences 1324, (2014): 7-144, doi: 10.1111/nyas.12540.

[12] Krishna, N. K., Sandeep, S., Mini, K. M. “Study on concrete with partial replacement of cement by rice husk ash.” IOP Conf. Series: Materials Science and Engineering, 149 (2016): 1 – 11. doi:10.1088/1757-899X/149/1/012109.

[13] Chen, H., T. Siebenmorgen & K. Griffin. "Quality characteristics of long-grain rice milled in two commercial systems." Cereal Chemistry Journal, vol. 75, issue 4, (1998): 560–565. doi:10.1094/cchem.1998.75.4.560

[14] Rambabu, P. V., Varma, V. C. and Ramarao, G. V. "Experimental Study on Rice Husk Ash for Optimum Level of Replacement of Cement in Concrete." International Journal of Engineering Research & Technology, vol. 4, issue 10, (2015): 354 – 359. doi:10.17577/ijertv4is100395

[15] Hwang, C. L. and Chandra, S. "The Use of Rice Husk Ash in Concrete." Waste Materials Used in Concrete Manufacturing, (1996): 184 – 234. doi:10.1016/b978-081551393-3.50007-7

[16] Bernas 2018. Rice Process. Retrieved on September 04, 2018.

[17] Nair, D. G., Fraaij, A., Klaassen, A. A. K., Kentgens, A. P. M. "A structural investigation relating to the pozzolanic activity of rice husk ashes." Cement and Concrete Research, vol. 38, issue 6, (2008): 861 – 869. doi:10.1016/j.cemconres.2007.10.004

[18] Swaminathen, A. N. and Ravi, S. B. "Use of rice husk ash and metakaolin as Pozzolans for concrete: a review." International Journal of Applied Engineering Research, vol. 11, issue 1, (2016): 656 – 664.

[19] Rego, J. H. S., Nepomuceno, A. A., Figueiredo, E. P., Hasparyk, N. P. and Borges, L. D. "Effect of particle size of residual rice-husk ash in consumption of $Ca(OH)_2$" ASCE Journal of Materials in Civil Engineering, vol. 27, issue 6, (2015): 1 – 8. doi:10.1061/(asce)mt.1943-5533.0001136.

[20] Mahmud, H. B., Bahri, S., Yee, Y. W. and Yeap, Y. Y. "Effect of rice husk ash on the strength and durability of high strength performance concrete." World Acad. Sci. Eng. Technol., vol. 10, issue 3, (2016): 375 – 380.

[21] Hadipramana, J., Samad, A. A. A., Zaidi, A. M. A., Mohammad, N. and Riza, F. V. "Effect of uncontrolled burning rice husk ash in foamed concrete." Advanced Materials Research. 626, (2013): 769 - 775. doi: 10.4028/www.scientific.net/amr.626.769.

[22] Memon, SA., Shaikh, MA., Akbar, H. "Production of low cost self-compacting concrete using rice husk ash" First International Conference on Construction in Developing Countries (ICCIDC–I), August 4, 5, 2008, Karachi, Pakistan, (2008): 260– 269.

[23] Kartini, K. "Rice Husk Ash – Pozzolanic Material for Sustainability." International Journal of Applied Science and Technology, vol. 1, issue 6, (2011): 169 – 178.

[24] Karim, M. R., Hossain, M. M., Khan, M. N. N., Zain, M. F. M., Jamil, M. and Lai F. C. "On the Utilization of Pozzolanic Wastes as an Alternative Resource of Cement." Materials 2014(7), (2014): 7809 – 7827. doi:10.3390/ma7127809.

[25] Gupta, N., Kumar, P., Mishra A. and Srivastava, R. P. "Characterization and Application of Rice Husk Ash as Pozzolanic Material in Concrete." IOSR Journal of Mechanical and Civil Engineering, vol. 12, issue 3, (2015): 28 – 32.

[26] Asman, N. S. A., Dullah, S., Ayog, J. L., Amaludin, A., Amaludin, H., Lim, C. H. and Baharum, A. "Mechanical Properties of Concrete Using Eggshell Ash and Rice Husk Ash as Partial Replacement of Cement." MATEC Web of Conferences 103, (2017): 1 – 6. doi:10.1051/matecconf/201710301002.

[27] Tangchirapat, W., Tangpagasit, J., Waew-kum, S. and Jaturapitakkul, C. "A new pozzolanic material from palm oil fuel ash." KMUTT Research and Development Journal 26, (2013): 459 – 473.

[28] Chao-Lung, H., Tuan, B. L., and Tsun, C. C. "Effect of rice husk ash on the strength and durability characteristics of concrete." Construction and Building Materials. 25, (2011): 3768 – 3772. doi:10.1016/j.conbuildmat.2011.04.009.

[29] Kishore, R., Bhikshma, V. and Prakash P. J. "Study on strength characteristics of high strength Rice Husk Ash concrete." Procedia Engineering. 14, (2011): 2666 – 2672. doi:10.1016/j.proeng.2011.07.335.

[30] Kachwala, A., Pammani, A., Raval, A. "Effect of rice husk ash as a partial replacement of ordinary Portland cement in concrete." International Research Journal of Engineering and Technology, vol. 2, issue 5, (2015): 175 – 177.

[31] Rahim, M. A., Ibrahim, N. M., Idris, Z., Ghazaly, Z. M., Shahidan, S., Rahim, N. L., Sofri, L. A. and Isa, N. F. "Properties of Concrete with Different Percentage of the Rice Husk Ash (RHA) as Partial Cement Replacement." Materials Science Forum, 803, (2014): 288 – 293.

[32] Obilade, I. O. "Experimental Study on Rice Husk as Fine Aggregates in Concrete." The International Journal of Engineering and Science, vol. 3, issue 8, (2014): 09 – 14.

[33] Miranda, J. M., Anton, X., Redondo-Valbuena, C., Roca-Saavedra, P., Rodriguez J. A., Lamas, A., Franco, C. M. and Cepeda, A. "Egg and Egg-Derived Foods: Effects on Human Health and Use as Functional Foods." Nutrients, vol. 7, issue 1, (2015): 706 – 729. doi:10.3390/nu7010706.

[34] Astro Awani 2018. Malaysians consume 1.8 million chickens daily - Ahmad Shabery Malaysians consume 1.8 million chickens daily - Ahmad Shabery. Retrieved on August 22, 2018.

[35] Gaonkar, M., Chakraborty, A. P. "Application of Eggshell as Fertilizer and Calcium Supplement Tablet." International Journal of Innovative Research in Science, Engineering and Technology, vol. 5, issue 3, (2016): 3520 – 3525.

[36] Qureshi, A. M., Moon, A. S. and Hirapure, A. S. "Innovative use of Rice Husk Ash Fly Ash and Egg Shell Powder in Concrete." IJSRD - International Journal for Scientific Research & Development, vol. 3, issue 01, (2015): 946 – 948.

[37] Parthasarathi, N., Prakash, M., Satyanarayanan, K. S. "Experimental Study on Partial Replacement of Cement with Egg Shell Powder and Silica Fume." Rasayan Journal of Chemistry, vol. 10, issue 2, (2017): 442 - 449. doi:10.7324/rjc.2017.1021689.

[38] Ansari, M. M., Kumar M. D., Charles J. M. and Vani, G. "Replacement of Cement using Eggshell Powder." SSRG International Journal of Civil Engineering, vol. 3, issue 3, (2016): 1 – 3. doi:10.14445/23488352/IJCE-V3I3P101.

[39] Khalid N. H. A., Hussin M. W., Mirza J., Ariffin N. F., Ismail M. A., Lee H.-S., Mohamed A. and Jaya R. P. "Palm oil fuel ash as potential green micro-filler in polymer concrete." Construction and Building Materials, 102, (2016): 950 – 960. doi:10.1016/j.conbuildmat.2015.11.038.

[40] Yerramala, A. "Properties of concrete with egg shell powder as cement replacement." The Indian Concrete Journal, (2014): 94 – 104.

[41] Jain, N., Garg, M. and Minocha, A. K. "Green Concrete from Sustainable Recycled Coarse Aggregates: Mechanical and Durability Properties." Journal of Waste Management, (2015): 1 – 8. doi:10.1155/2015/281043.

[42] Tan, Y. Y., Doh, S. I. and Chin, S. C. "The Effect of Different Curing Methods on the Compressive Strength of Eggshell Concrete." Indian Journal of Science and Technology, vol. 10, issue 6, (2017): 1 – 4. doi: 10.17485/ijst/2017/v10i6/111210.

[43] Karthick, J., Jeyanthi, R. and Petchiyammal, M. "Experimental Study on Usage of Egg Shell as Partial Replacement for Sand in Concrete." International Journal of Advanced Research in Education Technology (IJARET), vol. 1, issue 1, (2014): 7 – 10.

[44] Priyanka, M., Ranjini, A. and Sarathapriya, A. "Experimental Investigation of Eggshell Powder and Rice Husk Ash as Partial Replacement of Cement." International Journal of Advanced Research Trends in Engineering and Technology (IJARTET), vol. 4, issue 11, (2017): 58 – 62.

[45] Massazza, F. "Pozzolana and Pozzolanic Cements, Lea's Chemistry of Cement and Concrete." Volume 4, edited by Peter Hewitt, Arnold, John Wiley and Sons Inc, New York, (2003): 471 – 635.

[46] Isaia, G. C., Gastaldini, A. L. G., Moraes, R. 2003. "Physical and pozzolanic action of mineral additions on the mechanical strength of high-performance concrete." Cement and Concrete Composites, vol. 25, issue 1, (2003): 69 – 76. doi:10.1016/S0958-9465(01)00057-9.