© Universiti Tun Hussein Onn Malaysia Publisher's Office

JSMBE

http://publisher.uthm.edu.my/ojs/index.php/jsmbe

e-ISSN : 2821-3432

Journal of Structural Monitoring and Built Environment

Strength Performance of Mortar Containing Bagasse Ash and Rice Husk Ash as Cementitious Material

Sarfraz Hyder[1], Sajjad Ali Mangi[1*], Suhail Ali[1], Rukhsar Ali Narejo[1], Shahiron Shahidan[2]

[1]Department of Civil Engineering,
Mehran University of Engineering and Technology, SZAB Campus Khairpur Mir's, PAKISTAN

[2]Jamilus Research Center, Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussien Onn Malaysia, MALAYSIA

*Corresponding Author

DOI: https://doi.org/10.30880/jsmbe.2021.01.01.006
Received 27 November 2021; Accepted 10 December 2021; Available online 31 December 2021

Abstract: The use of cement as a main binding material in the field of civil engineering is no doubt at the next level due to growth in urbanization. It is mainly used to make cement mortar, concrete, and other composite construction material. The extensive use of OPC in the construction industry has caused increment in the production of CO_2 at atmosphere. This has deteriorated the environment and has urged everyone to study and research the sustainable progress by using different waste products as replacement in concrete and mortar. Therefore, the purpose of this study was to investigate the strength performance of cement mortar containing Sugarcane Bagasse Ash (SCBA) and Rice Husk Ash (RHA) as a Cementitious Material. In this study, we have substituted the cement with different percentages i.e., 0%, 5%, 10% and 15% of both sugarcane bagasse ash (SCBA) and rice husk ash (RHA) to obtain sustainable mortar. Flowability, Density and compressive strength were examined by casting 36 standard cubes of 50mm size and cured for 3, 7 and 28 days. Test outcomes indicated that the flowability of mortar paste kept on decreasing with the increase in partial replacement by SCBA and RHA. As we have fixed the water cement ratio for all type of mix i.e., 0.5. From the outcomes of Density and Compressive Strength of Cubes cured in plain water, we come to know that as % replacement was increasing the density and compressive strength of cubes cured was reducing. For Compressive Strength, it was found that at each specified day, the compressive strength of cubes up to 10% replacement has given a reasonable value but intensely decreased at 15% replacement. At 5% replacement of both SCBA and RHA on 28th day test it was pointed that compressive strength of cubes has the highest values for all % of replacement.

Keywords: Sugarcane bagasse ash, rice husk ash, cement mortar, flowability, compressive strength

1. Introduction

Construction is an ancient human activity. It started with the basic need for a sensitive environment to protect against the effects of the weather. Shelters have been one of the means of adapting to a wide variety of climates and becoming a global species. They were initially very simple and could only last a few days or months. However, later the structures developed, and more permanent structures appeared, and people began to stay in one place for a long time. Some structures were supposed to have their symbolic and functional value and marked the beginning of the distinction between architecture and buildings.

**Corresponding author: sajjad.nec@gmail.com*

Along with the rapid growth and increase of environmental problems, the world is facing. Engineers are doing everything they can to reduce the risk of these problems in the construction industry (Mangi et al. 2020). The removal of sugarcane bagasse and rice husk ash is already causing environmental problems in our industry. On the other hand, the use of cement in mortar entails the emission of carbon dioxide (CO2) (Ogbeide 2010). It causes 8-10% of CO2 in global greenhouse gas emissions (Fapohunda 2017). In addition, increased construction activity led to a shortage of most concrete fabrication materials, especially cement, leading to higher prices.

Therefore, environmentalists are worried about OPC manufacturing and looking for alternative resources as cementitious material. Among these resources, agricultural and industrial waste seems to be promising sources (Chowdhury et al. 2015). The demand for cement is expected to be met by supplementary cementitious materials (SCMs) through the utilization of industrial waste biomass in the form of ash as a cement replacement material, which can considerably reduce environmental burden rise due to industrial by-products. It was generally observed that utilization of SCMs as OPC replacement can significantly bring a reduction in the production of CO2 emissions. In recent years, effective cementitious materials have been given serious attention. However, the biomasses, namely sugarcane bagasse and rice husk, are the major wastes produced from the sugar industry and ricemills< respectively. The use of these wastes as an energy source for the generation of energy for the boilers in the industries. However, the incineration or burning of such wastes could reduce the volume of the waste, but it produces another problem that is the formation ash. However, after the burning process of sugarcane bagasse delivers the ash which is known as sugarcane bagasse ash (SCBA). Whereas rice husk after burning process left behind the ash which is branded as rice husk ash (RHA). Usually, rice husk produced by rice mills is utilized as the main source of energy to produce heat energy in a kiln to produce masonry bricks. But particularly, in the Sindh province of Pakistan, small-scale rice mills do not have a proper plan to dispose rice husk, and it was observed that rice husk produced by rice mills are not handled properly, which may result in serious environmental and health problems. There are several research studies available on the utilization of different industrial wastes as cementitious material. There are few famous ashes known as SBCA and RHA which were adopted earlier as partial replacement of OPC individually.

It was previously declared by Chi (2012) that SCBA has good potentiality as a cementitious material and declared that the 10% replacement of OPC with SCBA could be the optimum. Also, SCBA contains a reactive silica content in its composition and can be used in concrete as a cementitious material, it strives to achieve durable and sustainable concrete which can resolve the disposal problem significantly (Bahurudeen 2015). Besides that, the utilization of RHA in concrete is also considered as a suitable alternative solution for sustainable concrete production (Ramadhansyah et al. 2011). It was earlier found that 10% incorporation of RHA gives 30.8% strength development as compared to the control mix (Habeeb and Mahmud 2010).

However, the chemical composition of these ashes presented in Table 1. It can be observed that these materials have a good amount of silica which indicates the potentiality of pozzolanic reactivity (Mangi et al. 2018). Pozzolanic properties are important for the later age strength development of the concrete. The utilization of individual RHA and SCBA has long been known as cementitious material for mortar production. However, no research is done on combine use of both materials so, we are doing this research to know the combine effect of both RHA and SCBA on compressive strength of mortar.

Table 1 - Oxide composition of RHA and SCBA

Oxide	RHA **[** Garrett et al. 2020**]**	SCBA [Garrett et al. 2020]	Class F ash prerequisite as per ASTM C618
SiO_2	94.3	71.36	
Al_2O_3	0.77	11.2	70% (min) SiO_2+
Fe_2O_3	0.05	3.79	Al_2O_3+Fe_2O_3
CaO	0.66	6.83	
MgO	0.58	1.56	

2. Materials and Methodology

2.1 Experimental Set-Up

This study considered two selected agro-industrial wastes named as sugarcane bagasse and rice husk which are locally available in abundant quantities. The sugarcane bagasse was collected from Khairpur Sugar Mills, and rice husk was collected from Badin rice mills. After transporting, both were processed through burning to convert waste into ash. Then, this study considered combined recycling these two ashes to produce blended cement. Next, the performance of mortar containing SCBA and RHA as cementitious material was evaluated in terms of the fresh and hardened properties of mortar. The mix ratio 1:3 of cement and fine aggregate is selected for the research study. Total 36 number of cubes of size 50×50×50 mm3 were made. 0%, 5%, 10% and 15% of Sugarcane bagasse ash and Rice husk ash had been replaced with cement. OPC cement of Lucky Cement brand was used. The weight batching has been done during execution experiment. After casting Flowability and compressive strength were carried out. The specimens were casted in molds and demolded after 24 h. After demolding, specimens were kept in a water curing tank for the period of 3days, 7 days, 28 days. After the designated period of curing, the specimens were tested at the concrete laboratory of the MUET SZAB Campus Khairpur. This study required a total of 36 specimens, as the detail is provided in Table 2.

Table 2 - Total no: of specimens

Code	SCBA %	RHA %	OPC	Cubes cured for 3 days	Cubes cured for 7 days	Cubes cured for 28 days
M1	0	0	100%	3	3	3
M2	5	5	90%	3	3	3
M3	10	10	80%	3	3	3
M4	15	15	70%	3	3	3
				Total Sample required		36

2.2 Materials

The ordinary Portland cement (OPC) was used as the main binding material in this study, and agro-wastes, i.e., sugarcane bagasse and rice husk, were collected from local industries in Sindh, Pakistan. Next, the sugarcane bagasse and rice husk were processed through uncontrolled open burning separately to get fine ashes. After the burning process, ashes were passed through a 300-μ sieve. Moreover, mortar mixes were prepared, as the detail is shown in Table 2. Initially, mortar with 100% OPC with proportion 1:3 (cement: sand) was prepared without any agro-industrial waste. Then, OPC was replaced with SCBA and RHA combined with 10%, 20%, and 30% by weight of cement. These proportions of SCBA and RHA were selected from earlier research (Habeeb and Mahmud 2010; Mangi et al 2021). However, the detailed research methodology is provided in Fig. 1. It shows that fresh mix mortar was tested for flowability, and hardened mortar was evaluated for compressive strength at different curing ages of 3 days, 7 days, and 28 days.

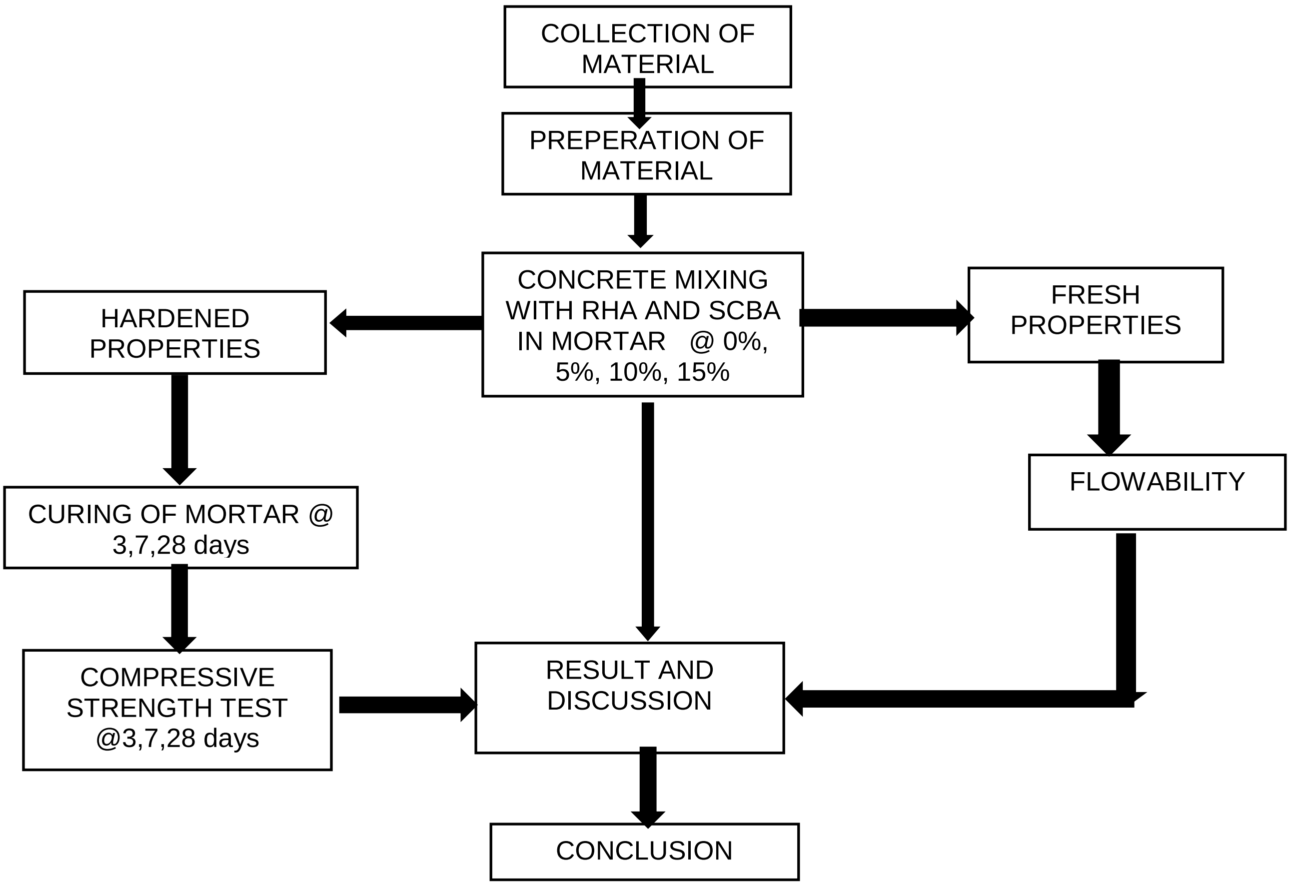

Fig. 1 - Flow chart of experimental work

3. Results and Discussion

3.1 Flowability

The flowability results are indicates in the Fig. 2 which shows that the cement mortar including 0-30% of SCBA and RHA combined as OPC replacement material in the mixture. The flowability of mortar paste is decreasing with the rise in partial replacement by SCBA and RHA at 5% to 10% and 15%. As we have fixed the water cement ratio for all type of mix i.e., 0.5. This aspect of research investigation was achieved by Bheel et al. (2019a, b), in which the workability of concrete is dropped with growing in the percentages of OPC replaced with RHA in concrete. Moreover, the flow of mixture blended with 10-30% of combined use of SCBA and RHA as SCM in mortar, as shown in **Fig. 2**. The maximum flow is estimated by 150 mm at the control mix and the minimum flow is recorded by 122 mm at 15% of SCBA and 15% of RHA as OPC replacement material in the mixture. The outcomes have been perceived that the flow of the green mixture is dropped as growing the quantity of SCBA and RHA as SCM in mortar. This drop in flow value might be due to the porous particles of SCBA and RHA as compared to OPC which absorbs more amount of water. Therefore, it can be concluded from the results that RHA and SCBA increased the water demand of the mortar (Harini et al. 2012), which means if same workability is to be required w/c should be increased gradually or one can use different admixtures like plasticizers or superplasticizers to maintain the desired strength with required workability.

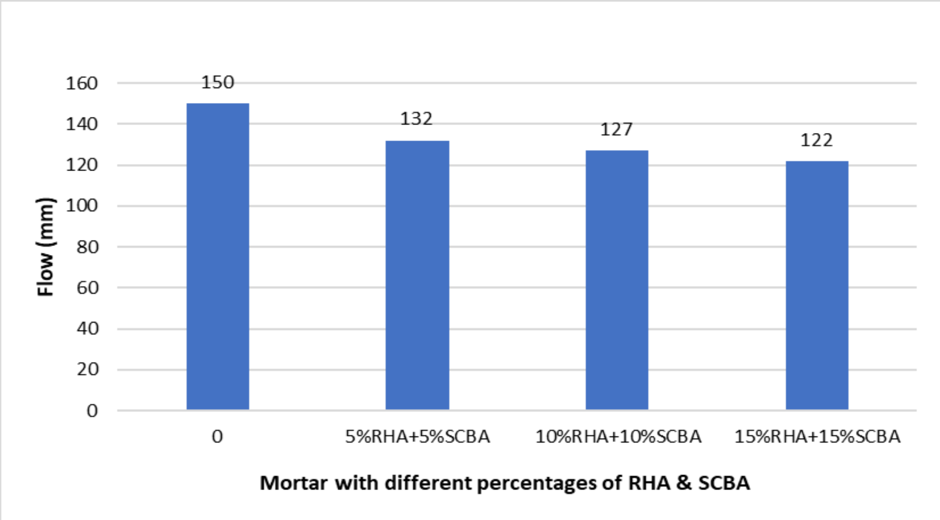

Fig. 2 - Variation in flowability chart with different %

3.2 Compressive Strength

Compressive strength is the capacity of mortar cubes to withstand compressive loads or the resistance of the material to breaking under compression. The test involves applying a compressing axial load to molded cubes at a level that is within a specified range until failure occurs (Mangi, et al., 2019). The compressive strength shall be calculated by dividing the highest possible load attained throughout the test by the cross-section area of the sample. Fig 3 displays the mixture of mortar including several proportions of SCBA and RHA as OPC replacement material for determining the compressive strength of mortar at 3 days, 7 days, 28 days.

The use of SCBA and RHA as SCM in the mixture for investigating the compressive strength showed that with partial replacement of SCBA and RHA as cementations material, compression strength decreases as percentage of SCBA and RHA increases. This decrease in compressive strength may be due to the pore structure induced by rice husk addition (Yuzer et al, 2013) or due to the dilution effect of SCBA and RHA on OPC that results in reducing the calcium hydroxide which is present for product formation (Garrett et al. 2020). Also, it may be due to sieve size as it was passed from 300 micron while the size of cement is 45 microns. It was observed from the experimental study and comparison with the earlier findings, which indicates that particle fineness of SCBA and RHA has a great influence on the strength performance of concrete; the more the finer particle results in the greater the strength performances (Bayapureddy et al. 2020). The greater strength at 0% in control specimen is probably due to the denser structure (Yuzer et al, 2013). However, the compressive strength of cubes at 5% replacement and cured for 28 days was greatest.

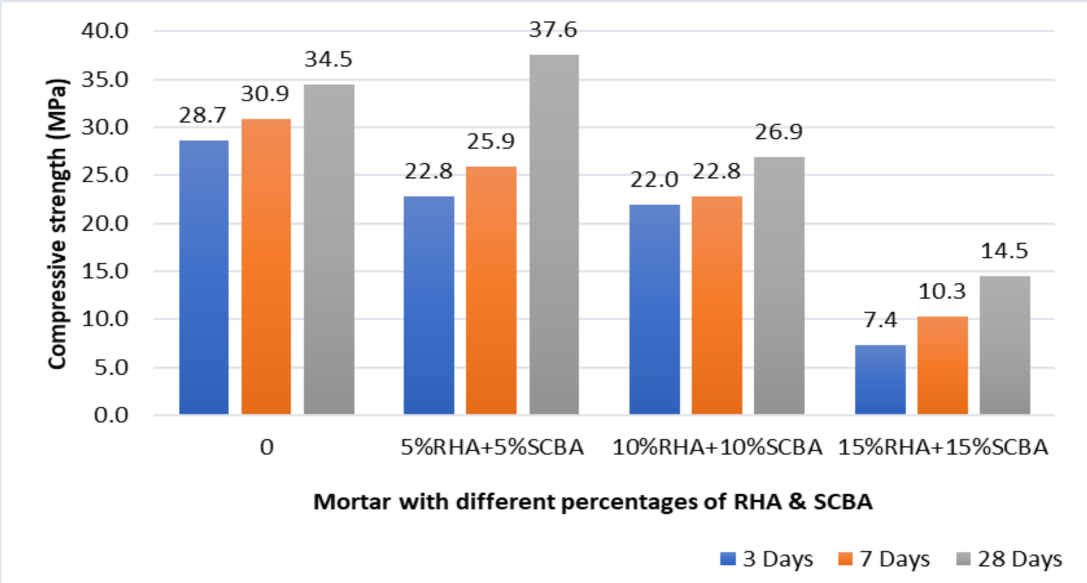

Fig. 3 - Compressive strength of mortar paste containing SCBA and RHA

3.3 Density

The density of cement mortar cubes was evaluated at 3, 7 and 28 days as results are shown in Fig. 4. It was determined by calculating their weight and volume. From above results it has been observed that the density of cubes is increasing with time. Earlier research has shown that RHA increase porosity and reduce the density of mortar and concrete (Yuzer et al, 2013). From fig:5 we can see that with increasing substitution of RHA and SCBA, density of cubes is first increasing because of larger particle size of SCBA and RHA and then decreasing due to increasing porosity, which results in reduction in mass of mortar cubes and hence density is also decreasing.

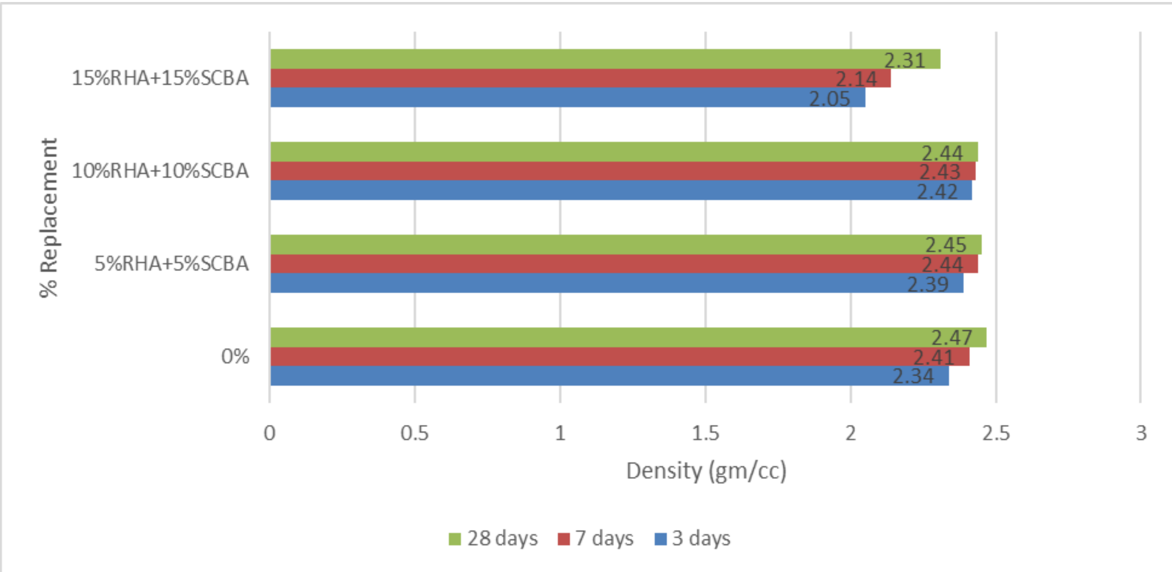

Fig. 4 - Replacement chart of density

3.4 Density vs Compressive Strength

The relationship among density and compressive strength of mortar was established with supplementary cementations materials (SCM) like SCBA and RHA at different proportions. From the Fig. 5 (a) to Fig. 5 (d), we can see that a linear relationship between density and compressive strength of mortar cube is obtained, means if density is increasing then compressive strength is also increasing. This is due to the fact, that a denser mortar cube generally provides higher strength and it also have fewer number of voids and porosity (Iffat, 2015).

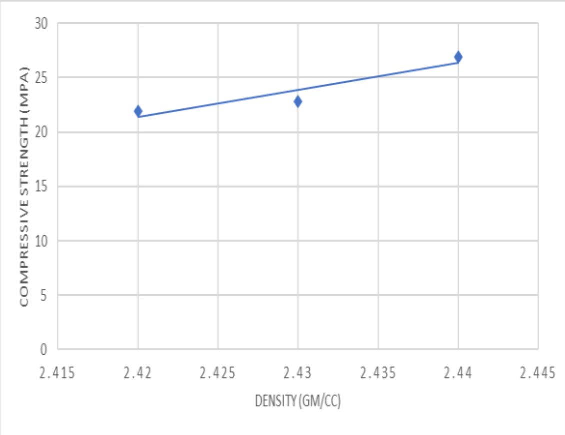

Fig. 5 (a) - Density vs Compressive strength @ 0%

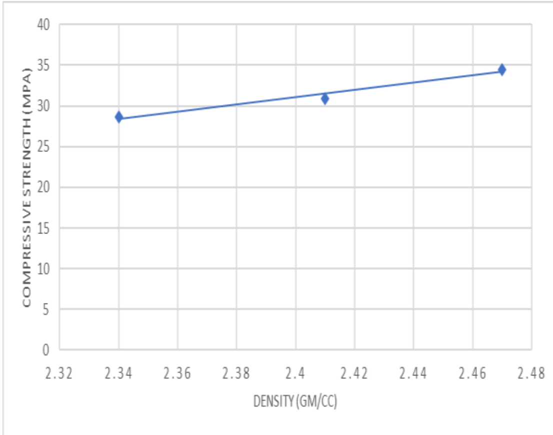

Fig. 5 (b) - Density vs Compressive strength @ 5%

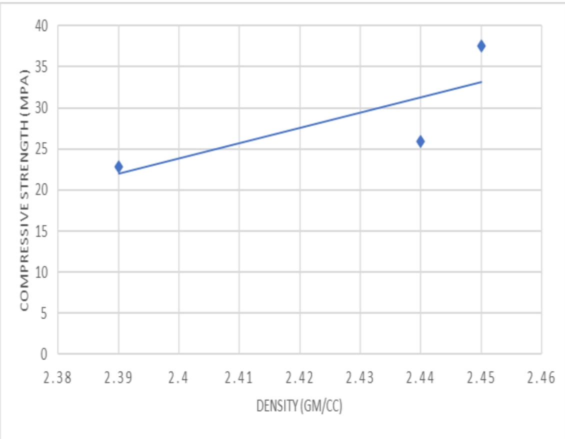

Fig. 5 (c) - Density vs Compressive strength @ 10%

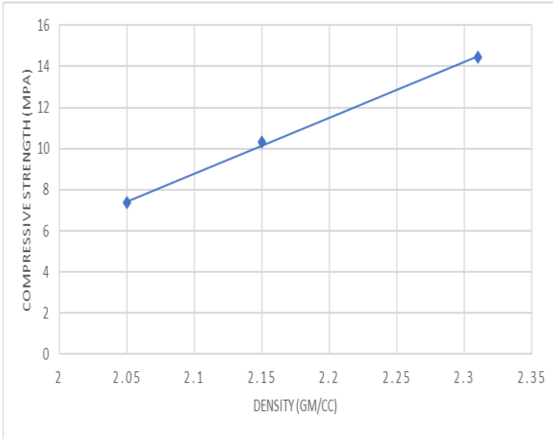

Fig. 5 (d) - Density vs Compressive strength @ 15%

4. Conclusion and Suggestions

The basic aim of this study was the utilization of RHA and SCBA as partial replacement of OPC in mortar and determined their effect on fresh and hardened properties. From this experimental study, the following conclusions were drawn.

1. Flowability decreases with increasing content of SCBA and RHA.
2. For maintaining the w/c ratio of mortar use some additional water in substitutions, otherwise RHA and SCBA will absorb almost all water needed for proper mixing of mortar.
3. SCBA and RHA are proved to be good substitute for replacement of Cement mortar, as the strength of mortar paste does not decrease at such amount and use of cement can be reduced which causes CO2 at a large quantity.
4. It was observed that the time taken by 0% replacement of mortar cubes for SDD condition was lowest, while 15% replacement of mortar cubes for SDD condition was highest.
5. It was found that at 15% of replacement, the strength of compressive cubes was highly decreased at every specified day.
6. At 28 Days test, it was observed that Compressive Strength of cubes with 5% replacement has the largest value.

Based on the experimental results of this study, it was observed that the finer SCBA and RHA particles could produce a better pozzolanic reaction which results in strength development. Therefore, it is recommended for future studies to utilize finer particles of SCBA and RHA to get better strength performances for long-term analysis.

Acknowledgement

The Authors acknowledged the support of Mehran University of Engineering & Technology, SZAB Campus Khairpur Mir's, Sindh, Pakistan.

Reference

Ahmed, A., Mangi, S.A., Muhammad, A.W. and Din, N.U., 2020. Strength Performance of Concrete containing Date Seeds as Partial Replacement of Coarse Aggregates under the Exposure of NaCl and Na2SO4. Indonesian Journal of Social and Environmental Issues (IJSEI), 1(3), pp.206-212.

Ogbeide S.O., Developing an opti mization model for CO2 reduction in cement production process, JESTR Journal, 2010; 3: 85-88.

Fapohunda, C., Akinbile, B. and Shittu, A., 2017. Structure and properties of mortar and concrete with rice husk ash as partial replacement of ordinary Portland cement-A review. *International Journal of Sustainable Built Environment*, *6*(2), pp.675-692.

Chowdhury S, Maniar A, Suganya OM (2015) Strength development in concrete with wood ash blended cement and use of soft computing models to predict strength parameters. J Adv Res 6(6):907-913. https://doi.org/10.1016/j.jare.2014.08.006

Chi M-C (2012) Effects of sugar cane bagasse ash as a cement replacement on properties of mortars. Sci Eng Compos Mater 19(3):279- 285. https://doi.org/10.1515/secm-2012-0014

Bahurudeen, M. Santhanam, K.S. Vaisakh, Availability of sugarcane bagasse ash and potential for use as a supplementary cementitious material in concrete, Indian Concr J 89 (6) (2015) 41-50.

Ramadhansyah PJ, Abu Bakar BH, Megat Azmi MJ, Wan Ibrahim MH (2011) Engineering properties ofnormal concrete grade 40 containing rice husk ash at different grinding times. Int J Technol 2(1):10- 19. https://doi.org/10.2478/v10077-011-0001-0

Habeeb GA, Mahmud HB (2010) Study on properties of rice husk ash and its use as cement replacement material. Mater Res 13(2):185- 190. https://doi.org/10.1590/S1516-14392010000200011

Mangi SA, HazimanM,Ibrahim W, JamaluddinN,ArshadMF, Memon FA et al (2018) A review on potential use of coal bottom ash as a supplementary cementing material in sustainable concrete construction. International Journal of Integrated Engineering 10(9):127-135

Garrett, T.D., Cardenas, H.E. and Lynam, J.G., 2020. Sugarcane bagasse and rice husk ash pozzolans: Cement strength and corrosion effects when using saltwater. *Current Research in Green and Sustainable Chemistry*, *1*, pp.7-13.

ASTM C618-05, in: Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete, Annu. B. ASTM Stand., 2005, pp. 3-6.

Mangi SA, Wan Ibrahim MH, Jamaluddin N, Arshad MF, Khahro SH, Ramadhansyah PJ (2021) Influence of coal ash on the concrete properties and its performance under sulphate and chloride conditions. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-02115006-x

Bheel N, Abro AW, Shar IA, Dayo AA, Shaikh S, Shaikh ZH (2019a) Use of rice husk ash as cementitious material in concrete. Engineering, Technology & Applied Science Research 9(3):4209-4212

Bheel ND, Meghwar SK, Abbasi RA, Ghunio IA, Shaikh ZH (2019b) Use of sugarcane bagasse ash as cement replacement materials in concrete. In International Conference on Sustainable Development in Civil Engineering, Jamshoro, Pakistan (pp 1-4)

Harini, M., Shaalini, G. and Dhinakaran, G., 2012. Effect of size and type of fine aggregates on flowability of mortar. *KSCE Journal of Civil Engineering*, *16*(1), pp.163-168.

Mangi SA, Wan Ibrahim MH, Jamaluddin N, Arshad MF, Ramadhansyah PJ (2019) Effects of ground coal bottom ash on the properties of concrete. Journal of Engineering Science and Technology 14(1):338-350

Yuzer, N., Cinar, Z., Akoz, F., Biricik, H., Gurkan, Y.Y., Kabay, N. and Kizilkanat, A.B., 2013. Influence of raw rice husk addition on structure and properties of concrete. *Construction and Building Materials*, *44*, pp.54-62.

Garrett TD, Cardenas HE, Lynam JG (2020) Sugarcane bagasse and rice husk ash pozzolans: cement strength and corrosion effects when using saltwater. Current Research in Green and Sustainable Chemistry 1-2:7-13. https://doi.org/10.1016/j.crgsc.2020.04.003

Bayapureddy Y, Muniraj K, Mutukuru MRG (2020) Sugarcane bagasse ash as supplementary cementitious material in cement composites: strength, durability, and microstructural analysis. J Korean Ceram Soc 57:513-519. https://doi.org/10.1007/s43207-020-00055-8

Iffat, S., 2015. Relation between density and compressive strength of hardened concrete. *Concrete Research Letters*, *6*(4), pp.182-189.