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Characteristics of Concrete With Rice Husk Ash Local Kutai Kartanegara

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Abstract. Concrete material made from natural waste was developed to balance the use of concrete materials resulting from natural exploration with an impact on environmental damage, rice husk is a waste material from rice mills and contains reactive silica and has the benefit of reducing energy consumption in cement production. Laboratory test method in the form of testing the compressive characteristics used standard cube concrete 150 mm x 150 mm x 150 mm with a total sample of 24 samples. The effect of concrete strength on the amount of cement replacement is 0%; 5%; 10% ; and 15% which could be compared with concrete without using husk ash. The compressive strength obtained in terms of the age of the concrete is 28 days. The mechanical properties of husk ash at the age of 28 days gave optimal compressive strength results with the addition of 5% husk ash.

Key word : *Concrete*, *Rice Husk Ash, Characteristics*, *Compressive Strength*

INTRODUCTION

Kutai Kartanegara Regency has an area of 27,263.10 km^2 located between 115°26' - 117°36' east longitude and 1°28' north longitude and 1°08' south longitude [1]. The husk ash is the result of rice milling located in Mahulu Village, Tenggarong District. The construction industry has contributed significantly to various pollution problems. This is because cement manufacturing has been reported to be a major source of dust, toxins, and carbon dioxide emissions, which are significant contributors to greenhouse gases [2].

Cement is the most widely used construction material worldwide. Nevertheless, the cement industry faces environmental and energy challenges, including generating 5% and 10% of the world's total anthropogenic CO_2 emissions [3], which has been growing at an alarming rate with the growth of the human population and the unprecedented industrialization revolution. Therefore, researchers and manufacturers are focusing on environmentally friendly concrete materials and their application in structures in order to lessen environmental stress and the depletion of natural resources. This is done by mixing recycled elements into concrete. [4].

Because of its changing quality due to its high carbon content and partial presence of SiO2 in the crystalline phase, rice husk ash is still rarely used in the concrete industry, despite growing awareness of the environmental harm caused by the high production of regular portland cement (non-reactive) [5]. Rice husk ash contains 80-85% silica which is highly reactive, depending on temperature [6]. The moisture content of RHA ranges from 8.68 to 10.44%, and the bulk density ranges from 86-114 kg/m3 [7].

Concrete is still the main construction material worldwide and to face the challenge of early structural damage, the durability of concrete must be ensured [8]. Concrete is an appropriate mixture of cement, fine aggregate, coarse aggregate and water. Additives (minerals and/or chemicals) are sometimes incorporated into concrete to improve some of the characteristics of fresh and/or hardened concrete, and the mixing process. Hardening of concrete occurs because of the chemical reaction between water and cement that lasts a long time and contributes to the strength of concrete with treatment and age [9]. The current average concrete production is 4.4 billion tons per year. It is expected to increase by 5.5 billion tonnes by 2050 to accommodate the needs of the world's growing population [10].

Alwan et.al. (2022) in a study stated the addition of rice husk ash in different ratios (0%, 7%, and 14%) as a substitute for ordinary Portland cement with different water-cement ratios (0.3, 0.5, and 0.7) and treatment in water for various periods (10, 20, and 30 days) on both the durability and strength of the concrete and its corrosion was investigated that adding finer (not wider) RHA particles increased the flexural, compressive and tensile strength values and limited ion penetration. chloride over time [11].

Vieira et.al. (2020) in a study stated that the evolution of the compressive strength of high-strength concrete with rice husk ash (RHA) was evaluated as a function of RHA particle size, porous structure and substitute content. The porous structure of RHA was investigated with an N2 absorption isotherm and its effect on hydration was evaluated using isothermal calorimetry and thermogravimetry. The results showed that the particle size of RHA affected the compressive strength until the age of 28 days, while at the age of 91 days the substitute content became a significant factor. [12].

Nana et.al (2021) research results show that The volcanic ash content and rice husk ash content have a significant impact on the mechanical strength and physical qualities, with rice husk ash having the best mechanical strength (19.3 and 60.73 MPa for flexural and compressive strength), obtained with a composite sample containing 20% by weight of volcanic ash and 10% by weight of rice husk ash. Because the presence of additives that increase the compactness and microstructure of the obtained geopolymer matrix and the increase in the SiO_2/Al_2O_3 ratio with the addition of rice husk ash [13].

Research on the characteristics of concrete mixed with rice husk ash, with percentages of 5, 10, and 15% increasing the compressive strength of concrete, the addition of 5% husk ash has a more optimal compressive strength than rice husk ash with percentages of 10 and 15%. In this paper, the characteristics of concrete with the addition of rice husk ash with a compressive strength review of 28 days were analyzed in this study.

MATERIAL AND RESEARCH METHODS

Material

To achieve increased performance, durability and quality, the materials used in concrete must be tested according to standards [14]. The materials used in this study consisted of cement, coarse aggregate, sand sourced from Palu, Central Sulawesi, and local rice husk ash from Mahulu Village, Tenggarong District, Kutai Kertanegara Regency. The use of coarse aggregate and sand in concrete needs to be tested for the physical properties of these materials to contribute to the compressive strength of concrete. The results of the examination of the physical properties of crushed stone and sand can be seen in Table 1.

TABLE 1. Aggregate test result

parameter	result		terms	method
	coarse aggregate	sand		
specific gravity	2,767		≥. 2,5	SNI 1969-2008
		2,644		SNI 1970-2008
absoption	1,647		max. 3 %	SNI 1969-2008
		1,750	max. 2 %	SNI 1970-2008
unit weight	1,55	1,67		SNI 03 4804 1998
water content	0,778	1,165		SNI 03 1971 1990
mud content	1,737		max. 1 %	SNI 03 1971 1990
		1,087	max. 5 %	SNI 03 2816 1992
abrasion	25,40		max. 27 %	SNI 2417 2008
		-	-	-

Combined Aggregate Grading

Optimized aggregate grading can reduce the cement content by a significant amount which is the most valuable part of concrete [15]. Gradation or particle size distribution of sand affects concrete properties such as density, void content, workability and strength [16]. The particle size distribution for the product of each test was measured incorporating manual sieving for the material [17]. Aggregate is an important component of concrete, and its characteristics have an important influence on the performance of fresh and hardened concrete, such as particle size, shape and gradation. [18]. The combined gradation of aggregates will determine the value of the fine modulus of sand grains and fine modulus of crushed stone, the result of the fine modulus values will be obtained as a percentage of the volume of sand and coarse aggregate for the concrete mixture. The results of the combined aggregate gradation can be seen in Figure 1.

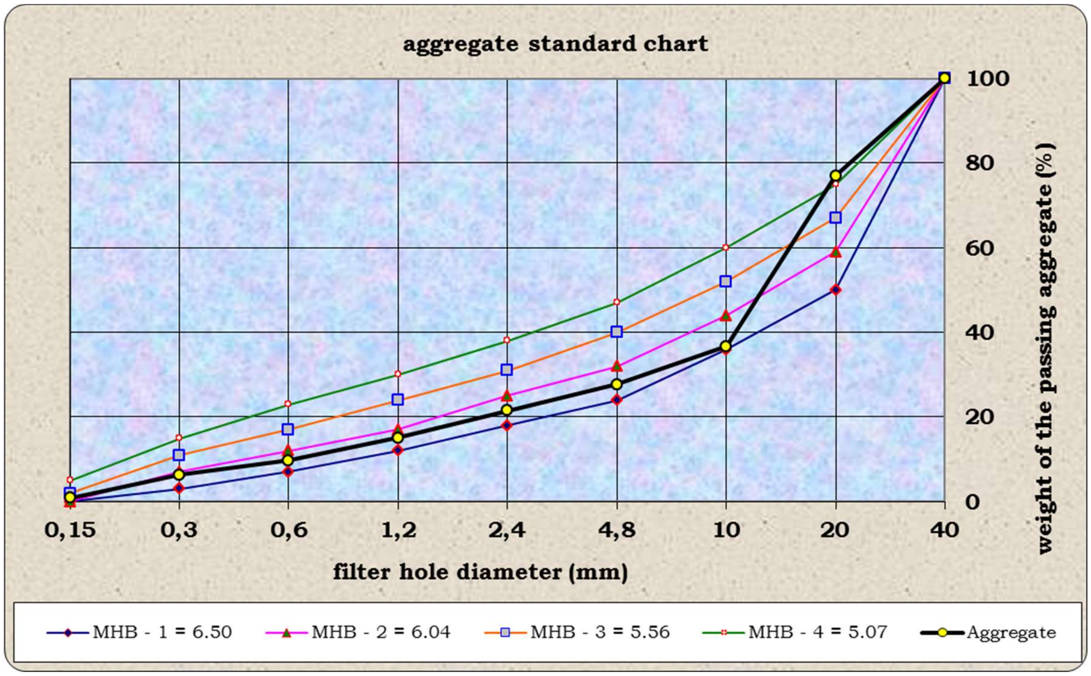


FIGURE 1. Aggregate combined gradation

Calculation of grain modulus using Equation 1.

$$Wh : Wk = [mk - mc] : [mc - mh] \qquad (1)$$

Wh = weight of fine aggregate, Wk = weight of coarse aggregate, mk = fine modulus of coarse aggregate grain, mc = fine modulus of mixed aggregate, mh = fine modulus of sand.

Rice Husk Ash

Rice husk is the hardest layer which includes karyopsis which consists of two parts called lemma and palea which are interlocked and in the milling process 20 - 30% husk is obtained, rice husk ash has a high silica content so that it can be classified as a material that has good pozzolanic properties. Rice husk ash began to be used because of environmental pollution and sustainability factors, generally an agricultural by-product obtained from burning rice husk ash under a controlled temperature of 800 C, which is 85% to 90% amorphous silica plus about 5% alumina together with the ash as 25 %. Because RHA is more absorbent, RHA concrete requires more water consistency. By incorporating rice husk ash into the concrete, the concrete becomes environmentally friendly [19]. The chemical composition of rice husk ash can be seen in Table 2.

TABLE 2. Chemical composition of rice husk ash

composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI
rice husk ash	94,20	1,15	1,85	0,76	0,35	0,04	0,13	1,65	0,76

The physical properties of rice husk ash can be seen in Table 3.

TABLE 3. Physical properties of rice husk ash

material	specific gravity
rice husk ash	2,07

Cement

Cement is an adhesive substance in concrete through a combination of chemical processes, dry powder and serves as an adhesive when reacting with water will provide strength to the structure that produces hardness in addition to being a strong binding medium for aggregates in concrete. Pozzolans are silica and alumina materials that react with calcium hydroxide [Ca(OH)2] in the presence of water to produce a hardened structure with excellent mechanical properties [20]. The cement used is type 1 Portland Cement which is generally used in the manufacture of concrete. The chemical composition of cement can be seen in Table 4.

TABLE 4. Chemical composition of cement

composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	LOI
cement	14,88	3,84	3,07	60,76	0,85	2,35	0,13	0,35	13,2

The physical properties of type 1 OPC cement can be seen in Table 5.

TABLE 5. Cement properties

material	specific gravity
cement	2,05

Concrete Sample Preparation

Sample preparation prior to the compressive strength test. For testing the number of samples carried out in the study of 120 cube samples (150 mm x 150 mm x 150 mm), the percentage of husk ash was 0%; 5%; 10% and 15%, the number of 24 cube samples by reviewing the compressive strength of 28 days. The purpose of experimental measurements is to determine the effect of the number of core samples on the quality of the data obtained [21]. The number of samples can be seen in Table 6.

TABLE 6. Number of cube samples

rice husk ash (%)	age 28 days	total sample
0	6	24
5	6	
10	6	
15	6	

Compressive Strength Plan

Compressive strength is one of the most important properties in designing structures and assessing the quality of concrete. The compressive strength of concrete is usually determined from a uniaxial compression test. This type of loading test can be carried out on concrete specimens of different shapes (eg cylinders or cubes) with several recommended sizes [22]. Concrete is a complex engineering material with different materials and design variables. Therefore, an accurate prediction of the compressive strength of concrete must consider its nonlinearity [23]. The compressive strength of the concrete cube to be achieved is based on the design results of 24.5 MPa or 250 Kg/cm2. Testing the compressive strength of concrete was carried out to determine the effect of adding rice husk ash with varying percentages.

Preparation of Mixtures and Proportions

To prepare samples [24]. Mix proportion (step 1) is the process of weighing determined amount of dry matter [25]. All coarse aggregate, sand, dry cement and rice husk ash were pre-mixed in a laboratory mixer for 8 minutes. The ratio of the concrete composition 1 ; 1,6 ; 4.3. The water-cement ratio [26], was 0.63 and remained constant for all mixtures. The slump is between 60-180 mm, the gradation is in the form of aggregate grain distribution in percentage units, coarse aggregate material passes through 20 mm size sieve, and the sand passes through 4.75 mm sieve [27], according to the mix design. After mixing the concrete, it is carried out in stages maximizing the workability of the concrete [28]. The proportion of concrete mixture is an important parameter to determine the water absorption ability of concrete. The role of each individual component determines the feasibility of the process [29].

RESULT AND DISCUSSION

Grain Fine Modulus

The fine grain modulus is an index value used to measure the fineness or coarseness of the concrete grains, the fine grain modulus is described as the cumulative percentage of concrete grains retained on the sieve and divided by one hundred. The results of the combined gradation analysis of the fine modulus of the sand grains are 3.275 and the coarse aggregate fine modulus is 7.063. The fine modulus of the mixed granules is 6.05 so that the weight percentage of sand to coarse aggregate is 36.50%. The results of fine modulus of crushed stone and sand can be seen in Table 7.

TABLE 7. Fine modulus of concrete granules

sieve (mm)	coarse aggregate		sand	
	hold (%)	cumulative hold (%)	hold (%)	cumulative hold (%)
40	0,00	0,00	0,00	0,00
20	31,34	31,34	0,00	0,00
10	55,07	86,41	0,00	0,00
4,8	8,70	95,10	9,83	9,83
2,4	2,53	97,64	16,07	25,90
1,2	0,63	98,27	22,45	48,35
0,6	0,40	98,68	18,78	67,13
0,3	0,35	99,02	11,74	78,87
0,15	0,81	99,83	18,56	97,43
residu	0,17	-	2,57	-
amount	100	706,28	100	327,51

Mixed Design

The mix design aims to get the weight of each concrete material consisted of cement, coarse aggregate, sand, water, and rice husk ash. The control mixture only contained Portland cement, natural aggregate and drinking water which was called PC (Control Mixture) [30]. The effect of the proportion of cement paste mixing on the compressive strength is very large [31]. Concrete mix design is usually carried out according to standard procedures specified in codes developed by recognized institutions such as the Building Research Institute [32]. The composition of the concrete mixture according to the Indonesian National Standard procedure can be seen in Table 8.

TABLE 8. Composition of concrete mix (m^3)

material	rice husk ash persentage			
	0 %	5 %	10 %	15 %
cement	321,85 kg	305,78 kg	289,67 kg	273,56 kg
rice husk ash	0,00 kg	16,09 kg	32,19 kg	48,28 kg
sand	513,29 kg			
coarse aggregate	1387,80 kg			
water	202,76 liter			
Proportion	1 ; 1,59 ; 4,31	1 ; 1,67 ; 4,53	1 ; 1,77 ; 4,79	1 ; 1,87 ; 5,07

Compressive Strength

The test results obtained from the compressive strength for all concrete mixtures are represented graphically [33]. Compressive strength characterizes concrete according to its properties of structural use. Knowledge of the compressive strength of concrete is very important when any material is used to replace raw materials [34]. The water cement factor has an influence on the compressive strength of 28 days. The compressive strength of normal concrete [35] or 0% rice husk ash is 8.18% lower than the compressive strength of concrete with the addition of 5% rice husk ash. The compressive strength of concrete with 10% rice husk ash decreased by 8.97% against the compressive strength of 0% husk ash and the compressive strength of 15% of rice husk ash decreased by 9.46 % against the compressive strength of 0% husk ash. The results of the compressive strength can be seen in Figure 2.

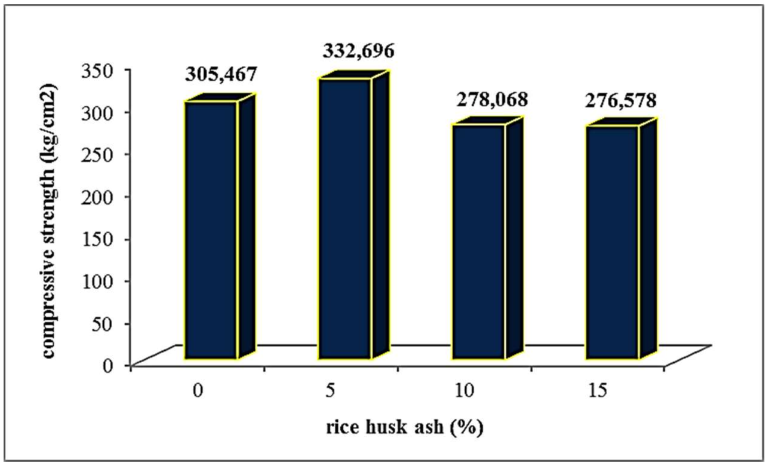
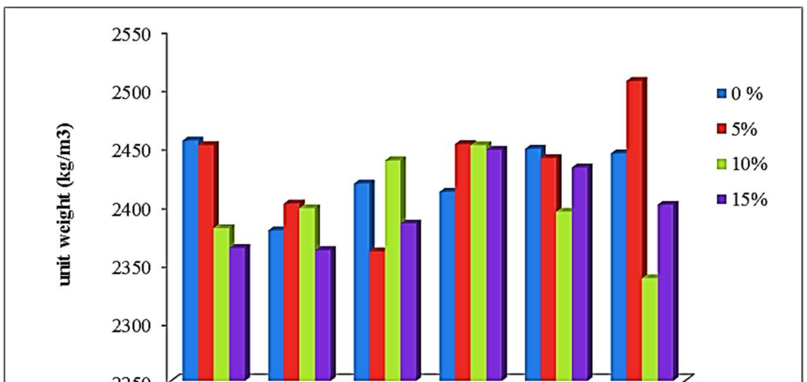


FIGURE 2. Compressive strength

Unit Weight

Unit weight was used to evaluate the concrete mix with 0%; 5%; 10% ; 15% rice husk ash. The unit weight of the concrete mixture was determined after 28 days of immersion by measuring the weight and volume of the test object. Automatic scales were used to measure weight while the dimensions of the test object measured using a caliper [36]. The results of the unit weight of concrete can be seen in Figure 3.



	28	28	28	28	28	28
0 %	2456	2379	2419	2412	2449	2445
5%	2452	2402	2361	2453	2441	2507
10%	2381	2398	2439	2452	2395	2338
15%	2364	2362	2385	2448	2433	2401

FIGURE 3. Unit weight of concrete

CONCLUSION

The characteristics of the addition of 5% husk ash concrete have a better compressive strength compared to the percentage of husk ash 10 and 15%. Within 28 days, there was an increase in compressive strength of 8.18% with the addition of 5% husk ash, a decrease in compressive strength of 8.97% with the addition of 10% husk ash. and a decrease in compressive strength of 9.46% with the addition of 15% husk ash. Overall, the use of rice husk ash with a percentage of 5%; 10% ; and 15% of the planned compressive strength of 24.5 MPa or 250 Kg/cm^2 is achieved. This is influenced by the water-cement factor and the increase in the SiO_2/Al_2O_3 ratio with the addition of rice husk ash, and the use of water-cement factor of 0.63 and 5% husk ash has a stronger ratio. Rice husk ash shows effective pozzolanic behavior due to its high silica content.

REFERENCES

[1] Badan Pusat Statistik. Kutai Kartanegara Dalam Angka 2022. ISSN: 2746-2854, No Publikasi: 64030.2001, CV. Mahendra Jaya, (2022).

[2] Adnan Z. S., Ariffin N. F., Mohsin S. M. S., and Lim N. H. A. S. *Review Paper: Performance of Rice Husk Ash as a Material for Partial Cement Replacement in Concrete*. Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2021.02.400.

[3] Shaaban M. *Properties of Concrete with Binary Binder System of Calcined Dolomite Powder and Rice Husk Ash*. Heliyon 7 (2021) e06311, https://doi.org/10.1016/j.heliyon.2021.e06311.

[4] Tayeh B. A., Alyousef R., Alabduljabbar H., and Alaskar A. *Recycling of Rice Husk Waste for a Sustainable Concrete: A Critical Review*. Journal of Cleaner Production 312 (2021) 127734, https://doi.org/10.1016/j.jclepro.2021.127734.

[5] Kwan W. H., and Wong Y. S. *Acid Leached Rice Husk Ash (RHA) in Concrete: A Review*. Materials Science For Energy Technologies 3 (2020) 501-507, https://doi.org/10.1016/j.mset.2020.05.001.

[6] Kishore R., Bhikshma V., and Prakash P. J. *Study of Strength Characteristics of High Strength Rice Husk Ash Concrete*. Procedia Engineering 14 (2011) 2666-2672, https://doi.org/10.1016/j.proeng.2011.07.335.

[7] Masanja D. N., Muya M. S., and Nyangi P. *Characteristics of Combined Rice and Wheat Husk Ashes as a Partial Replecement for Cement in Mortar*. Civil Engineering Journal, e-ISSN: 2476-3055, Vol 8, No 04, April, (2022), http://dx.doi.org/10.28991/CEJ-2022-08-04-04.

[8] Rumman R., Bari M. S., Manzur T., Kamal M. R., and Noor M. A. *A Durable Concrete Mix Design Approach Using Combined Aggregate Gradation Bands and Rice Huask Ash Based Blanded Cement*. Journal of Building Engineering, 30 (2020) 101303, https://doi.org/10.1016/j.jobe.2020.101303.

[9] Singh A., Kumar R., Metha P. K., and Tripathi D. *Effect of Nitric Acid on Rice Husk Ash Steel Fiber Reinforced Concrete*. Materials Today: Proceedings 27 (2020) 995-1000, https://doi.org/10.1016/j.matpr.2020.01.310.

[10] Aslam F., Elkotb M. A., Iqtidar A., Khan M. A., Javed M. F., Usanova K. I., Khan M. I., Alamri S., Musarat M. A. *Compressive Strength Prediction of Rice Husk Ash Using Multiphysics Genetic Expression Programming*. Ain Shams Engineering Journal 13 (2022) 101593, https://doi.org/10.1016/j.asej.2021.09.020.

[11] Al-Alwan A. A. K., Al-Bazoon M., Mussa F. I., Alalwan H. A., Shadhar M. H., Mohammed M. M., and Mohammed M. F. *The Impact of Using Rice Husk Ash as a Replacement Material in Concrete: An Experimental Study*. Journal of King Saud University-Engineerung Sciences, https://doi.org/10.1016/jjkseus.2022.03.002.

[12] Vieira A. P., Filho R. D. T., Tavares L. M., and Cordeiro G. C. *Effect of Particle Size, Porous Struture and Content of Rice Husk Ash on hte Hydration Process and Compressive Strength Evolution of Concrete*. Construction and Building Materials 236 (2020) 117553, https://doi.org/10.1016/j.conbuildmat.2019.117553.

[13] Nana A., Epey N., Rodrique K. C., Deutou J. G. N., Djobo J. N. Y., Tome S., Alomayri T. S., Ngoune N. *Mechanical Strength and Microstructure of Metakaolin/Volcanic Ash-Based Geopolymer Composites Reinforced with Reactive Silica from Rice Husk Ash*. Materialia 19 (2021) 101083, https://doi.org/101.1016/j.mtla.2021.101083.

[14] Chetan D., and Aravindan A. *An Experimental Investigation on Strength Characteristics by Partial Replacement of Rice Husk Ash and Robo Sand in Concrete*. Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.05.075.

[15] Ashraf W. B., and Noor M. A. *Performance-Evaluation of Concrete Properties for Different Combined Aggregate Gradation Approaches*. Procedia Engineering 14 (2011) 2627-2634, https://doi.org/10.1016/j.proeng.2011.07.330.

[16] Sabih G., Tarefder R. A., and Jamil S. M. *Optimization of Gradation and Fine Modulus of Naturally Fine Sands for Improved Performance as Fine Aggregate in Concrete*. Procedia Engineering 145 (2016) 66-73, https://doi.org/10.1016/j.proeng.2016.04.016.

[17] Fladvad M., and Onnela T. *Influence of Jaw Crusher Parameters on the Quality of Primary Crushed Aggregates*. Minerals Engineering 151 (2020) 106338, https://doi.org/10.1016/j.mineng.2020.106338.

[18] Yan W., Cui W., and Qi L. *Effect of Aggregate Gradation and Mortar Rheology on Static Segregation of Self-Compaction Concrete*. Construction and Building Materials 259 (2020) 119816, https://doi.org/10.1016/j.conbuildmat.2020.119816.

[19] Anand S. S., Nirmala R., Kumar D. A., Srikanth V., and Kumar M. S. *An Eksperimental and Numerical Investigation on Flexural Characteristics of Wire Mesh Reinforced Concrete Beam Blended with Rice Husk Ash (RHA).* Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.11.298.

[20] Tulashie S. K., Ebo P., Ansah J. K., Mensah D., *Production of Potrland Pozzolana Cement from Rise Husk Ash*. Materialia 16 (2021) 101048, https://doi.org/10.1016/j.mtla.2021.101048.

[21] Mynarcik P. *Core Sampling for Fiber Concrete Construction-Context Between Quantity of Core Samples and Evaluation of Fiber Concrete Characteristics*. Procedia Engineering 114 (2015) 493-499, https://doi.org/10.1016/j.proeng.2015.08.097.

[22] Vu C. C., Ho N. K., and Pham T. A. *Weibull Statistical Analysis and Experimental Investigation of Size Effects on the Compressive Strength of Concrete Building Materials*. Case Studies in Construction Materials 17 (2022) e01231, https://doi.org/10.1016/j.cscm.2022.e01231.

[23] Al-Jamimi H. A., Al-kutti W. A., Alwahaishi S., and Alotaibi K. S. *Prediction of Compressive Strength in Plain and Blended Cement Concrete Using a Hybrid Artificial Intelligence Model*. Case Studies in Construction Materials 17 (2022) e01238, https://doi.org/10.1016/j.cscm.2022.e01238.

[24] Lu J. X., Shen P., Ali H. A., and Poon C. S. *Mix Design and Performance of Lightweight Ultra High-Performance Concrete*. Materials & Design 216 (2022) 110553, https://doi.org/10.1016/j.matdes.2022.110553.

[25] Wangler T., Peleggi R., Gurel S., and Flatt R. J. *A Chemical Process Engineering Look at Digital Concrete Processes: Critical Step Design, Inline Mixing, and Scaleup*. Cement and Concrete Research 155 (2022) 106782, https://doi.org/10.1016/j.cemconcres.2022.106782.

[26] Mohe N. S., Shewalul Y. W., and Agon E. C. *Experimental Investigation on Mechanical Properties of Concrete Using Different Sources of Water for Mixing and Curing Concrete*. Case Studies in Construction Materials 16 (2022) e00959, https://doi.org/10.1016/j.cscm.2022.e00959.

[27] Syahrul., Tjaronge M. W., Djamaluddin R., Amiruddin. A. A. *Flexural Behavior of Normal and Lightweight Concrete Composite Beam*. Civil Engineering Journal, e-ISSN: 2476-3055, Vol 7, No 03, March, (2021), http://dx.doi.org/10.28991/cej-2021-03091673.

[28] Cuesta V. R., Evangelista L., Brito J. D., Skaf M., Manso J. M. *Shringkage Prediction of Recycled Aggregate Structural Concrete With Alternative Binder Through Partial Correction Coefficients*. Cement and Concrete Composite 129 (2022) 104506, https://doi.org/10.1016/j.cemconcomp.2022.104506.

[29] Sahoo A. K., and Kar B. B. *Water Absorptivity and its Impact on Various Properties of the Concrete Materials*. Materials Today: Proceeding, https://doi.org/10.1016/j.matpr.2021.01.474.

[30] Nwaubani S. O., Parsons L. A. *Properties, Durability and Microstructure of Concrete Incorporating Waste Electrical and Electronic Plastics as Partial Replacement for Aggregates in Concrete*. Case Studies in Construction Materials 15 (2021) e00731, https://doi.org/10.106/j.cscm.2021.e00731.

[31] Park S., Moges K. A., Wu S., Pyo S. *Characteristics of Hybrid Alkaline Cement Composite with High Cement Content: Flash Set and High Compressive Strength*. Journal of Materials Research and Technology 2022 ; 17 : 1582 1597.

[32] Joshua O., Olusola K. O., Ndaku D. O., Ede A. N., Olofinnade O. M., and Job O. F. *Modified Mix Design Development Specification Batched by Volume from Specified Mix Design by Weight Towards Improved Concrete Production*. Methodsx 7 (2020) 100817, https://doi.org/10.1016/j.mex.2020.100817.

[33] Panda K. C., Behera S., and Jena S. *Effect of Rice Husk Ash on Mechanical Properties of Concrete Containing Crushed Seashell as Fine Aggregate*. Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.04.049.

[34] Fernandes F. A. D. S., Arcaro S., Junior E. F. T., Serra J. C. V., and Bergmann C. P. *Glass Foams Produced from Soda-Lime Glass Waste and Rice Husk Ash Applied as Partial Subtitutes for Concrete Aggregates*. Process Safety and Environmental Protection 128 (2019) 74-84, https://doi.org/10.1016/j.psep.2019.05.044.

[35] Zhu L., Zhao C., and Dai J. *Prediction of Compressive Strength of Recycled Aggregate Concrete Based on Gray Correlation Analysis*. Construction and Building Materials 273 (2021) 121750, https://doi.org/10.106/j.conbuildmat.2020.121750.

[36] Azees M. O., Ahmad S., Al-dulaijan S. U., Maslehuddin M., Naqvi A. A. *Radiation Shielding Performance of Heavy-Weight Concrete Mixtures*. Construction and Building Materials 224 (2019) 284-291, https://doi.org/10.1016/j.conbuildmat.2019.07.077.