

Rice Husk Ash and Fly Ash Effects on the Mechanical Properties of Concrete

Naraindas Bheel

Civil Engineering Department
Hyderabad College of Science &
Technology
Sindh, Pakistan
naraindas04@gmail.com

Muneer Ali Jokhio

Civil Engineering Department
Hyderabad College of Science &
Technology
Sindh, Pakistan
jokhiomuneer08@gmail.com

Javed Ahmed Abbasi

Hyderabad College of Science &
Technology
Sindh, Pakistan
javikalhor77@gmail.com

Hyder Bux Lashari

Hyderabad College of Science &
Technology
Sindh, Pakistan
nbprinces12@gmail.com

Muhammad Imran Qureshi

Hyderabad College of Science &
Technology
Sindh, Pakistan
muhammadimranqureshi276@gmail.com

Abdul Salam Qureshi

Hyderabad College of Science &
Technology
Sindh, Pakistan
qureshi.salam@gmail.com

Abstract—Cement production involves high amounts of energy consumption and carbon dioxide emissions. Pakistan is facing a serious energy crisis and cement's cost is increasing. In addition, landfilling of potential concrete components can lead to environmental degradation. The use of waste as cement replacement not only reduces cement production cost by reducing energy consumption, but it is also environmentally friendly. The purpose of this study is to analyze the characteristics of concrete by partially replacing cement with Rice Husk Ash (RHA) and Fly Ash (FA). This study is mainly focused on the performance of concrete conducting a slump test, and investigating indirect tensile and compressive strength. Cement was replaced with RHA and FA by 5% (2.5% RHA + 2.5% FA), 10% (5% RHA + 5% FA), 15% (7.5% RHA + 7.5% FA) and 20% (10% RHA+10% FA) by weight. Ninety concrete samples were cast with mix proportions of 1:2:4 and 0.55 water/cement ratio. Cube and cylindrical samples were used for measuring compressive and split tensile strength respectively, after 7 and 28 days. The results showed that after 28 days, the 5% RHA+5% FA sample's compressive strength was enhanced by 16.14% and its indirect tensile strength was improved by 15.20% compared to the conventional sample. Moreover, the sample's slump value dropped as the content of RHA and FA increased.

Keywords—rice husk ash; fly ash; cement replacement; increased strength; reduced environmental pollution

I. INTRODUCTION

Concrete is extensively used in artificial materials. Due to its adaptability and relative profitability, it is considered as a competitive building material [1]. Concrete consists of cement, aggregates, and water. Aggregates comprise about 75-80% of the total volume of concrete, affecting the properties of fresh and hardened concrete and its performance [2-3]. Cement manufacturing has some disadvantages, such as high production cost and energy requirements. Cement production

also leads to mass emissions of CO₂ and other greenhouse gases. The production of one tone of cement emits 1-1.25 tons of CO₂ [4-6], requires about 1.60MWh of energy, and thus it is considered as an expensive and non-environment friendly process [7].

According to [8], human activity produces more than 5,000 tons of solid waste per year, which include ingredients such as silica fumes, RHA [9, 10], FA, and corncob ash. Considerable savings in cost and energy consumption could be achieved by utilizing these by-products as partial cement replacements [11]. The utilization of agricultural waste such as RHA, sugarcane bagasse ash [12], waste glass powder, FA, and millet husk ash [13], in order to reduce cost, waste and CO₂ emissions, was investigated in [14, 15]. Routine treatments of agricultural and industrial waste are a major concern. RHA and FA are agricultural by-products [16-18], and they are considered hazardous as they are usually burnt [19, 20]. RHA and FA are highly pozzolanic in nature, and they could be utilized as Portland cement replacements. Due to their high silica content and low cost, these materials have a high potential in the production of secondary cementing material [21]. The annual production of rice husk is about 120 million tons [22]. RHA has a silica content of 85%, called amorphous silica, and it could be utilized as a cementitious material in concrete [23, 24]. Under industrial conditions, FA is generated by burning coal. Nowadays, with the use of pollution control equipment such as electrostatic precipitators or other filtering equipment, FA is captured before flue gases enter the chimney of a coal-fired power plant. About 43% of FA from coal-fired power plants in USA is collected and utilized as a cementitious material in the making of concrete [25]. The main goal of this research is to evaluate the properties of fresh, physical and hardened concrete using RHA and FA as cement replacements.

Corresponding author: Naraindas Bheel

II. RESEARCH METHODOLOGY

The properties of fresh and hardened concrete were studied for five concrete mixtures: 0%RHA+0%FA, 2.5%RHA+2.5%FA, 5%RHA+5%FA, 7.5%RHA+7.5%FA, and 10%RHA+10%FA. Ninety concrete samples were prepared, in 60 cylinders and 30 prisms, with 1:2:4 mix proportions, 0.55 water/cement ratio and were cured for 7 and 28 days. In order to determine the characteristic strength of concrete samples, they were tested on an Universal Testin Machine (UTM), and the ASTM C192 Standard was met. Concrete cubes (100×100×100mm) were used to measure compressive strength, and cylinder samples (200×100mm) were used for determining indirect tensile strength. Similarly, the density and the water absorption of the samples were measured after 28 days. Three concrete samples were cast for each ratio, and the final result was determined as the mean of the three samples. The study was conducted in the laboratory of Concrete Technology, H.C.S.T Hyderabad, Sindh, Pakistan [26].

III. MATERIALS USED

A. Cement

Locally available Ordinary Portland Cement, under the brand name “Pakland”, was utilized as a binding material. Its experimental physical properties are shown in Table I.

TABLE I. PHYSICAL PROPERTIES OF CEMENT

S.N.	Tests	Results
01	Normal consistency	33%
02	Initial setting time	50 min
03	Final setting time	260 min

B. Fine and Coarse Aggregates

The aggregates used are locally available in the region of Hyderabad. Hill sand passing through #4 sieve was used as fine aggregates, and 20mm crushed stone was used as coarse aggregates. The properties of the laboratory test results of aggregates are shown in Table II.

TABLE II. PHYSICAL PROPERTIES OF AGGREGATES

S.N.	Properties	Fine aggregates	Coarse aggregates
01	Fineness modulus	2.26	---
02	Sieve analysis	Zone-II	---
03	Water absorption	1.80%	1.20%
04	Specific gravity	2.67	2.63
05	Bulk density	123lb/ft ³	102lb/ft ³

C. Rice Husk Ash

The husk of rice was collected from the region of Hyderabad. After its collection, the rice husk was burnt under uncontrolled burning temperature to produce ash. This ash was sieved through #30 sieves.

D. Fly Ash

The FA, generated in the form of very fine powder passing from #30 sieves, was collected from the Lakhra coal power plant. The Lakhra coal power plant generates about 2 million tons of FA annually, which are dumped in a landfill. Utilizing

the FA produced in the power plant as a cement replacement could reduce this.

E. Water:

Potable water was used.

IV. RESULTS AND DISCUSSION

A. Workability of Fresh Concrete

The highest slump value measured was 42mm for the 0%RHA+0%FA samples, while the lowest was 20mm for the 10%RHA+10%FA mixture. The slump value reduced with the rise of RHA and FA content, as shown in Figure 1.

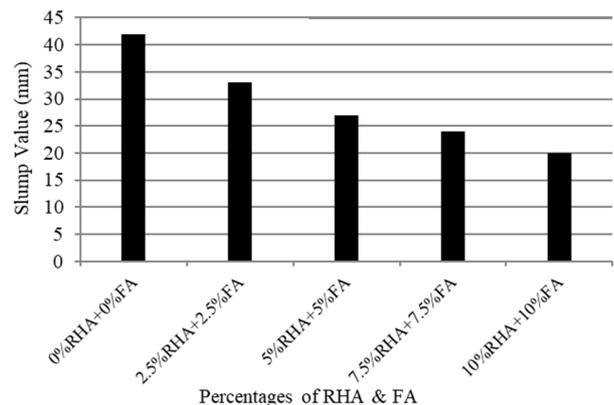


Fig. 1. Workability of fresh concrete

B. Density of Concrete

The density of the samples was measured on the 28th day. The conventional (0%RHA+0%FA) sample had the highest density (2392kg/m³), while the 10%RHA+10%FA had the lowest (2288kg/m³). The density of the concrete reduced as the RHA and FA increased, as shown in Figure 2.

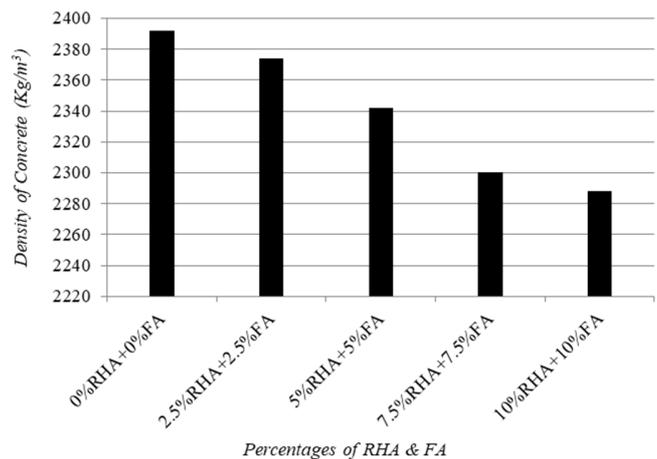


Fig. 2. Density of concrete

C. Water Absorption

The water absorption of the concrete samples was analyzed on the 28th day. The highest water absorption was found to be 4.65% for the 10%RHA+10%FA sample, while the lowest was

2.89% for the conventional sample. The water absorption of concrete augmented with the rise of RHA and FA as shown in Figure 3.

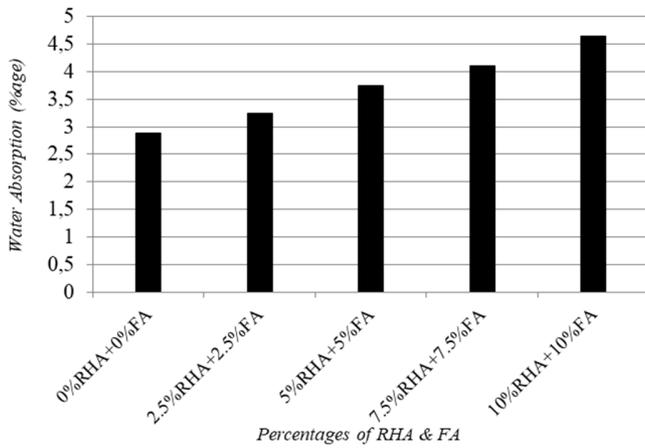


Fig. 3. Water absorption of concrete

D. Compressive Strength

The cubical samples (100×100×100mm) were used for investigating the compressive strength of concrete. Compressive strength was enhanced by 14.5% and 16.14% in comparison with the conventional mix when cement was replaced by 5%RHA+5%FA, while it was reduced by 13.7% and 12.90% for the 10%RHA+10%FA sample, on the 7th and the 28th day respectively as shown in Figure 4.

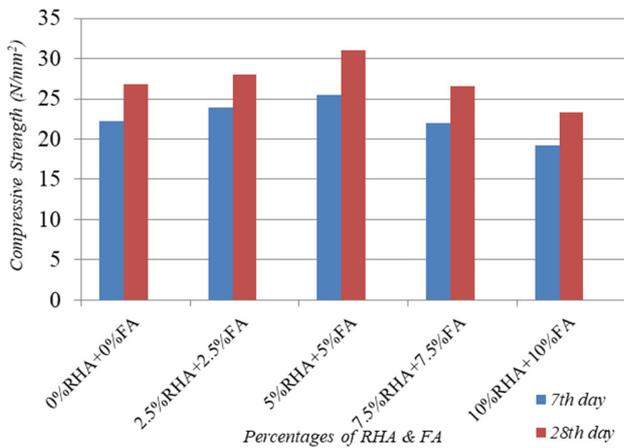


Fig. 4. Compressive strength of concrete

E. Indirect Tensile Strength of Concrete

The cylindrical samples (100×200mm) were used for determining split tensile strength. The indirect tensile strength improved by 11.4% and 15.20% in comparison with the conventional concrete for the 5%RHA+5%FA sample, while it reduced by 19.6% and 9.30% for the 10%RHA+10%FA sample, on the 7th and 28th day respectively, as shown in Figure 5.

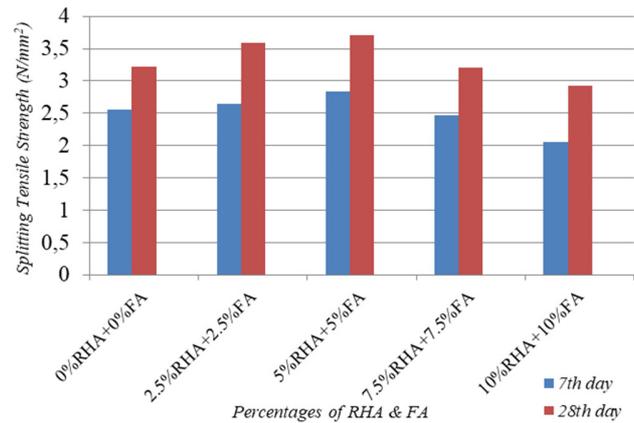


Fig. 5. Split tensile strength of concrete

V. CONCLUSION

Based on the experimental results obtained, it is concluded that the highest measured slump value was 42mm for the conventional sample, while the lowest was 20mm for the 10%RHA+10%FA. The highest density measured after 28 days was 2392kg/m³ for the conventional sample, while the lowest was 2288kg/m³ for the 10%RHA+10%FA. The optimum water absorption measured after 28 days was 4.65% for the 10%RHA+10%FA sample, while the lowest was 2.89% for the conventional sample. Compressive strength improved by 14.5% and 16.14% compared to the conventional mix when cement was replaced by 5%RHA and 5%FA, while it was reduced by 13.7% and 12.90% in the 10%RHA+10%FA sample, measured on the 7th and the 28th day respectively. Indirect tensile strength was enhanced by 11.4% and 15.20% compared to the conventional sample when cement was replaced by 5% RHA and 5% FA, while it reduced by 19.6% and 9.30% for the 10%RHA+10%FA sample on the 7th and the 28th day respectively.

In conclusion, optimum hardened properties were obtained by using 5% RHA and 5% FA as cement replacement material in concrete.

REFERENCES

- [1] S. Ghosal, S.C. Moulik, "Use of rice husk ash as partial replacement with cement in concrete-a review", International Journal of Engineering Research, Vol. 4, No. 9, pp. 506-509, 2015
- [2] A. M. Neville, J. J. Brooks, Concrete technology, Pearson Education Asia Pte Ltd, 2008
- [3] M. Alexander, S. Mindness, Aggregates in concrete, Taylor and Francis, 2005
- [4] P. V. Naidu, P. K. Pandey, "Replacement of cement in concrete", International Journal of Environmental Research and Development, Vol. 4, No. 1, pp. 91-98, 2014
- [5] Z. H., Shaikh, A. Kumar, M. A., Kerio, N. Bheel, A. A., Dayo, A. W. Abro, "Investigation on selected properties of concrete blended with maize cob ash", 10th International Civil Engineering Conference, Karachi, Pakistan, February 23-24, 2019
- [6] N. Bheel, R. A. Abbasi, S. Sohu, S. A. Abbasi, A. W. Abro, Z. H. Shaikh, "Effect of tile powder used as a cementitious material on the mechanical properties of concrete", Engineering, Technology & Applied Science Research, Vol. 9, No. 5, pp. 4596-4599, 2019
- [7] A. M. Neville, Properties of concrete, Pearson Education Asia Pte Ltd, 2000

- [8] V. W. Ramasamy, "Compressive strength and durability properties of rice husk ash concrete", *KSCE Journal of Civil Engineering*, Vol. 16, No. 1, pp. 93-102, 2012
- [9] N. Bheel, A. W. Abro, I. A. Shar, A. A. Dayo, S. Shaikh, Z. H. Shaikh, "Use of rice husk ash as cementitious material in concrete", *Engineering, Technology & Applied Science Research*, Vol. 9, No. 3, pp. 4209-4212, 2019
- [10] N. Bheel, S. L. Meghwar, S. A. Abbasi, L. C. Marwari, J. A. Muger, R. A. Abbasi, "Effect of rice husk ash and water-cement ratio on strength of concrete", *Civil Engineering Journal*, Vol. 4, No. 10, pp. 2373-2382, 2018
- [11] J. P. Broomfield, *Corrosion of steel in concrete: understanding, investigation and repair*, CRC Press, 2006
- [12] A. A. Dayo, A. Kumar, A. Raja, N. Bheel, Z. H. Shaikh, "Use of sugarcane bagasse ash as a fine aggregate in cement concrete", *Engineering Science and Technology International Research Journal*, Vol. 3, No. 3, pp. 8-11, 2019
- [13] N. D. Bheela, F. A. Memon, S. L. Meghwar, A. W. Abro, I. A. Shar, "Millet husk ash as environmental friendly material in cement concrete", 5th International Conference on Energy, Environment and Sustainable Development, Mehran UET Jamshoro, Pakistan, November 14-16, 2018
- [14] R. R. Hussain, T. Ishida, "Critical carbonation depth for initiation of steel corrosion in fully carbonated concrete and development of electrochemical carbonation induced corrosion model", *International Journal of Electrochemical Science*, Vol. 4, No. 8, pp. 1178-1195, 2009
- [15] N. Kad, M. Vinod, "Review research paper on influence of rice husk ash on the properties of concrete", *International Journal of Research*, Vol. 2, No. 5, pp. 873-877, 2015
- [16] M. Anwar, T. Miyagawa, M. Gaweesh, "Using rice husk ash as a cement replacement material in concrete", *Waste Management Series*, Vol. 1, pp. 671-684, 2000
- [17] S. D. Nagrale, H. Hajare, P. R. Modak, "Utilization of rice husk ash", *International Journal of Engineering Research and Applications*, Vol. 2, No. 6, pp. 1-5, 2012
- [18] I. B. Ologunagba, A. S. Daramola, A.O. Aliu, "Feasibility of using rice husk ash as partial replacement for concrete", *International Journal of Engineering Trends and Technology*, Vol. 30, No. 5, pp. 267-269, 2015
- [19] A. N. Givi, S. A. Rashid, F. N. A. Aziz, M. A. M. Salleh, "Contribution of rice husk ash to the properties of mortar and concrete: a review", *Journal of American Science*, Vol. 6, No. 3, pp. 157-165, 2010
- [20] N. Bheel, S. L. Meghwar, S. Sohu, A. R. Khoso, A. Kumar, Z. H. Shaikh, "Experimental study on recycled concrete aggregates with rice husk ash as partial cement replacement", *Civil Engineering Journal*, Vol. 4, No. 10, pp. 2305-2314, 2018
- [21] H. B. Mahmud, N. A. A. Hamid, K. Y. Chin, "Production of high strength concrete incorporating an agricultural waste-rice husk ash", 2nd International Conference on Chemical, Biological and Environmental Engineering, Cairo, Egypt, November 2-4, 2010
- [22] H. T. Le, K. Siewert, H. M. Ludwig, "Alkali silica reaction in mortar formulated from self-compacting high performance concrete containing rice husk ash", *Construction and Building Materials*, Vol. 88, pp. 10-19, 2015
- [23] N. P. Hasparyk, P. J. Monteiro, H. Carasek, "Effect of silica fume and rice husk ash on alkali-silica reaction", *Materials Journal*, Vol. 97, No. 4, pp. 486-492, 2000
- [24] K. Sakr, "Effects of silica fume and rice husk ash on the properties of heavy weight concrete", *Journal of Materials in Civil Engineering*, Vol. 18, No. 3, pp. 367-376, 2006
- [25] V. Goud, N. Soni, G. Varma, K. Kushwah, S. Chaurasia, V. Sharma, "Partial replacement of cement with fly ash in concrete and its effect", *IOSR Journal of Engineering*, Vol. 6, No. 10, pp. 69-75, 2016
- [26] N. D. Bheel, S. A. Abbasi, S. L. Meghwar, F. A. Shaikh, "Effect of human hair as fibers in cement concrete", International Conference on Sustainable Development in Civil Engineering, Jamshoro, Pakistan, November 23-25, 2017