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Original Article

Non-Destructive Test on Concrete Blended with Partially Replaced Recycled Coarse Aggregate and Seashore Sand

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Abstract - *The extraction of natural aggregates is depleting the sources and posing a challenge for producing technically and environmentally suitable concrete. To mitigate ecological and environmental concerns arising from excessive mining, the utilization of Recycled Coarse Aggregate (RCA) and seashore sand is being explored as a viable solution. This research paper assesses concrete's strength and durability characteristics by partially substituting recycled coarse aggregates and seashore sand, employing non-destructive tests like the Rebound hammer test, Ultrasonic pulse velocity, Carbonation test, and Half-cell potentiometer test. The findings are compared with conventional concrete, revealing that the partial incorporation of alternative materials like RCA and seashore sand yields significant enhancements in concrete strength and durability.*

Keywords - *Carbonation test, Half-cell potentiometer test, Rebound hammer test, Recycled coarse aggregates, Seashore sand, Ultrasonic pulse velocity.*

1. Introduction

The transformation of concrete waste into recycled coarse aggregates (RCA) has been recognized as a promising supplier of construction aggregates. Earlier research has emphasized the advantages of widespread concrete waste recycling, including diminishing the volume of concrete waste that would otherwise be deposited in landfills, reducing the construction industry's reliance on natural aggregates, thus conserving natural resources, generating cost savings in waste disposal management, and offering substitute sources for urban regions experiencing a scarcity of natural aggregates [1]. Durability refers to the ability of concrete to maintain its shape, serviceability and strength even after exposure to environmental conditions.

The lower durability performance of Recycled Aggregate Concrete (RAC) compared to Natural Aggregate Concrete (NAC) may be attributed to its higher water absorption capacity and porosity [2-4]. The presence of old mortar attached to the surface of the recycled aggregate and the interfacial transition zone (ITZ) between the old mortar and parent aggregate are the two primary factors contributing to the increased porosity and water absorption of recycled aggregate [5-8]. It is widely accepted among researchers that the weaker and porous old mortar within the Recycled Coarse Aggregate (RCA) particles is the leading cause of the unfavourable characteristics of RCA and the overall deterioration of concrete's mechanical strength. The interface zone between the aggregate and the cement paste is crucial regarding the concrete microstructure since it governs the material's mechanical strength [9]. Numerous approaches and treatment methods have been developed and investigated to enhance the properties of RCA and mitigate its drawbacks. Surface treatment is an innovative and beneficial technique that modifies and improves the physical properties of RCA prior to its use in concrete mixes. The literature mentions various procedures for surface treatment in RCA. For example, Liang Wang et al. [10] suggested using a low concentration of acetic acid to minimize the presence of weak or loose mortars on the surface of RCA particles, thus enhancing the contact between the aggregate and the cement mortar.

The seashore sand possesses advantages over manufactured and recycled sand, such as low clay content, cost-effectiveness, desired size fractions, and abundant storage [11, 12]. Experimental and theoretical analyses have examined the properties of concrete using seashore sand. The results indicated that chloride ions (Cl-) and shell particles influenced seashore sand concrete's workability, durability, and mechanical properties. Limeira et al. [13], Kumar et al. [14] and Surya et al. [15] discovered differences in the workability of seashore sand concrete compared to ordinary concrete. The fluidity and density of concrete with seashore sand decreased, while the absorption change was insignificant. Seashore sand concrete's compressive and tensile strength varied with the Cl- content in seashore sand [16, 17]. In Sri Lanka, substantial deposits of seashore sand are available in nearby offshore areas, which are extracted and piled up to 30 meters high in the Muthurajawela area under the supervision of the Land Reclamation Department. These stockpiles of seashore sand have been made accessible to the public for construction purposes. Experimental work has shown that washed seashore sand can provide sufficient strength compared to river sand in conventional concrete at lower proportions. Natural exposure to monsoon conditions for one to two years reduces the chloride content in seashore sand stockpiles, making them suitable for concrete production [18].

The utilization of seashore sand in construction requires the removal of salt content and organic matter. An experimental setup involving boiling and multiple washes with ample water has been devised to reduce the salt content and eliminate the micro-organic matter. The sea sand is washed with water and a chemical solution [19, 20]. The study indicates that offshore sand obtained from distances of 2 to 7 km from the Western coast immediately after dredging can serve as an alternative to river sand, considering factors such as availability, extraction convenience, environmental impact, and cost. However, some offshore sand may require washing to eliminate organic matter that cannot be physically separated through sieving and other contaminants [21].

The study reveals that the chloride level in treated seashore sand is below the acceptable threshold of 0.075% weight of sand [22]. The compressive strength of seashore sand recycled coarse aggregate is higher than that of ordinary concrete. The impact of Cl- in seashore sand on the elastic modulus decreases with increasing content of recycled coarse aggregate in seashore sand [23]. It is recommended that foundry sand, with a substitution rate of up to 30% instead of natural sand, is favourable for concrete production without adversely affecting the strength and durability criteria [24]. This paper uses non-destructive tests to present the strength and durability properties of concrete made with simultaneous partial replacement of treated RCA and seashore sand.

2. Materials and Methods

2.1. Materials

The following materials are used for this project:

- The cement used was Ordinary Portland cement of 53 grades, confirming IS 8112-1989 with a specific gravity of 3.18.
- River sand was used as fine aggregate conforming to zone II confirms to IS 383-1970 (Reaffirmed 2002).
- Locally available Crushed coarse aggregate between 20mm and 10mm in size, conforming to Indian Standard 383-1970, was used.
- Crushed and demolished concrete waste was collected from nearby institutions and was used as recycled coarse aggregate (RCA). The crushed concrete waste was manually crushed. [25]
- Seashore sand used to replace River-sand was conforming to zone IV.
- Potable water was used to mix the concrete with a pH of 7.8.
- The properties of all materials are shown in Tables 1, 2 & 3.

2.2. Methods to Enhance Properties of Recycled Coarse Aggregate (RCA) and Seashore Sand

The study explores techniques for improving Recycled Coarse Aggregate (RCA) quality, including an eco-friendly chemical treatment method to remove mortar residue. Furthermore, it examines the suitability of sea sand obtained from the eastern coast of Parangipettai, Tamil Nadu, India, as an alternative to river sand, focusing on its salt content.

2.2.1. RCA Treatment Technique

The crushed Recycled Coarse Aggregate (RCA) specimens were immersed in a solution of acetic acid with a concentration of 1% at room temperature for one day, as illustrated in Fig. 1a and 1b. The container was intermittently agitated to facilitate an effective interaction between the acid and the loosely attached particles on the initial aggregate. Following the one-day immersion, the aggregates were removed from the solution and dried under sunlight. The treated RCA samples, which passed through a sieve size of 20mm and were retained on a size of 10mm, can be utilized in the concrete mixture.

2.2.2. Sea Sand Treatment Technique

The saltiness in sea sand must be controllable and can be eradicated through natural or artificial washing techniques. The sea sand obtained from the eastern coastal areas of Parangipettai was employed in this study. The seashore sand underwent natural treatment for one year, as depicted in Fig. 2. It was exposed to open-air conditions, allowing it to be influenced by rainfall and environmental factors. This process facilitated eliminating the salt content without requiring substantial effort or expenses.

2.3. Mix Proportion

The concrete mix for grade M30 was designed based on the Indian Standard method IS 10262-2009. Tables 4 & 5 present the details of the mixture used in the concrete preparation.

3. Experimental Programme

This section describes the experimental procedure of nondestructive tests conducted on the hardened concrete to obtain its compressive strength using a Rebound Hammer and ultrasonic pulse velocity (UPV) to assess the probability of corrosion using a half-cell potentiometer and carbonation test.

3.1. Compressive Strength Test

The potency of the samples was ascertained by assessing the crushing strength by examining cubic specimens measuring 150 mm x 150 mm x 150 mm. The evaluation adhered to the guidelines outlined in IS 516-1959. In each test, three specimens were analyzed, and the average measurements were recorded as the strength of the samples. The maximum load endured at the point of failure was observed, and the compressive strength (fck) was calculated using the following formula:

$$\text{Cube Compressive Strength, fck} = \frac{Load\ at\ failure\ in\ N}{Area\ of\ cube\ in\ mm^2} \qquad (1)$$

3.1.1. Rebound Hammer Test

The quality of concrete was evaluated by performing a Rebound Hammer test on concrete cubes measuring 150mm x 150mm x 150mm. The assessment utilized Portable Rebound Hammer equipment, as depicted in Fig. 3, by the guidelines outlined in Indian Standards IS 516 (Part 5/ Sec 4): 2020. The test was conducted in a vertical upward direction. It should be noted that the rebound number will vary for the same concrete due to the different effects of gravity as the test angle is changed. Therefore, separate calibration is necessary. The relationships between rebound number and concrete strength provided by instrument manufacturers should only be used as an indication of the relative strength of the concrete.

3.1.2. Ultrasonic Pulse Velocity Test

The examinations were executed employing Portable Ultrasonic Non-destructive Digital Indicating Tester equipment, as illustrated in Fig. 4, by the directives specified in Indian Standards IS 516 (Part 5/ Sec 1): 2018, Amd. -1 2019. The Ultrasonic Pulse Velocity (UPV) test was conducted using the direct transmission method for each individual concrete sample at varying curing durations of 28 days. The time the ultrasonic wave took to traverse through the specimen was documented. Table 6 presents the velocity thresholds that determine the quality grading of the concrete by the IS code 516.

3.2. Half-Cell Potentiometer

The potential half-cell test is the sole corrosion monitoring technique standardized in ASTM C876 – 15 for assessing the Corrosion Potentials of Uncoated Reinforcing Steel in Concrete. Beams measuring 100 x 200 x 1200mm were fabricated to evaluate the probability of corrosion occurring within the reinforcement bars in reinforced concrete structures.

This method involves measuring the electrical potential difference between the upper steel rebars and a standard portable reference electrode in contact with the concrete surface, as depicted in Fig. 5. The concrete acts as an electrolyte, and the potential difference measured can be empirically linked to the risk of corrosion near the test location. Table 7 presents the correlation between the potential values and the probability of corrosion, as adapted from ASTMC 876.

3.3. Carbonation Test

Concrete cylinders with 150mm × 300mm dimensions were prepared for the carbonation test. Following a curing period of 28 days, all specimens were subjected to air curing for 180 days before being split open. The split surface of the concrete was meticulously cleaned, and a phenolphthalein indicator was uniformly applied along the entire length using a brush, as shown in Fig. 6. In the noncarbonated portion of the specimen, where the concrete retained a high alkaline state, a purple-red colour was observed. Conversely, no colour change occurred in the carbonated region of the specimen, where the concrete's alkalinity was reduced. The average carbonation depth was measured at three locations, rounded to the nearest 1mm, from the outer surface to the colourless region indicated by phenolphthalein [28]. The carbonation coefficient, a metric commonly proposed by researchers [26, 28], is typically used to compare carbonation resistance.

$$C = \frac{X}{T^{0.5}} \qquad (2)$$

Where C is the carbonation coefficient (mm/year$^{0.5}$), and X and T are the Carbonation depth in mm and period of exposure in years, respectively.

4. Results and Discussion

4.1. Compressive Strength Test

Compressive strength tests were conducted on cubes measuring 150mm x 150mm x 150mm, following the guidelines specified in IS 516-1959. These tests were performed on conventional and concrete samples with various replacement percentages of natural coarse aggregate with treated Recycled Coarse Aggregate (RCA). The replacement percentages evaluated were 10%, 20%, 30%, 40%, 50%, 75%, and 100%. The results of the compressive strength tests conducted after 28 days were graphically presented in Fig. 7. The graph demonstrates that the compressive strength of concrete at a 40% RCA replacement is higher than conventional concrete. However, adhered mortar increases beyond a 40% RCA replacement, reducing compressive strength. To determine the optimal value for seashore sand replacement, the 40% RCA replacement was maintained constant, and seashore sand was used as a substitute for river sand in proportions of 0%, 10%, 20%, 30%, 40%, 50%, and 100%. Non-destructive tests were conducted to assess the optimal value of seashore sand replacement.

4.1.1. Rebound Hammer Test

The Rebound hammer test is a non-destructive method used to assess the compressive strength of concrete by measuring the energy rebounded upon impact. The actual compressive strength of concrete is determined using a compression testing machine, and the results obtained from the Rebound hammer test are compared to the actual values. The relationship between the Rebound hammer results and the actual compressive strength is graphically represented in Fig.

8 & 9. The Rebound hammer test is conducted to evaluate the uniformity of the concrete, and the observed compressive strength values from the Rebound hammer test follow a similar trend to the actual compressive strength, indicating the uniformity of the concrete. However, the values obtained from the Rebound hammer test are lower estimates of the actual compressive strength. Despite this, the results from the Rebound hammer test are comparable to the actual values. Among the concrete specimens, the 40% RCA + 30% seashore sand mixture exhibited higher compressive strength than the control concrete specimen. Replacing treated seashore sand yielded improved results compared to untreated seashore sand.

This can be attributed to several factors: (1) Reduction of pores in the adhered mortar of RCA due to the filling of pores by finer particles of seashore sand, resulting in denser concrete. (2) The formation of a solid and insoluble Friedel's salt (3CaO_Al2O3_CaCl2_10H2O) through chemical reactions between the appropriate chloride content of seashore sand and the C3A component of cement (3CaO_Al2O3), which further fills pores in the cement paste and promotes densification of the concrete. (3) Beyond a 30% replacement of seashore sand, the excessive chloride presence, along with the increased fineness of seashore sand particles, leads to an increase in the number of tiny pores, reducing the dense structure of the concrete. The correlation between the actual compressive strength and the compressive strength obtained from the Rebound hammer test for all concrete mixtures is demonstrated in Fig. 10. The untreated seashore sand concrete with 40% RCA and the treated seashore sand concrete with 40% RCA achieved strong correlations, as indicated by the R-square values of 0.81 and 0.77, respectively.

4.1.2. Ultrasonic Pulse Velocity Test

The Ultrasonic Pulse Velocity (UPV) test was performed on concrete cubes measuring 150mm x 150mm x 150mm to evaluate the concrete quality. Among the concrete specimens, the mixture containing 40% RCA and 30% seashore sand exhibited higher UPV values than the control concrete specimen, as shown graphically in Fig. 11 & 12. Replacing treated seashore sand yielded improved results compared to untreated seashore sand. This finding can be attributed to several factors: (1) Enhancement of quality and reduction of pores in the adhered mortar content of RCA due to the filling of pores by finer particles of seashore sand, leading to an improved microstructure of the interfacial transition zone (ITZ) and enhanced bond strength between the new cement paste and the recycled aggregate (RA).

(2) Formation of a solid and insoluble Friedel's salt (3CaO_Al2O3_CaCl2_10H2O) through chemical reactions between the appropriate chloride content of seashore sand and the C3A component of cement (3CaO_Al2O3), which further fills pores in the cement paste and contributes to the formation of dense concrete. (3) Beyond a 30% replacement of seashore sand, the excessive chloride presence and the fineness of seashore sand particles lead to an increase in tiny pores. This can result in a reduction in the dense structure of the concrete. These factors collectively contribute to the higher UPV values observed in the 40% RCA + 30% seashore sand mixture compared to the other specimens.

4.2. Half-Cell Potentiometer

The beam's half-cell potential test was performed to assess its corrosion characteristics. The measurements were taken randomly across six different locations of the beam elements. Tables 8 & 9 display the recorded data, showing the minimum and maximum values obtained at each location for untreated and treated seashore sand replacement. The readings ranged from -102.90 mV to -346.90 mV. Based on the observed half-cell potential reading, the probability of corrosion activity was less than 5% for concrete up to 40% seashore sand replacement with 40% RCA.

The improvement in resistance against corrosion activity can be ascribed to the following factors: (1) The reduction in porosity of Recycled Concrete Aggregate (RCA) due to the filling effect of seashore sand leads to increased resistance against corrosion activity. (2)The presence of appropriate chloride content in seashore sand facilitates chemical hydration reactions with C3A in cement (3CaO_Al2O3), resulting in the formation of insoluble Friedel's salt (3CaO_Al2O3_CaCl2_10H2O). This formation helps fill the pores in the cement paste and creates a strong skeleton, contributing to corrosion resistance. (3) When seashore sand is used to replace more than 40% of the aggregate, the finer particles of seashore sand generate smaller pores. This, in turn, reduces resistance to chloride ingress and may result in increased corrosion activity.

4.3. Carbonation Test

The carbonation of concrete is a crucial factor associated with steel reinforcement corrosion. The carbonation depth of all mixtures was assessed at 180 days. Cylindrical specimens measuring 150mm x 300mm were subjected to carbonation tests. Fig. 13 and 14 illustrate the accelerated carbonation depth of all concrete specimens at 180 days. The concrete control specimens exhibited an accelerated carbonation depth of 1.01mm, which increased to 3.86mm for concrete specimens containing 40% RCA and 0% seashore sand. This increase can be attributed to the higher porosity of RCA adhered to cement mortar compared to natural aggregate, allowing greater CO2 penetration into the concrete [27].

However, an increase in resistance to carbonation was observed for replacement rates of 10% to 30% of river sand with seashore sand. Beyond 30% replacement, the resistance to carbonation decreased. Based on the observations presented in Table 10, it was concluded that concrete with a substitution rate of 40% RCA and 30% seashore sand could be considered good, as the carbonation coefficient never exceeded 6 mm/year$^{0.5}$ [28, 29]. Furthermore, replacing treated seashore sand demonstrated superior results to untreated seashore sand. The improvement in resistance against carbonation can be attributed to (1) The reduction in porosity of RCA due to the filling effect of seashore sand in the tiny pores of the scanty adhered mortar on the RCA surface. Beyond 30% Replacement, the presence of finer seashore sand particles with increased fineness reduces the resistance to carbonation. (2) The presence of appropriate chloride content in seashore sand participates in chemical hydration reactions with C3A in cement (3CaO_Al2O3), resulting in the formation of insoluble Friedel's salt (3CaO_Al2O3_CaCl2_10H2O) [23], which fills pores in the cement paste and forms a strong skeleton. (3) Beyond 30% replacement of seashore sand, the excessive presence of chloride, apart from being involved in chemical reactions, reduces carbonation resistance.

Table 1. Physical properties of fine aggregates

Properties	River Sand	Seashore Sand
Bulk density, kg/m3	1565.00	1580.00
Specific gravity	2.72	2.64
Fineness modulus	3.09	1.95

Table 2. Physical properties of coarse aggregates

Properties	Natural Aggregate	Recycled Coarse Aggregate
Bulk density, kg/m3	1526.00	1409.00
Specific gravity	2.83	2.78
Fineness modulus	7.20	7.41
Impact value %	9.24	15.88
Crushing value %	14.83	24.66

Table 3. Chemical properties of fine aggregates

Properties	River Sand	Untreated Sea Sand	Treated Sea Sand
PH Value	7.89	8.32	8.15
Chloride	98 mg/l	467mg/l	208mg/l

Table 4. Mix design used to make concrete

Constituents	Cement	Sand	Gravel	Water
Proportion (ratio)	1	1.61	2.86	---
Proportion(kg/m3)	422	680	1205	190

Table 5. Details of mix proportion with w/c ratio=0.45 and superplasticizer = 0.34%

S.No.	% of replacement of seashore sand with 40% RCA	% of replacement of seashore sand	Cement	River sand	Seashore sand	Natural Aggregate	Coarse aggregate	Remarks
1.	0	0	422	680	0	1205	0	CONTROL
2.	40	0	422	680	0	723	482	USS0
3,		10	422	612	68	723	482	USS10
4.		20	422	544	136	723	482	USS20
5.		30	422	476	204	723	482	USS30
6.		40	422	408	272	723	482	USS40
7.		50	422	340	340	723	482	USS50
8.		100	422	0	680	723	482	USS100
9.	40	0	422	680	0	723	482	TSS0
10.		10	422	612	68	723	482	TSS10
11.		20	422	544	136	723	482	TSS20
12.		30	422	476	204	723	482	TSS30
13.		40	422	408	272	723	482	TSS40
14.		50	422	340	340	723	482	TSS50
15.		100	422	0	680	723	482	TSS100

Table 6. Velocity ranges for concrete quality grading

S.No.	Average Value of Pulse Velocity by cross probing	Concrete Quality Grading
1.	Below 3.75	Doubtful*
2.	3.75 - 4.50	Good
3.	Above 4.50	Excellent

**In case of doubtful quality, it shall be carried out the necessary test.*

Table 7. Probability of corrosion according to half-cell potential values

Measured Half-Cell Potential Value(mV)	Possibility of Corrosion
More negative than -350mV	>95%
-200mV to -350mV	50%
More positive than -200mV	<5%

Table 8. Half cell potentiometer readings-untreated seashore sand replacement

S. No.	Designation	Half cell potentiometer reading						Average Half cell potentiometer	Remarks
		1	2	3	4	5	6		
1.	CONTROL	-162.90	-113.00	-138.90	-108.90	-104.90	-115.90	-124.08	<5% possibility of corrosion activity in concrete members
2.	USS0	-234.90	-161.90	-125.90	-143.90	-107.90	-102.90	-146.23	
3.	USS10	-293.90	-141.90	-147.90	-129.90	-109.90	-102.90	-154.40	
4.	USS20	-141.90	-217.90	-196.90	-121.90	-157.90	-103.90	-156.73	
5.	USS30	-141.90	-217.90	-196.90	-181.90	-157.90	-103.90	-166.73	
6.	USS40	-245.90	-195.90	-169.90	-145.90	-148.90	-126.90	-172.23	
7.	USS50	-346.90	-282.90	-229.90	-182.90	-179.90	-122.90	-224.23	>95% possibility of corrosion activity in concrete members
8.	USS100	-245.90	-189.90	-305.90	-296.90	-324.90	-294.90	-293.07	

Table 9. Half cell potentiometer readings-treated seashore sand replacement

S. No.	Designation	Half cell potentiometer reading						Average Half cell potentiometer	Remarks
		1	2	3	4	5	6		
1.	CONTROL	-162.90	-113.00	-138.90	-108.90	-104.90	-115.90	-124.08	<5% possibility of corrosion activity in concrete members
2.	TSS0	-234.90	-161.90	-125.90	-143.90	-107.90	-102.90	-146.23	
3.	TSS10	-193.90	-141.90	-165.90	-124.90	-119.90	-156.90	-150.57	
4.	TSS20	-176.90	-163.90	-136.90	-149.90	-139.90	-146.90	-152.40	
5.	TSS30	189.90	122.90	106.90	196.90	163.90	178.90	-159.90	
6.	TSS40	-199.60	-205.90	-106.90	-102.90	-162.90	-184.90	-160.52	
7.	TSS50	-346.90	282.90	189.90	152.90	159.90	122.90	-209.53	>95% possibility of corrosion activity in concrete members

Table 10. Carbonation test results

Mix Designation	Carbonation depth in mm	Carbonation Coefficient (mm/year$^{0.5}$)
CONTROL	1.01	1.428
USS0	3.86	5.459
USS10	3.52	4.978
USS20	2.94	4.158
USS30	1.83	2.588
USS40	2.24	3.167
USS50	2.95	4.172
USS100	5.97	8.443
TSS0	3.86	5.459
TSS10	3.37	4.766
TSS20	2.72	3.847
TSS30	1.43	2.022
TSS40	1.94	2.744
TSS50	2.65	3.748
TSS100	4.31	6.095

Fig. 1a Presoaking in acetic acid

Fig. 1b Treated RCA samples

Fig. 2 Treated seashore sand Samples

Fig. 3 Rebound hammer test

Fig. 4 Ultrasonic pulse velocity test

Fig. 5 Half cell potentiometer test

Fig. 6 Carbonation test

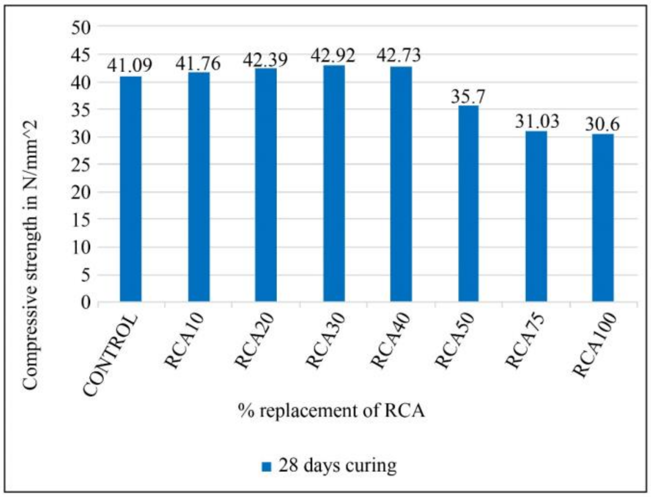

Fig. 7 Compressive strength of RCA replacement

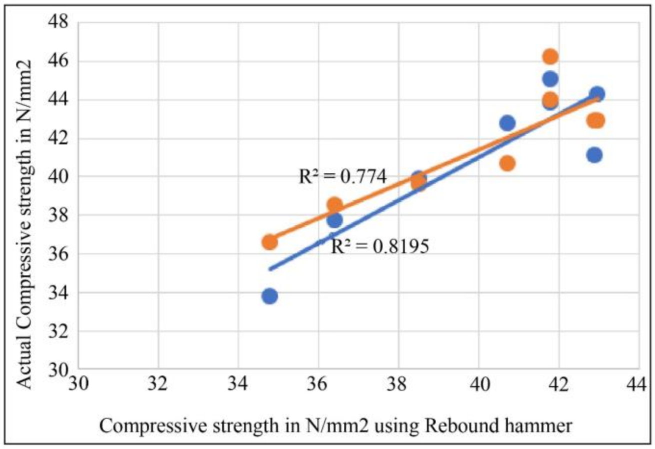

Fig. 10 Relationship between actual compressive strength and compressive strength by rebound hammer test

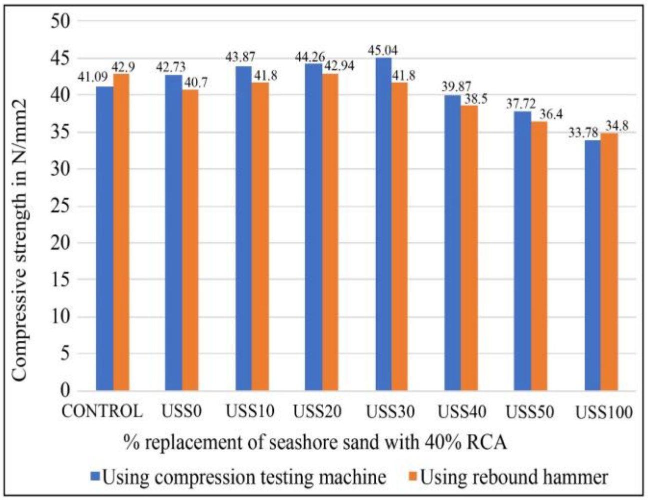

Fig. 8 Rebound hammer test results-untreated seashore sand

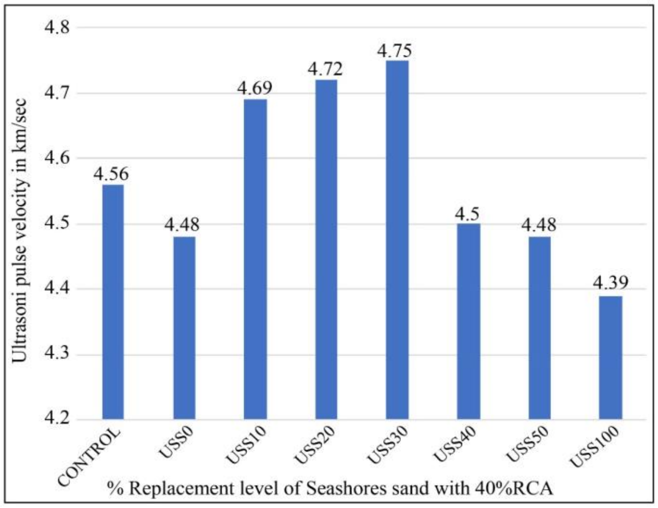

Fig. 11 Ultrasonic pulse velocity test results-untreated seashore sand

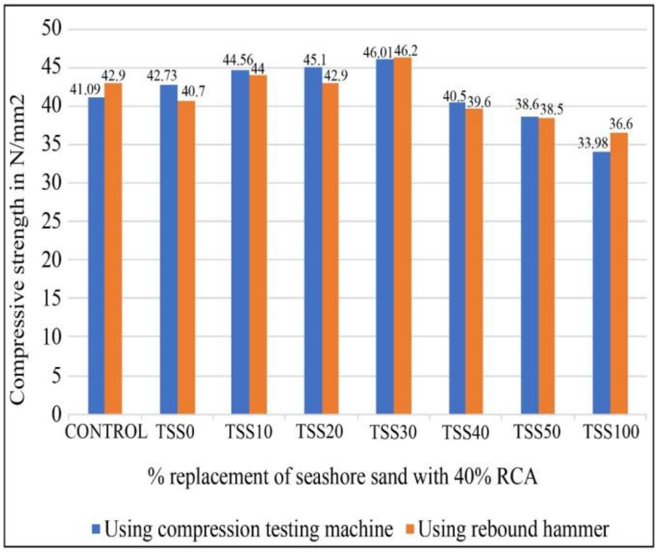

Fig. 9 Rebound hammer test results-treated seashore sand

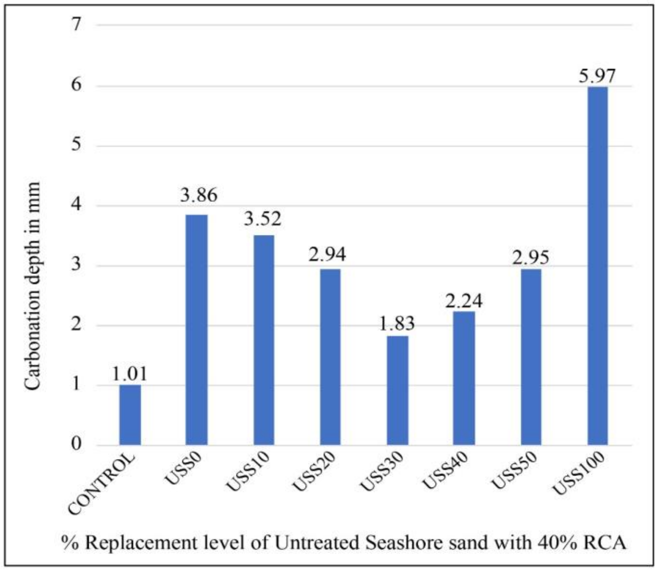

Fig. 12 Ultrasonic pulse velocity test results-treated seashore sand

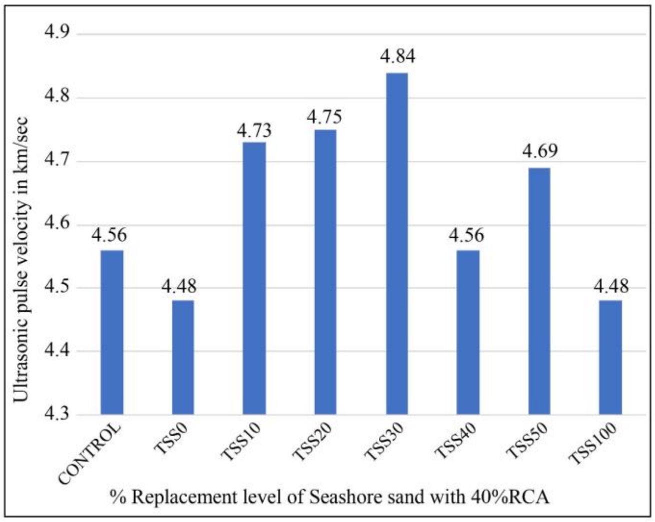

Fig. 13 Carbonation test results-untreated seashore sand

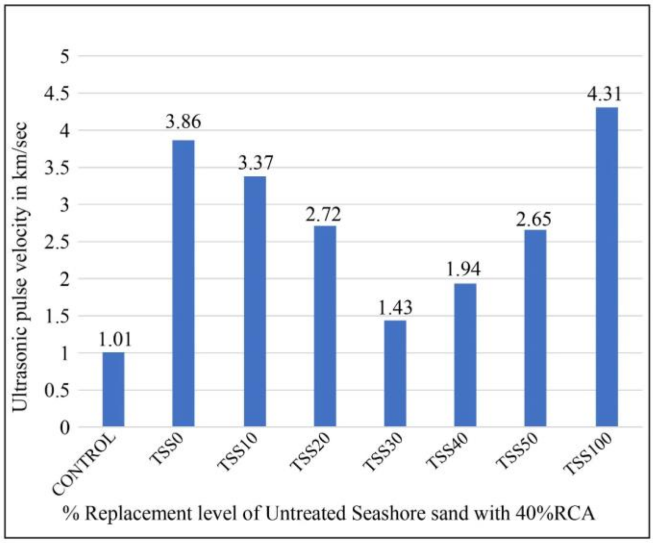

Fig. 14 Carbonation test results-treated seashore sand

5. Conclusion

Based on the experimental results, the impact of incorporating RCA and seashore sand in concrete can be summarized as follows:

- Concrete containing 30% seashore sand and 40% RCA exhibited higher compressive strength than the control concrete, as determined by the rebound hammer test and ultrasonic pulse velocity.
- Various research studies have shown that half-cell potential measurements only indicate the probability of corrosion at a specific location and time. Long-term testing through continuous measurement of half-cell potential values may be appropriate. Replacing up to 40% seashore sand with 40% RCA in concrete resulted in less than 5% corrosion probability in concrete elements.
- The carbonation coefficient of the concrete mixture with a substitution rate of up to 50% seashore sand with 40% RCA never exceeded the value of 6 mm/year^0.5, indicating that it can be considered good concrete in terms of resistance to carbonation.
- Using treated seashore sand in concrete yielded better results than untreated seashore sand.
- The treatment methods significantly improved the quality and properties of recycled coarse aggregate and seashore sand. These methods are cost-effective, sustainable, and environmentally friendly recycling techniques, making them suitable for large-scale projects.

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References

[1] Sallehan Ismail, and Mahyuddin Ramli, “Mechanical Strength and Drying Shrinkage Properties of Concrete Containing Treated Coarse Recycled Concrete Aggregates,” *Construction and Building Materials*, vol. 68, pp. 726–739, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[2] Syed Minhaj Saleem Kazmi et al., “Effect of Recycled Aggregate Treatment Techniques on the Durability of Concrete: A Comparative Evaluation,” *Construction and Building Materials*, vol. 264, pp. 120–284, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[3] S Syed Minhaj Saleem Kazmi et al., “Axial Stress Strain Behavior of Macro-Synthetic Fiber Reinforced Recycled Aggregate Concrete,” *Cement and Concrete Composites*, vol. 97, pp. 341–356, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[4] Muhammad Junaid Munir et al., “Stress Strain Performance of Steel Spiral Confined Recycled Aggregate Concrete,” *Cement and Concrete Composites*, vol. 108, pp. 103–535, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[5] I. F. Sáez del Bosque et al., “Properties of Interfacial Transition Zones (ITZs) in Concrete Containing Recycled Mixed Aggregate,” *Cement and Concrete Composites*, vol. 81, pp. 25–34, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[6] Jiake Zhang et al., “Performance Enhancement of Recycled Concrete Aggregates through Carbonation,” *Journal of Materials in Civil Engineering*, vol. 27, no. 11, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[7] Kho Pin Verian, Warda Ashraf, and Yizheng Cao, “Properties of Recycled Concrete Aggregate and Their Influence in New Concrete Production,” *Resources, Conservation and Recycling*, vol. 133, pp. 30–49, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[8] Rasha H Ali, “Investigation of Ferrocement Bricks Properties with Different Recycled Coarse Aggregates,” *SSRG International Journal of Civil Engineering*, vol. 8, no. 6, pp. 48-52, 2021. [CrossRef] [Publisher Link]

[9] Mark Alexander, and Sidney Mindess, *Aggregates in Concrete*, Taylor & Francis, 2005. [Google Scholar] [Publisher Link]

[10] Liang Wang et al., “An Environmentally Friendly Method to Improve the Quality of Recycled Concrete Aggregates,” *Construction and Building Materials*, vol. 144, pp. 432–444, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[11] J. Limeira, L. Agullo, and M. Etxeberria, “Dredged Marine Sand as a New Source for Construction Materials,” *Materiales de Construcción*, vol. 62, no. 305, pp. 7–24, 2012. [CrossRef] [Publisher Link]

[12] S. Hasdemir, A. Tugrul, and M. Yilmaz, “The Effect of Natural Sand Composition on Concrete Strength,” *Construction and Building Materials*, vol. 112, pp. 940–948, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[13] J. Limeira et al., “Mechanical and Durability Properties of Concrete Made with Dredged Sea Sand,” *Construction and Building Materials*, vol. 25, pp. 4165–4174, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[14] B. Naga Niranjan Kumar et al., “An Experimental Study on Sea Sand by Partial Replacement of Sea Sand in Concrete,” *International Journal of Scientific Research in Science and Technology*, vol. 2, no. 2, pp. 181–184, 2016. [Google Scholar] [Publisher Link]

[15] Surya. I, Surya.M, and Deepan Chakravarthi. A.V., “Experimental Investigation of Fly Ash Based Solid Block Masonry Prism by Using M-Sand as Partial Replacement of Fine Aggregate,” *International Journal of Recent Engineering Science*, vol. 7, no. 3, pp. 25-29, 2020. [CrossRef] [Publisher Link]

[16] Caiyi Chen et al., “Workability, Mechanical Properties and Affinity of Artificial Reef Concrete,” *Construction and Building Materials*, vol. 98, pp. 227–236, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[17] J. Limeira, L. Agullo, and M. Etxeberria, “Dredged Marine Sand in Concrete: An Experimental Section of a Harbor Pavement,” *Construction and Building Materials*, vol. 24, pp. 863–870, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[18] N. P. Ratnayake et al., “Evaluation of the Potential of Seashore Sand as an Alternative to River Sand for Concrete Production In Sri Lanka,” *Journal of Geological Society of Sri Lanka*, vol. 16, pp. 109–117, 2014. [Google Scholar] [Publisher Link]

[19] Kartheek Thunga, and T. Venkat Das, “An Experimental Investigation on Concrete with Replacement of Treated Sea Sand as Fine Aggregate,” *Materials Today: Proceedings*, vol. 27, no. 2, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[20] Praveen Nagulu.S, Ayyan Raj. A, and Deepan Chakravarthi. A.V., “Evaluation of Workability and Strength of Fly Ash Based Solid Block using M-Sand as Replacement of Fine Aggregate,” *International Journal of Recent Engineering Science*, vol. 7, no. 3, pp. 19-24, 2020. [CrossRef] [Publisher Link]

[21] D. A. R. Dolage, M. G. S. Dias, and C. T. Ariyawansa, “Offshore Sand as a Fine Aggregate for Concrete Production,” *Current Journal of Applied Science and Technology*, vol. 3, no. 4, pp. 813–825, 2013. [CrossRef] [Publisher Link]

[22] M. Karthikeyan and V. Nagarajan, “Chloride Analysis of Sea Sand for Making Concrete,” *National Academy Science Letters*, vol. 40, no. 1, pp. 29–31, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[23] Yijie Huang et al., “Mechanical Properties of Sea Sand Recycled Aggregate Concrete Under Axial Compression,” *Construction and Building Materials*, vol. 175, pp. 55–63, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[24] G. Ganesh Prabhu et al., “Mechanical and Durability Properties of Concrete Made with Used Foundry Sand as Fine Aggregate,” *Advances in Building Technologies and Construction Materials*, vol. 2015, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[25] Priya Gajjal, and M R Dahake, “A Novel Optimal Solution for Utilizing Plastic Waste for Making Construction Material,” *International Journal of Engineering Trends and Technology*, vol. 70, no. 9, pp. 93-104, 2022. [CrossRef] [Publisher Link]

[26] R. Siddique et al., “Strength, Durability, and Micro-Structural Properties of Concrete Made with Used-Foundry Sand (UFS),” *Construction and Building Materials*, vol. 25, no. 4, pp. 1916–1925, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[27] Pedro Amorim, Jorge de Brito, and Luís Evangelista, “Concrete Made with Coarse Concrete Aggregate: Influence of Curing on Durability,” *ACI Materials Journal*, vol. 109, no. 2, pp. 195–204, 2012. [Google Scholar] [Publisher Link]

[28] 26 Nigarila. R, Rajalakshmi. N, and Deepan Chakravarthi A.V., “Strength and Durability of Concrete Block by Partial Replacement of Cement with Granite Dust and Fine Aggregate with M-Sand,” *International Journal of Recent Engineering Science*, vol. 7, no. 3, pp. 12-18, 2020. [CrossRef] [Publisher Link]

[29] P Castro, M.A Sanjuán, and J Genescá, “Carbonation of concrete in Mexico Gulf,” *Building and Environment*, vol. 35, pp. 145–149, 2000. [CrossRef] [Google Scholar] [Publisher Link]