ASSESSMENT OF DURABILITY PROPERTIES OF M35 AND M70 GRADE CONCRETECOMPRISING CRAB SHELL POWDER

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Abstract

Recycling of waste materials generated during building and demolition is becoming a requirement for modern civilizations seeking environmental sustainability. To yet, only a small amount of crab shell powder (CSP) has been used to substitute cement in the production of high-quality concrete. Crab shells are the leftovers after the edible section of the crab has been removed. They are frequently abandoned as waste in the environment, causing contamination.The goal of this study was to compare concrete mixes of M35 and M70 made from these discarded shells to cement. Because of their pozzolan character, crab shell mixes were utilized as a partial replacement for cement in this project. The results of the investigation revealed that Crab shell mix concrete mold had better durability properties such as sulphate resistance, acid resistance and alkaline resistance than standard concrete mold at partial weight replacement of30% in both grades.

Keywords: Crab Shell Powder; Durability Properties; Sulphate Resistance; Acid Resistance; Alkaline Resistance

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1. INTRODUCTION

The rapid urbanization and industrialization in different countries have increased the demand of the concrete as a basic construction material. Approximately, 4.4 billion tons of concrete is being produced worldwide annually, which has been estimated to rise over 5.5 billion tons bythe year 2050. Consequently, there is a boost in the demand of raw materials in production of concrete in last few decades. Also in conjunction with heavy utilization of energy the production of concrete has many adverse influences on the environment, basically in terms ofCO_2 emission and depletion of raw materials (Kuder et al., 2012).

Another concern is related to the solid wastes, produced from industry and agriculture, which create serious disposal problems. Hence, to fulfill the rising demand of concrete keeping the environment safety in view, there is a need of sustainability in construction industries. Many past researchers have accomplished sustainability by utilizing the industrial wastes like fly ash (Khan et al., 2018) and silica fume (Meddah et al., 2018) as substitutes of cement. They mostly used fly ash, blast furnace slag, ferrochrome ash, silica fume etc. to reduce high cement consumption.Apart from industrial waste, there are agricultural wastes like rice husk, oil palm shell, etc. which are becoming a threat to the environment. India alone produces crab shells around 158.4 million tons annually. In crab shells producing countries, there is serious problemrelated to the disposal of crab shells, as it can occupy larger land area and their disposal by burning pollute the environment.

The purpose of this research is to compare the effect of discarded crab shells and their mixture as cementitious content for partial cement substitution on concrete durability. Although work on crab shell powder and regular concrete was done separately. Crab shells were chosen for this study due to their availability in the Tamil Nadu region, where they are primarily consumed locally and contribute to the majority of environmental contamination. Crab shells are exoskeletons that contain rigid and resistant components that play functional roles such as temperature protection, support, feeding, acting, and so on. Crab shells are marine animals (phylum Mollusca and class gastropod) that belong to the group of exoskeletons that contain rigid and resistant components that play functional roles such as temperature protection, support, feeding, acting, and so on. They vary in size and nature, but they all have a coiled nature, feeding behaviour's and patterns, shell hardness, and calcium carbonate content (CaCO3). Crab shells contain enough calcium carbonate to be used as a partial replacement for standard Portland cement. Crab is a single-valved sea crab that lives in brackish deep water and riverbeds, and is a seasonal creature. It is a mollusk species with hard and resistant components that provide a variety of functions such as predator protection, support, feeding, and acting. Flexure Strength Characteristics of Crab Shell Powder Blended Cement Concrete of M35 and M70 has been studied [10][11], and crab shell powder has been employed in cement concrete [12]. Crab shell is higher in micronutrients, according to research [13]. Crab shells also include the constituents of typical Portland cement that give it strength, especially calcium oxide (CaO) and silicon oxide (SiO2), according to research [14]. As a result, crab could be used to replace cement in some cases.

A control mix of M35 and M70 grade was prepared using only cement as binding material without substituting CSP. For comparison three mix proportions were used by replacing 27%,30%, and 33% of quantity of cement of control mix by CSP.

2. Materials

In this analysis, the crab shells are collected from Kanyakumari, Tamil Nadu. As per the procedure given in "BIS: 1727- 1967" [15], "the specific gravity of crab shell powder is 2.74 and as per "BIS: 4031 Part IV" [16], the standard consistency, Initial and final setting time of are 35%, 33 minutes and 4 hours 30 minutes".

Table 1. Physical Properties of Cement and Crab Shell Powder

Physical Propertiesof Pozzolans	**Result of Test**	
	Cement	**Crab Shell Powder**
Consistency	37%	35%
Specific Gravity	2.85	2.74
Initial Setting Time	23 minutes	33 minutes
Final Setting Time	2 hrs 15 min	4 hrs 30 min

2.1.1 Proportions of Mixes

A concrete mix for 28 days has been prepared according to "IS 10262: 2009" [28]. The four combinations were designed and listed in Table 3 with respect to durability of the crab shell powder-based concrete. The concrete with 100% cement has been taken into account as

the reference Concrete. The concrete that includes crab shell powder of 27%, 30%, and 33 % by weight were designed.

Table 2. Mix Calculations of Materials

	Mix A				Mix B			
Materials	A0CSP	A27CSP	A30CSP	A33CSP	B0CSP	B27CSP	B30CSP	B33CSP
OPC	440	320	308	296	440	300	288	276
CSP	0	120	132	144	0	140	152	164
CA	1003.45	1003.45	1003.45	1003.45	1003.45	1003.45	1003.45	1003.45
FA	800	800	800	800	800	800	800	800

2.2 Preparation and Casting of Specimens

After obtaining the required quantities of the materials, they are mixed in portable concrete mixer to get a homogenous workable mix. Firstly, the coarse aggregate followed by fine aggregate were mixed in the concrete mixer for 2min. Thereafter, the binder i.e. CSP is added to the aggregate mixture sequentially and the concrete mixer was again rotated for 2 min to form a solid mixture. Thereafter, to this solid mixture, water was slowly added and the mixer was again rotated for 3 min to get a homogenous workable fresh concrete mix.

The fresh concrete was then undergone for workability test with the help of a slump cone. Aftersatisfying the workability criteria fixed at 70mm–80mm slump value, the fresh concrete was poured into different molds of specified sizes. The molds were filled by fresh concrete in three layers and each layer was compacted by a 16 mm tamping rod 25 times. After 24h of casting, the specimens were removed from the respective molds and kept in water at 27°C in submergedcondition up to the desired age of curing.

3. Durability Property Tests

a. Sulphate Resistance

This test is carried out to determine the Sulphate attack on concrete specimens when fully immersed in the sulphate solution. There is no standard code practice for sulphate resistance of concrete. A reference spotlight similar to that of ASTM C 1012 (Standard Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulphate Solution) was trailed to execute the sulphate attack test. Totally 72 cubes (150mmx 150mm x 150mm) are cast; 3 cubes for each mix and the average values are taken. The cube specimens were cured and taken after 28 days of curing. Then the specimens are cleaned and weighed, the obtained value is recordedand considered as the initial weight. Followed by 5% of magnesium sulphate (MgSO4) was taken concerning the quantity of water required to experiment. The MgSO4 is dissolved in the water and the specimens are immersed into it for 30 days at a room temperature of 23 ± 2oC which is shown in Figure 3.44. The pH range of 6.0 to 8.0 for the solution was ensured each week. However, maintenance of pH range is not mentioned in the ASTM C 1012 but the importance of controlling the pH range is to associate the field conditions in which concrete is present in a neutral environment with a continual supply of sulphate ions. After 30 days the specimens are taken out from the solution, surface dried and weighed and the value is recorded as final weight i.e., after immersion of MgSO4. After the immersion period and dried process, white coloured deposition was physically observed on the surface of the concrete. Finally, the cube specimens are subjected to a compression test and the results are compared with normal water cured concretes. Based on the initial, final weight and compressive strength the percentage loss of weight and strength are obtained and those values are listed in Table 3.

Table 3. Sulphate resistance test results

Mix ID	Initial Weight (kg)	Final Weight (kg)	% of Weight Loss	Initial Compressive Strength N/mm^2	Final Compressive Strength N/mm^2	% of Strength Loss
A0CSP	7.89	7.75	1.77	42.9	40.11	6.5
A27CSP	7.78	7.65	1.67	43.8	41.87	4.4
A30CSP	7.76	7.64	1.55	45.2	43.62	3.5
A33CSP	8.16	8.00	1.96	44.3	42.48	4.1
B0CSP	7.92	7.84	1.01	77.7	72.88	6.2
B27CSP	8.15	8.02	1.60	78.9	75.67	4.1
B30CSP	8.25	8.19	0.73	82.0	79.29	3.3
B33CSP	8.38	8.29	1.07	79.6	76.58	3.8

b. Acid Resistance

Cube specimens of size 150 mm x 150 mm x 150 mm (3 cubes for each mix) are cast and underwent curing for 28 days. After 28 days of curing, the specimens are taken out from the curing tank and allowed to dry for 24 hours. Then weights of the cubes are taken and considered as initial weight. To perform this test 5% Hydrochloric Acid (HCL) is taken by volume of waterand diluted to the pH value of about 2. Then cubes are immersed in the acid solution for 30 days that are shown in Figure 3.45. The test is conducted as per the procedure of ASTM C 1898 20. The HCL solution is verified once a week to maintain its concentration. After 30 days the specimens were taken out from the HCL solution and Then the cubes are cleaned with the wire brush to remove unstable particles leached by acid and weighed (final weight) and then it is tested in a compression testing machine. Using initial, final weight and compressive strength the percentage loss of weight and strength are obtained and those values are listed in Table 4.

Table 4. Acid resistance test results

Mix ID	Initial Weight (kg)	Final Weight (kg)	% of Weight Loss	Initial Compressive Strength N/mm^2	Final Compressive Strength N/mm^2	% of Strength Loss
A0CSP	7.79	7.52	3.47	42.9	30.18	29.66
A27CSP	7.71	7.45	3.37	43.8	33.33	23.91
A30CSP	7.66	7.40	3.39	45.2	35.14	22.26
A33CSP	8.11	7.79	3.95	44.3	33.81	23.69
B0CSP	8.01	7.70	3.87	77.7	54.92	29.32
B27CSP	8.21	7.89	3.90	78.9	57.29	27.39
B30CSP	8.28	8.01	3.26	82.0	60.24	26.54
B33CSP	8.33	8.05	3.36	79.6	57.17	28.17

c. Alkaline Resistance

Alkaline resistance is similar to that of sulphate resistance and acid resistance. Cube specimens of size 150 mm x 150 mm x150 mm are cast and placed for curing for 28 days. After 28 days of curing, the specimens are taken out from the curing tank and allowed to dry for 24 hours. Then initial weights of the cubes are taken. To perform this test 5% sodium hydroxide (NaOH) is taken by volume of water and it is diluted to the pH value of about 13. Then cubes are immersed in NaOH solution for 30 days as shown in Figure 3.16. The NaOH solution is verified once a week to maintain the pH value. After 30 days the specimens are taken out from the NaOH solution. Glassy crystal, white precipitations and micro-cracks are formed on the surface of the concrete cubes that are physically observed after 30 days of immersion in NaOH solution. The cubes are cleaned, weighed (final weight) and then it is tested in a compression testing machine. Using initial, final weight and compressive strength the percentage weight and strength loss are calculated and are listed in Table 5.

Table 5. Alkaline resistance test results

Mix ID	Initial Weight (kg)	Final Weight (kg)	% of Weight Loss	Initial Compressive Strength N/mm^2	Final Compressive Strength N/mm^2	% of Strength Loss
A0CSP	7.72	7.70	0.26	42.9	40.14	6.43
A27CSP	7.82	7.81	0.13	43.8	41.24	5.84
A30CSP	7.77	7.75	0.26	45.2	43.27	4.26
A33CSP	8.12	8.11	0.12	44.3	41.64	6.01
A0CSP	8.05	8.03	0.25	77.7	74.97	3.51
A27CSP	8.25	8.23	0.24	78.9	76.49	3.05
A30CSP	829	8.28	0.12	82.0	79.77	2.71
A33CSP	8.35	8.32	0.36	79.6	77.08	3.16

4. RESULTS AND DISCUSSIONS

a. Sulphate Resistance Test

The test has been conducted to assess the resistance of M35& M70 grade concrete containing crab shell powder against sulphate attack. Concrete permeability is crucial in defending it fromsulphate attacks from the outside. Sulphate attack can result in concrete expansion, loss of compressive strength, and weight loss. It may be due to the formation of ettringites and gypsum. The percentage weight loss and strength loss of all the mixes were measured as shownin figure 1. After 28 days of immersion, visual observation of the concrete cubes indicated significant deterioration due to sulphate attack, when compared to the reference mix A0CSP & B0CSP the percentage strength loss of all the combinations was decreased up to 30% replacement of crab shell powder and starts increasing thereafter. This increment of strength loss is due to the excess amount of crab shell powder is remaining in the mixes. From figure 1 the minimum loss in strength was experienced with mixes A30CSP & B30CSP.

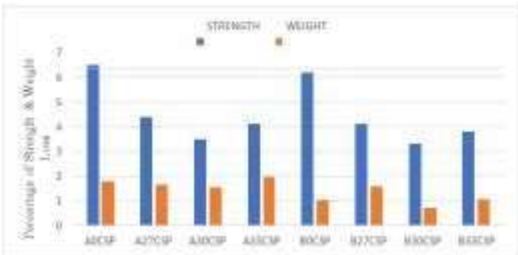

Fig 1. Strength & Weight Loss due to Sulphate Solution

b. Acid Resistance Test

The test has been conducted to assess the resistance of M35& M70 grade concrete containing crab shell powder against acid attack. Acid attack degrades the structural integrity of concrete, reducing its durability and service life. The percentage weight loss and strength loss of all the mixes were measured as shown in figure 2. After 28 days of immersion, visual observation ofthe concrete cubes indicated significant deterioration due to acid attack The corners were the first to fall off since the intrusion occurs from the two adjacent faces of the cube. Furthermore, when compared to the reference mix A0CSP & B0CSP the percentage strength loss of all the combinations was decreased up to 30% replacement of crab shell powder and starts increasing thereafter. This increment of strength loss is due to the excess amount of crab shell powder is remaining in the mixes. From figure 2 the minimum loss in strength was experienced with mixes A30CSP & B30CSP.

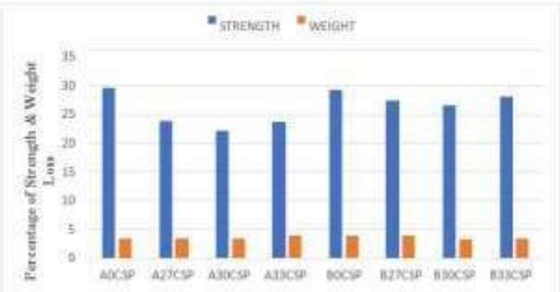

Fig 2. Strength & Weight Loss due to Acid Solution

c. Alkaline Resistance

The test has been conducted to assess the resistance of M35& M70 grade concrete containing crab shell powder against alkaline attack. The percentage weight loss and strength loss of all the mixes were measured as shown in figure 3. After 28 days of immersion, visual observationof the concrete cubes indicated significant deterioration due to alkaline attack, when compared to the reference mix A0CSP & B0CSP the percentage strength loss of all the combinations was decreased up to 30% replacement of crab shell powder and starts increasing thereafter. This increment of strength loss is due to the excess amount of crab shell powder is remaining in themixes. From figure 3 the minimum loss in strength was experienced with mixes A30CSP & B30CSP.

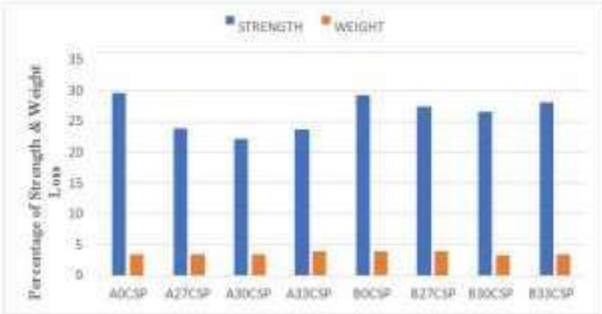

Fig 3. Strength & Weight Loss due to Alkaline Solution

5. Conclusions

Durability properties are identified in experimental investigations on uncalcined and calcined Crab Shell powder concrete.

- It is also established that the processing of Crab Shell powder does not result in an increase in the cost of concrete making. Because these shells are easily available at beachplaces, using them in concrete will reduce the amount of cement used. As a result, the cost of concrete falls, as does the use of cement in projects.
- When the Crab Shell powder is heated, the amount of silica increases, which aids in the improvement of pozzolanic reactions in mortar composite.
- Crab Shell particles are securely packed in the nominal concrete mix's gaps, or micro- cracks, resulting in a dense structure that results in C-S-H and C-H gel formation.
- The Ca/Si ratio in mix 30 is lower during the hydration process, ranging from 0.8 to 2.5, resulting in the "formation of C-S-H, C-H gel, and Ettringite".

- For Crab Shell powder, the absorption of water and capillary action are lower for mix

  30. This is owing to the ability of heated CSP to produce additional silica.
- Which aids in the resistance of sulphate, acid and alkaline. The findings show that the Crab Shell powder concrete samples are capable of being used in several civil engineering construction tasks.
- It has been demonstrated that the use of Crab Shell powder in any form has features thatare comparable to those of cement, and so the use of cement can be reduced by using Crab Shell powder instead of cement in buildings.
- Using Crab Shells in construction activities eliminates Crab Shell debris while also reducing environmental difficulties such as carbon dioxide emissions.

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Conflict of interest

None

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