JOURNAL OF STRUCTURAL MONITORING AND BUILT ENVIRONMENT
e-ISSN: 2821-3432

JSMBE

Vol. 4 No. 1 (2024) 1-8
https://publisher.uthm.edu.my/ojs/index.php/jsmbe

Non-Destructive Test of Seawater Concrete Containing Rice Husk Ash and Coal Bottom Ash as Cement and Sand Replacement

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DOI: https://doi.org/10.30880/jsmbe.2024.04.01.001

Article Info

Received: 12 March 2024
Accepted: 4 June 2024
Available online: 30 June 2024

Keywords

Seawater, rice hush ash, coal bottom ash, compressive strength

Abstract

The high demand for concrete production induced high consumption of freshwater, river sand, and cement. This had resulted in harmful issues for the environment such as a high carbon footprint, water shortage, greenhouse effect, and more. These negative impactions for environment had led to the use of rice husk ash (RHA) and coal bottom ash (CBA) as a replacement for cement and sand respectively. The main objective of this study is to investigate the concrete quality through the non-destructive test (NDT). Concrete with seawater, RHA, and CBA was tested on its surface and internal strength using rebound hammer test and ultrasonic pulse velocity test respectively. To achieve the objective, seven (7) series of mixtures were prepared. RHA is fixed to 10% of cement replacement by weight, while the volume of sand is replaced CBA by 10% increment up to 100%. All specimens are tested at 7 and 28 days. In addition, NDT's result was later compared with compressive strength. The outcomes of this investigation shown that regression values (R^2) more than 0.85 sufficiently indicate the relationship between the non-destructive test and compressive strength. As a result, the seawater concrete combining RHA and CBA produced by this study has a good quality and compressive strength. Hence, this study offered environmentally friendly materials, seawater, rice husk ash, and coal bottom ash are presented as eco-materials in concrete to partially replace conventional materials.

1. Introduction

The growing amount of waste in our nation today contributes to solid waste pollution. As a result, using waste materials in concrete can lessen environmental pollution and make sustainable building practices legal. The construction industry needs to be aware of all the benefits of using waste material in place of concrete. To partially replace cement while maintaining the sustainability of construction materials, it is important to use industrial waste products. Due to their accessibility and relatively high ash production when burned, rice husk ash (RHA) and coal bottom ash (CBA) have the most potential.

CBA is a waste product that increases yearly and adds to the solid waste pollution in Malaysia. In concrete mixtures, CBA is utilised to replace sand while also protecting the environment. Analogous to sand, CBA has a low chloride permeability and a strong ability to bind chloride ions. (Singh et al., 2020) reported CBA was disposed of in a landfill; however, because of the harmful and toxic particles, this procedure may be dangerous for both the environment and human health [1]. Compressive strength was more significantly affected by CBA, according to research on the mechanical characteristics and workability of concrete with excellent strength. (Singh, Arya, and

Mithulraj 2018) CBA is an acceptable material replacement for sand in concrete, according to their analysis. The 28th day after cure, they found that the inclusion of CBA in the concrete did not impact the pulse velocity or compressive strength. [2].

Seawater comprises a greater proportion of the Earth's surface water compared to freshwater. Seawater has a high concentration of salts, with the main components being sodium, chloride, and sulphate. Concrete exhibits aggressive behavior primarily because of the existence of magnesium sulfate ($MgSO_4$), magnesium chloride ($MgCl_2$), sodium chloride (NaCl), and various other soluble salts. Many studies have demonstrated how adding and curing seawater to cement-sand mixtures and corresponding concrete affects their compressive strength. The mixture with seawater has more strength when non-corrosive reinforcement with concrete reinforced is used instead of unreinforced concrete (Montanari et al., 2019) [3]. Therefore, utilising seawater in place of fresh water is still a viable option today. Research done by (Otsuki et al., 2019) has shown that the use of some environmental by-products such as CBA, slag, or silica fume as an admixture or for partial replacement of sand has resulted in the production of concrete with excellent resistance to freezing, minimal permeability, and a strong compressive strength [4].

Meanwhile, agricultural waste is known as rice husk ash (RHA) which achieved in most parts in Malaysia. It is predominantly utilized as a source of fuel, originating from paddy that has undergone milling in power plants or steam-producing boilers employed by diverse industrial sectors. The following deposit was mostly made of silica, which has a colour range of white to black and is not very reactive, making up about 90% of the mass. But every year, more of these by-products and residues are produced. Incorporating these solid wastes into the construction industry is therefore a major concern. Moreover, to the environmental risks brought on by the manufacture of cement, the production of industrial and agricultural waste has also exacerbated pollution-related problems (Kamaruddin et al., 2021) [5]. RHA shows promise as a viable alternative to cement, addressing the challenges at hand. This is primarily attributed to its elevated silica content, the specific crystallization phase of silica, the size of the material, and the surface area of its particles. Additionally, during the incineration process, RHA generates a greater quantity of non-crystalline silica dioxide (SiO_2). When incorporating RHA with pozzolanic properties into concrete, the result is an enhancement in both the overall strength and compressive strength of the concrete. This improvement occurs specifically when 10% of the concrete's weight is composed of RHA. Hence, instead of using cement in concrete, waste from the production of rice can be recycled and used to create admixtures or concrete substitutes. Reducing the amount of cement needed not only protects the environment but also provides a useful solution to get rid of this agricultural waste, which has few alternate purposes. Therefore, the objective of this research was to conduct non-destructive tests on Rice Husk Ash (RHA) and Coal Bottom Ash (CBA), which were employed as partial substitutes for cement and sand in order to assess their impact on the compressive properties of concrete after 7, and 28 days of curing.

2. Material Preparation and Testing

2.1 Materials

In this investigation, two different kinds of materials were utilised which are conventional materials and sustainable materials. The traditional components, including freshwater, Ordinary Portland Cement (OPC), sand, and coarse aggregate. In accordance with Malaysia Standard MS 197-7: 2007, Ordinary Portland Cement of Grade 42.5 was utilised as the binder. 5mm of sand was sieved. Coarse aggregate that has been air-dried before mixing and passed through a 20 mm sieve. The sustainable material in this study is the seawater, CBA, and RHA (see Fig. 1). In this investigation, the percentage of CBA in this study is 10%, 20%, 30%, 40%, 50%, and 100% used to replace the sand by volume and it must pass through a 5 mm sieve during the mixing process. However, RHA in this study only replaced 10% of the cement and was sieved through British Standard (BS) with a size of 75 μm sieve. Table 1 shows the description for each concrete series for both trial mix and actual mix.

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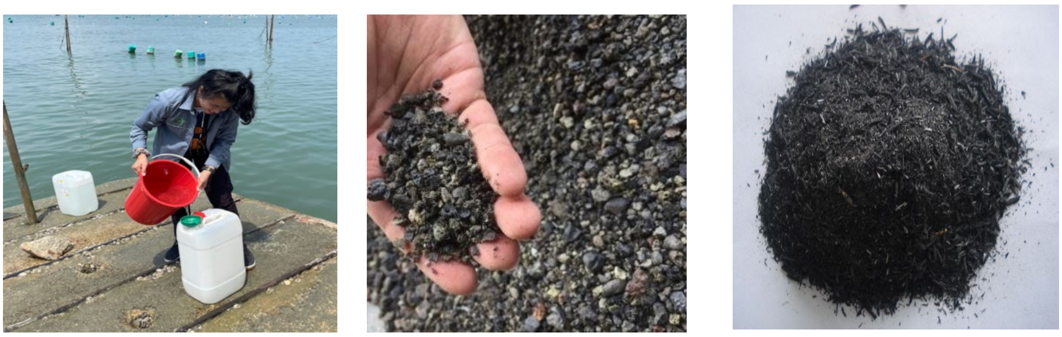

(a) **(b)** **(c)**

Fig. 1 *Sustainable material used in this study as (a) seawater; (b) coal bottom ash; and (c) rice husk ash*

Table 1 *Series description*

Mixing Water	Series	Description
Freshwater	Control	100 OPC + 100 Sand + 100 CA
Seawater	Series 2	100 OPC + 0 RHA + 100 CBA + 0 Sand + 100 CA
	Series 3	90 OPC + 10RHA + 10 CBA + 90 Sand + 100 CA
	Series 4	90 OPC + 10RHA + 20 CBA + 80 Sand + 100 CA
	Series 5	90 OPC + 10RHA + 30 CBA + 70 Sand + 100 CA
	Series 6	90 OPC + 10RHA + 40 CBA + 60 Sand + 100 CA
	Series 7	90 OPC + 10RHA + 50 CBA + 50 Sand + 100 CA

2.2 Experimental

Concrete was mixed with RHA and CBA as cement and sand replacement in seawater concrete were tested for ultrasonic velocity pulse test based on BS EN 12504-4:2021, rebound hammer test in accordance with BS 1881-202:1986, and compressive strength according to BS EN 12390-3:2019. All samples have dimensions of 100 x 100 x 100 mm and are subjected to testing after a curing period of 7 and 28 days.

3. Results and Discussion

3.1 Workability

Slump is a measurement used for evaluating the consistency or workability of concrete. The impact of RHA as an alternate to cement and CBA as a sand substitute on slump values in concrete mixtures are tabulated in Fig. 2. From this study, the result of workability indicated that workability is decreasing with increasing the percentage of CBA which may be due to the particle size, surface area or unpredictable shape of CBA. It may also due to the porous of CBA absorbing more water. Hence, to improve the workability of the mixture superplasticizer (SP) was added. Superplasticizer is an additive that enables the water content to be minimized. In this particular study, when there was not enough water present, SP was incorporated to enhance the workability.

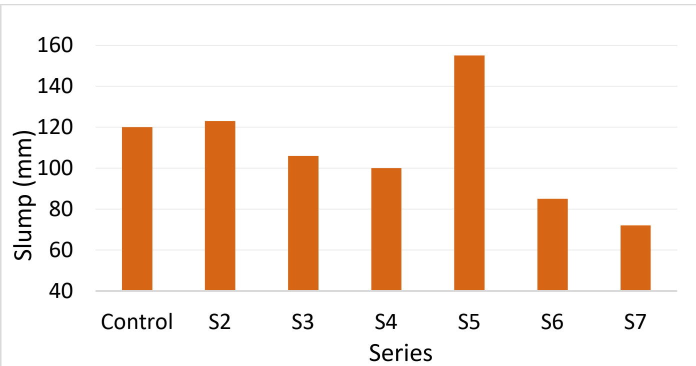

Fig. 2 *Slump value for mixing series*

3.2 Non-Destructive Test of Concrete Mixture

Non-destructive tests such as ultrasonic pulse velocity (UPV) and rebound hammer test (RHT) were conducted at Material Advanced laboratory E17, UTHM. The aim of the test is to evaluate the quality and strength of the seawater concrete with 10% RHA and significant volume of CBA. It also checks whether the specimen is suitable to be used in construction industry.

3.2.1 Ultrasonic Pulse Velocity (UPV)

Figure 3 shows that the UPV test has a greater value at 28 days compared to 7 days. For instance, series 5 with 30% CBA at 7 days is 4673 m/s and 4887 at 28 days. Hence, the greater the value of UPV (m/s), the shorter the transmission time. Based on ASTM C 597, at 7 days the quality of concrete shows an excellent quality. Meanwhile, at 28 days the quality of concrete is constantly excellent. In comparison to the control (series 1), the UPV value of the seawater mixture containing CBA as sand replacement was decreasing.

Furthermore, the ultrasonic pulse velocity test of the CBA concrete mixtures, containing 10%, 20%, 30%, 40%, 50%, and 100%, increased by 1.84%, 1.73%, 4.05%, 2.52%, 0.95%, and 1.19%, respectively, when the curing period was prolonged from 7 to 28 days. Therefore, based on the test findings, the ultrasonic pulse velocities of the CBA concrete mixtures decreased as the amount of CBA in the mixtures increased, while they slightly increased with longer curing periods. Figure 6 presents the results of the study, which reveal the connection between the compressive strength of CBA concrete and ultrasonic pulse velocity. As predicted, the CBA concrete's average compressive strength increased as the concrete's ultrasonic pulse velocity rose.

3.2.2 Rebound Hammer Test

The rebound hammer test was carried out on concrete test specimens that had a 7 and 28 days curing time. As a result, a list of rebound numbers was obtained in Figure 4. The rebound value was established by striking the concrete test specimens using a rebound hammer on four (4) different surfaces. The specimens were evaluated using ASTM C805, which assigned a qualitative rating based on the rebound number achieved. The rating classified the specimens as "good" when they fell within the range of 30 to 40. After 7 days, the concrete exhibits satisfactory quality. Even after 28 days, the concrete maintains its good condition. The rebound number of concrete increased when curing day at 28 days compared to curing at 7 days. The significant range of the data showcased the susceptibility of the rebound number to various factors that impact surface hardness. These factors include moisture content, age of the concrete, smoothness of the surface, and environmental conditions experienced by the concrete sample.

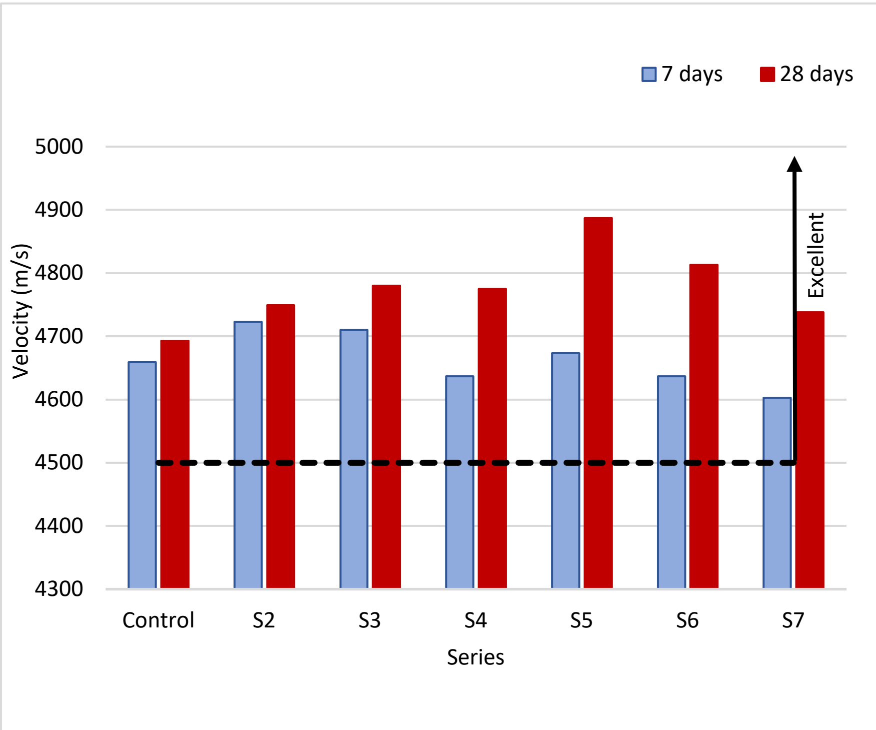

Fig. 3 *Ultrasonic pulse velocity test results of concrete mixture*

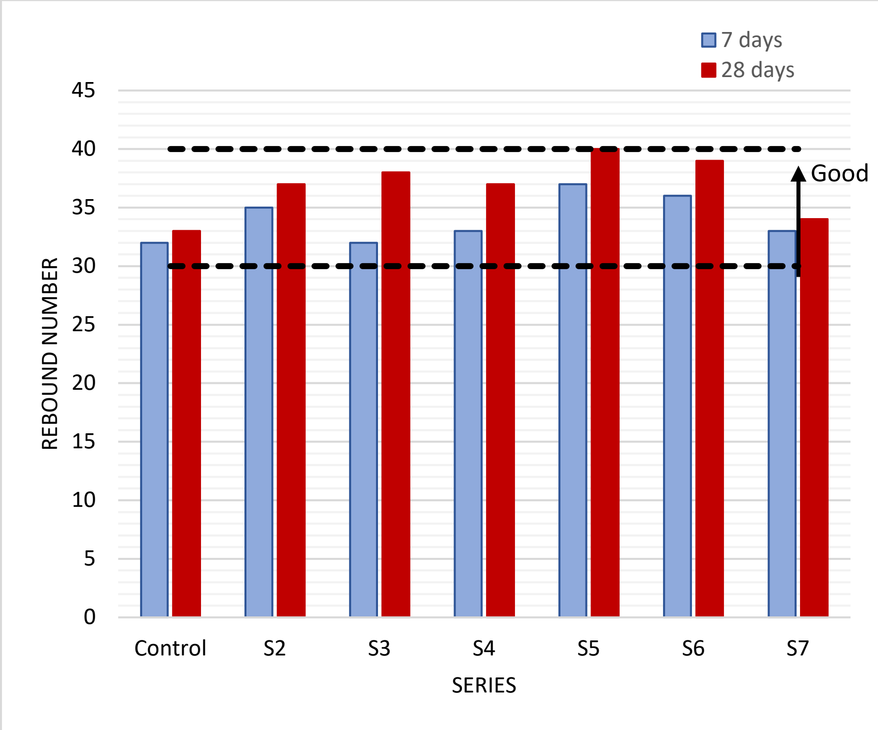

Fig. 4 *Rebound hammer test results of concrete mixture*

3.3 Compressive Strength

The assessment of the compressive strength of concrete cubes was conducted following the guidelines specified in BS EN 12390-3 (2009). The compressive strength results are provided in Figure 5. According to the study results, concrete including RHA and CBA is more resistant to seawater and has a significantly greater strength than control mix concrete. At a curing age of 28 days, the average compressive strength of the mixtures containing CBA decreased as the content of CBA increased.

Additionally, concrete with 10% RHA as a cement replacement had greater compressive strength as compared to normal concrete at 28 days consistently. The findings of this study showed that adding RHA up to 10% increases strength. This result is in line with (Bheel et al., 2022), which found that the maximum strength was attained 28 days after the OPC substituted out for 10% RHA in the combination [6]. Besides, this is in accordance with Li's findings, which claimed that the inclusion of RHA increased compressive strength [7].

Nevertheless, in terms of 28-day compressive strength, series 5 stood out as an exception. It achieved the highest compressive strength of 63.4 MPa when utilizing 30% CBA consumption, while the lowest strength of the mixture was recorded at 52.2 MPa when 100% CBA was used as a replacement for sand. The study's findings showed that adding CBA to sand to the extent of 30% increased compressive strength, which then decreased with further accumulation. This finding is in agreement with (Mangi et al., 2019), which found that the strength increased as CBA amount raised to the positive limit. The development of CBA content, which results in permeable concrete with additional holes dispersed throughout the surface of CBA in concrete, is what causes this decline in compressive strength [8].

Because of the CBA's pozzolanic activity, concrete produced with CBA may have greater long-term strength than concrete constructed using control. For example, Abdulmatin et al. (2018) showed that extending the curing ages from 28 to 90 days resulted in a 16.1-26.8% increase in the compressive strength of a CBA mortar. However, during the same period, the compressive strength of the control mortar improved by 17.7% [9]. However, this study focused on examining the impact of curing durations of 7 and 28 days on the strengths of CBA concrete. These specific curing ages were chosen as they are typically taken into account when designing concrete structures.

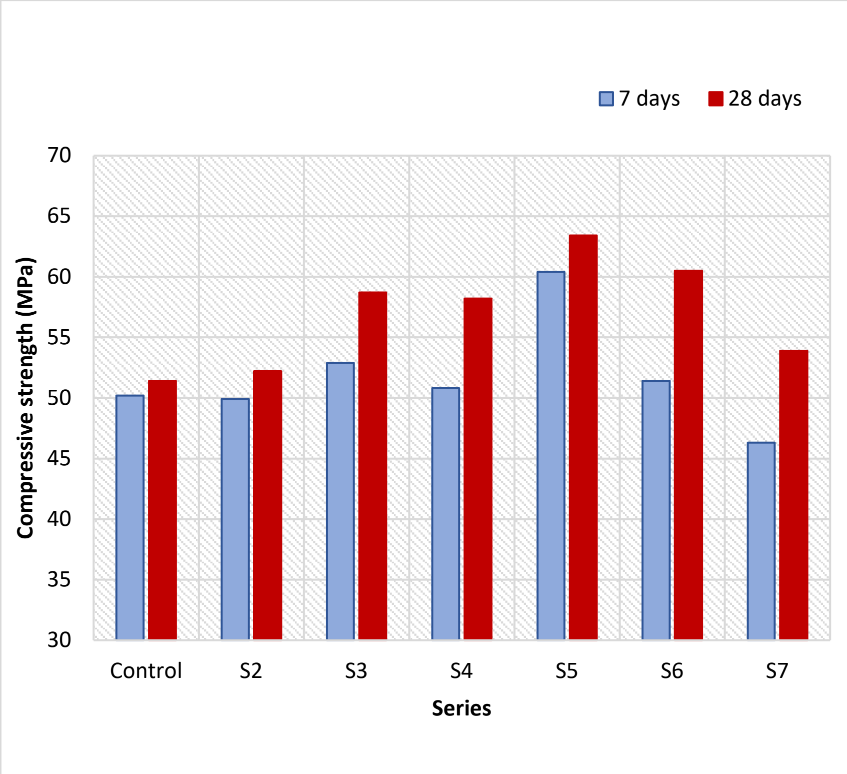

Fig. 5 *Compressive strength test results of concrete mixture*

3.4 Relationship between Compressive Strength, Ultrasonic Pulse Velocity, and Rebound Hammer

Figure 6 illustrates the relationship between the compressive strength and ultrasonic pulse velocity of the CBA concrete, as determined through this investigation. Furthermore, Figure 7 depicts the correlation between the compressive strength and rebound hammer of the CBA concrete, as determined in this study. As anticipated, the overall compressive strength of the CBA concrete demonstrated a positive correlation with the ultrasonic pulse velocity. Noteworthy discrepancies were observed between the measured values employed in this study and those reported in previous research. The discrepancy between the percentage of CBA used in this investigation and those in the previous experiments may be the cause of this phenomenon. The following equation is proposed based on these test findings for estimating the relation between the compressive strength and the ultrasonic pulse velocity of the CBA concrete:

$$y = 0.0684x - 269.95 , \qquad R^2 = 0.8776 \qquad (1)$$

$$y = 1.6283x - 2.8804 , \qquad R^2 = 0.8605 \qquad (2)$$

In equation (1), the variable y represents the compressive strength (in MPa), while x represents the ultrasonic pulse velocity (in m/s). On the other hand, in equation (2), the variable y stands for the compressive strength (in MPa), and x represents the rebound number. According to Figures 6 and 7, the equations from the UPV test have higher reliability than the equation from the rebound hammer test results because these equations have higher Regression (R2) values of 0.8776. Meanwhile, from the rebound hammer test results the regression value is 0.8605.

It is evident that equations (1) and (2) with regression values (R2) more than 0.85 adequately indicate the relationship between the non-destructive test and compressive strength. This indicates a significant correlation between the compressive strength and non-destructive tests, specifically the ultrasonic pulse velocity and rebound hammer.

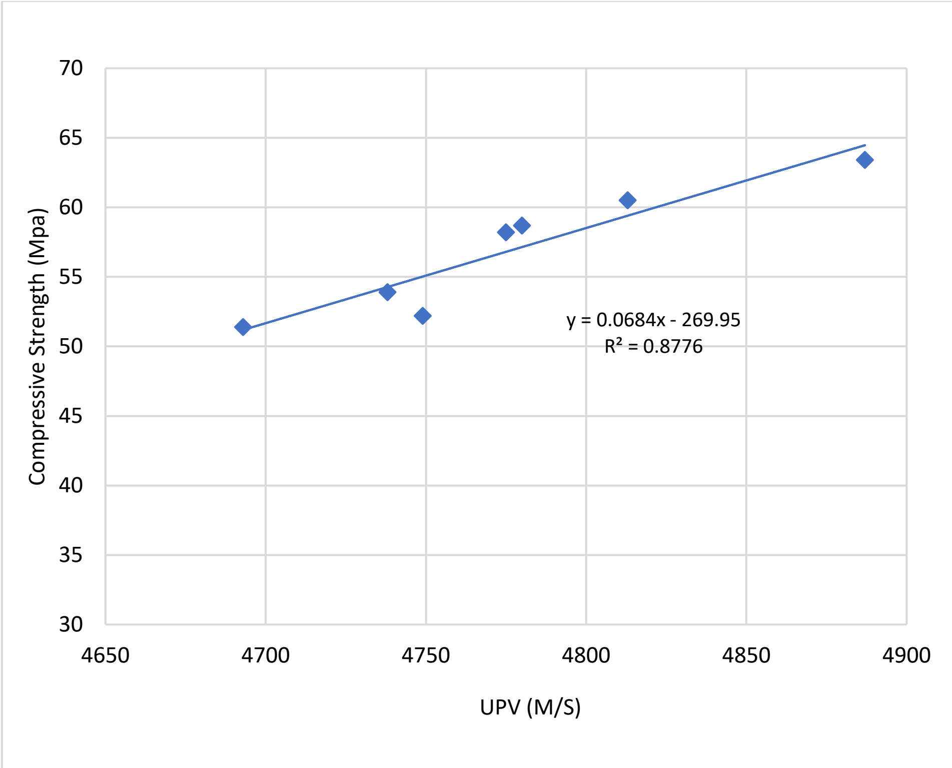

Fig. 6 *Relationship between compressive strength and ultrasonic pulse velocity in 28 days*

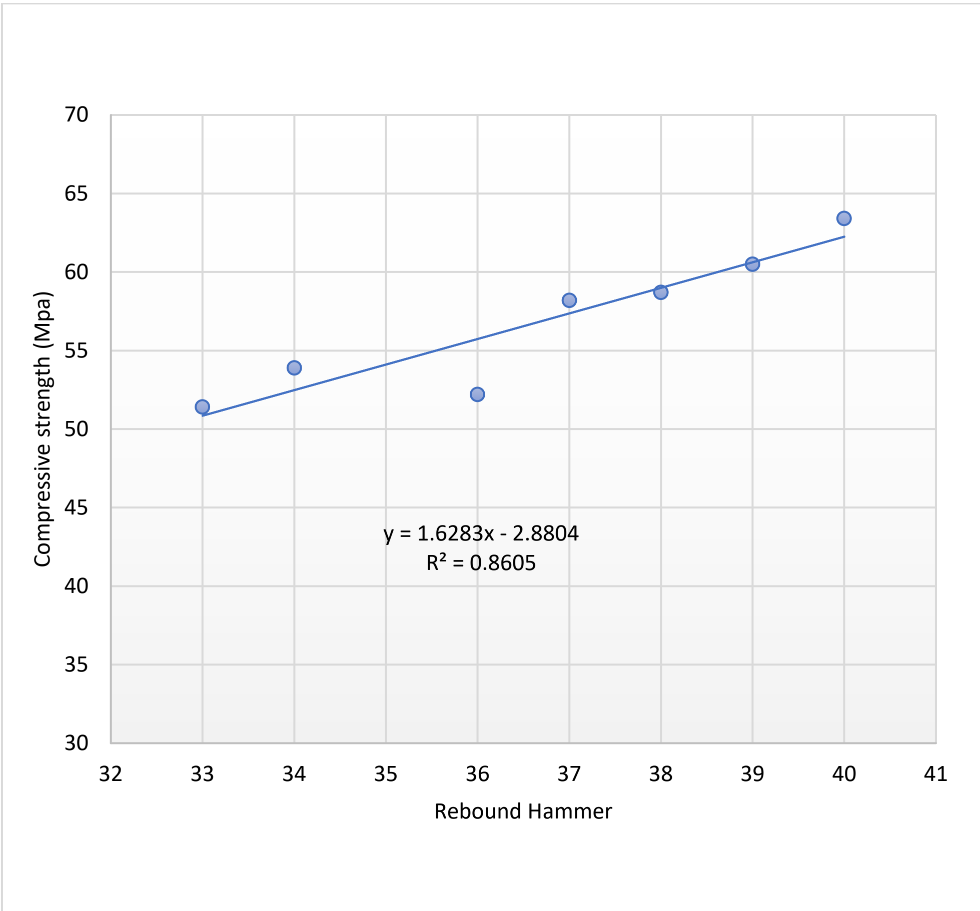

Fig. 7 *Relationship between compressive strength and rebound hammer in 28 days*

4. Conclusion

Based on the results of the experiment, the following conclusions can be related to the objectives:

1. The 0RHA-100CBA seawater concrete has 4748 m/s which increased by 0.53% compared to control (4723 m/s). Meanwhile, 10RHA-50CBA shows the higher UPV of 4738 m/s which increased by 0.32% compared to control (4723 m/s). Therefore, it is suggested that the volume of 100% CBA with 10RHA be increased for future investigations. This is due to the constant high concrete strength of 50CBA.
2. The seawater concrete, known as 0RHA-100CBA, was achieved at a level of 38, marking a 5.4% increase compared to the control value of 36. Meanwhile, 10RHA-50CBA shows the higher rebound number of 37 which increased by 2.74% compared to the control (36). Hence, it is advised that the amount of CBA be increased to 100% with 10RHA for subsequent experiments. This is due to the constantly high concrete strength of 50CBA concrete.
3. The 0RHA-100CBA seawater concrete attained 52.2 MPa which increased by 1.54% compared to control (51.4 MPa). Meanwhile, 10RHA-50CBA shows the higher compressive strength of 53.9MPa which increased by 4.75% compared to the control (51.4 MPa). Thus, for future studies it is advised that the volume of CBA be increased to 100% with 10RHA. This is a result of 50CBA is consistently high in concrete strength.
4. The idea of using CBA instead of sand improves the properties of concrete while simultaneously lowering the environmental damage brought on by inappropriate CBA disposal. It is generally of the highest priority for sustainable development. Therefore, it is recommended that future studies expand their findings of concrete performance when CBA is used as a sand replacement and exposed to seawater at room temperature.

References

[1] Singh, Navdeep & M., Mithulraj & Arya, Shubham. (2018). Influence of coal bottom ash as fine aggregates replacement on various properties of concretes: A review. Resources, Conservation and Recycling. 138. 257-271. 10.1016/j.resconrec.2018.07.025.

[2] N. Singh, M. Mithulraj, S. Arya, Utilization of coal bottom ash in recycled concrete aggregates based self compacting concrete blended with metakaolin, Resour. Conserv. Recycl. 144 (2018) 240-251.

[3] Montanari L, Suraneni P, Tsui-Chang M, Khatibmasjedi M, Ebead U, Weiss J and Nanni A (2019) Hydration pore solution and porosity of cementitious pastes made with seawater, Journal of Materials in Civil Engineering 31 04019154

[4] N. Otsuki, T. Saito, Y. Tadokoro, Possibility of Sea Water as Mixing Water in Concrete, Journal of Civil Engineering and Arquitecture. 6 (2018) 1273–1279.

[5] Kamaruddin, M. A., Yusoff, M. S., Rui, L. M., Isa, A. M., Zawawi, M. H., & Alrozi, R. (2021). An overview of municipal solid waste management and landfill leachate treatment: Malaysia and Asian perspectives. Environmental science and pollution research international, 24(35), 26988–27020. https://doi.org/10.1007/s11356-017-0303-9

[6] Bheel, Narain & Keerio, Manthar & Hindu, Aneel & Khan, Jam & Ali, Zohaib & Ali, Mouzzam & Sohu, Samiullah. (2022). An Investigation on Fresh and Hardened Properties of Concrete Blended with Rice Husk Ash as Cementitious Ingredient and Coal Bottom Ash as Sand Replacement Material. Silicon. 14. 1-12. 10.1007/s12633-020-00906-3.

[7] Amran M, Fediuk R, Murali G, Vatin N, Karelina M, Ozbakkaloglu T, Krishna RS, Sahoo AK, Das SK, Mishra J. Rice Husk Ash-Based Concrete Composites: A Critical Review of Their Properties and Applications. Crystals. 2021;11(2):168. https://doi.org/10.3390/cryst11020168.

[8] Mangi S A, Wan Ibrahim M H, Jamaluddin N, Arshad M F and Ramadhansyah P J (2019) Effects of ground coal bottom ash on the properties of concrete, Journal of Engineering Science and Technology 14 338–350

[9] A. Abdulmatin, W. Tangchirapat, and C. Jaturapitakkul, “An investigation of bottom ash as a pozzolanic material,” Con- struction and Building Materials, vol. 186, pp. 155–162, 2018.