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A Role of Bivalve Shell Powder as a Partial Replacement in Mortar: A Case Study from the Yadayanthittu Estuarian *Meretrix casta* shells

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ABSTRACT

Bivalve shells are covered with a hard part which is made up of calcium carbonate ($CaCO_3$). The bivalve shells have wide applications among one is a partial replacement of mortar. In this study, Yadayanthittu estuarian *Meretix casta* shells have experimented for partial replacement in the mortar. A variety of experiments were conducted and the results are discussed in details. The estuarian *M.casta* (bivalve) shells chemical constituents were measured by XRF instrument. The analytical results demonstrate that the *Meretrix casta* shells having a loss on ignition (LOI) about 44.00%; the calcium oxide (CaO) occupy 54.47%, and the other reported oxides accumulated to 1.5287 %. For mortar replacement study, a total of seven experiments (E1-E7) was performed with different combinations. The first combination (E1) without any replacement in mortar and the second (E2) with 12.5% of fly ash replacement and the remaining experiments (E3-E7) consist of *Meretrix casta* shell powder (MCSP) with various proportions of 12.5%, 8.75%, 8.33%, along with fine aggregates. Each combination was mixed with water and casted separately. After 07 and 28 days of curing, they cubes were removed, dried and measured the compressive strength. The compressive strength results indicate that the E7 combination exhibits higher strength by 41.80 and 56.8 Pa respectively. This could be due to the C-S-H gel formation in the mortar. The lowest results are observed in E4 combination, with the compressive strength of 32.42 and 47.42 at the age 07 and 28 days. These experiments show not enough binding capacity may be due to inadequate C-S-H gel formation.

Keywords: Yadayanthittu estuary**,** *Meretrix casta* shells, chemistry, mortar, compressive strength.

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INTRODUCTION

The study of bivalve is an important one and discussed in various fields of Science. Bivalve shells are covered with a hard part which is made up of calcium carbonate ($CaCO_3$) and the shells longevity as fossils helps geologist, archaeologists and anthropologists to understand old trade routes, rituals and traditions. Stable isotopes of bivalve shells can provide proxies for high-resolution records of environmental parameters[9]. The hard shells are composed of high CaCO3, has three polymorphs, namely aragonite, vaterite and calcite. The calcium carbonate is one of the predominant materials for various fields in the world, it is used as raw materials for the manufacture of lime, mortar, chemicals, fertilisers and flux material in iron and steel, ferro-alloy and other metallurgical industries[3, 8].The mortar made from lime shell is considered to be highly durable and superior quality, due to least quantity of magnesium oxide[16]. Of late lime shells are used in the biomedical field like artificial dental root implantations, orthopaedic application in bone repair, etc. In medicinal field, some bivalves are used for treating diseases like anaemia, hypertension, labour pain and constipation[5,7]. Estuaries play an essential role in rural livelihood by providing valuable resources like fishes, molluscs, crabs, prawns, shrimps, etc., They are highly productive in a dynamic and unique ecosystem, providing food, transport, recreation, etc[6]. Bivalves generally exist in estuaries, fits into their most productive ecosystem such as fresh water and salt water confluence[18]. India has rich estuarine and other brackish water resources along the east and west coasts formed by the Ganges, Mahanadi, Brahmaputra, Godavari, Krishna, Cauvery, Narmada and Tapati rivers, and smaller coastal rivers along the west coast, mainly in Kerala, Karnataka and Goa and east coast, mainly in Tamil Nadu, Andhra Pradesh and Odisha[13].The present study aims to understand the biochemical composition of *Meretrix casta* shells and its role in the partial replacement of mortar.

Study Area

The Yadayanthittu Estuary (Marakkanam Estuary) is falling in the toposheets No. 57P/16 and 66D/4 of 1:50,000 scale, and lies between the Latitudes 12˚ 12’ to 12˚ 15’ N and the Longitudes 79˚ 56’ to 80˚ 00’ E. The estuary is directly connected to the Bay of Bengal and develops a lagoon ecosystem. The estuary has a large area of intertidal mudflat that supports local flora and fauna. The site around Marakkanam exposes Cuddalore Sandstone of Mio-Pliocene age, resting over the charnockites and in turn, it is overlain by the Quaternary sediments [1,4]. The area location map is shown in Figure 1.

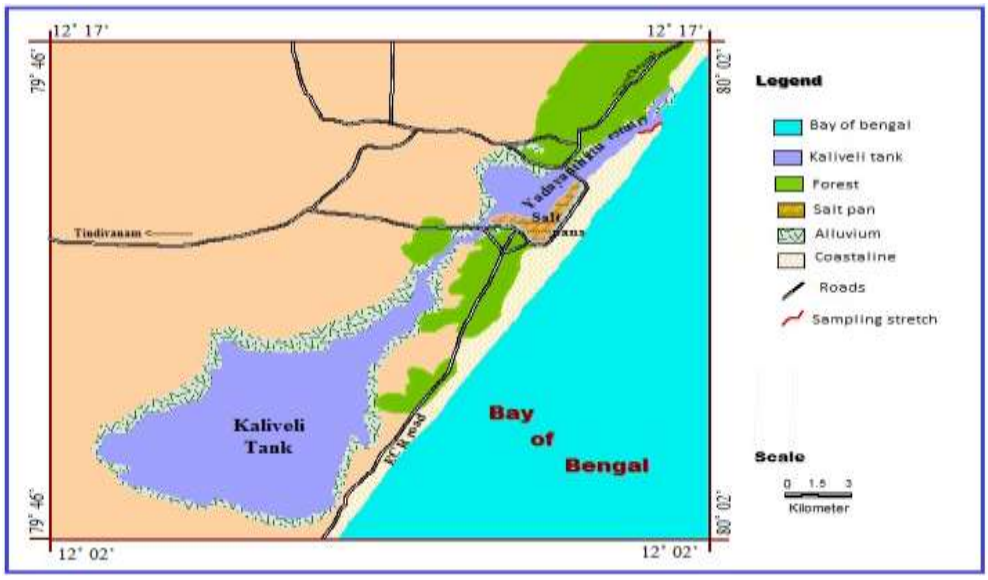

Figure 1: Location map of Yadayanthittu Estuary.

METHODOLOGY FOR BIOCHEMICAL STUDY

Analytical methods

The study area *Meretrix casta* shells, chemical measurements were done with an XRF instrument (Model: Thermo Scientific- ARL 9900 X-ray Workstation). The samples were dried in an oven at 100˚C for 24 hours, after initial surface free moisture removal at 40˚C for 4 hours. The dried samples were ground in an Insmart® ring mill with Tungsten Carbide elements to a fine powder in order to minimise particle size effect on the analysis. Approximately 9.0g of each resulting powder was mixed with 1ml of Cellulose, which acts as a binding agent [13] and then pressed into 25mm diameter disks and the disks were analysed on an XRF spectrometer using a Rh target X-ray tube operating at 60 KV and LiF 200 in a vacuum path for major oxides analysis.

Biochemical results of Yadayanthittu Estuarine *Meretrix casta* shells

Major components of *Meretrix casta* shells of the study area are shown in Table 1.

Table 1: The analytical results of *M. casta* shells of Yadayanthittu Estuary

Sl. No.	Compound	Formula	m/m %
1	Calcium oxide	CaO	54.47
2	Sodium oxide	Na_2O	0.697
3	Silicon oxide	SiO_2	0.241
4	Strontium oxide	SrO	0.184
5	Iron oxide	Fe_2O_3	0.116
6	Sulphur trioxide	SO_3	0.0664
7	Magnesium oxide	MgO	0.0661
8	Aluminium oxide	Al_2O_3	0.0587
9	Chlorine	Cl	0.0504
10	Cadmium oxide	CdO	0.0135
11	Phosphorus pentoxide	P_2O_5	0.0104

12	Scandium oxide	Sc_2O_3	0.0050
13	Zirconium oxide	ZrO_2	0.0041
14	Titanium oxide	TiO_2	0.0038
15	Potassium oxide	K_2O	0.0037
16	Rhenium oxide	Re_2O_7	0.0031
17	Nickel oxide	NiO	0.0025
18	Zinc oxide	ZnO	0.0018
19	Bromine	Br	0.0012

Major oxides

The analytical results demonstrate that the *Meretrix casta* shells of Yadayanthittu Estuary, having a loss on ignition (LOI) about 44.00%; the calcium oxide (CaO) occupies 54.47%, and the other reported oxides accumulated to 1.5287%.

STUDY OF *MERETRIX CASTA* (BIVALVE) SHELL POWDER AS PARTIAL REPLACEMENT IN CEMENT MORTAR

Materials

The Ordinary Portland Cement (OPC) of 53 grades confirming to IS 12269-1987[10] was used in this study. The OPC cement was used as the main binder. River sand confirming to grading zone II of IS 383-1970[12] was used as a fine aggregate. For the 75mm mortar cube, sand was passed through IS test sieve, range between 600µm to 1.18mm. *Meretrix casta* (bivalve) shell powder was used for the replacement of cement, it also has passed through 90 µm same finesse as cement conforming to the IS 12269-1987[10]. Fly ash was collected from NLC Tamil Nadu and sieved before used confirming to IS 3812 (part I[10]). Potable water (drinking water) confirming to IS: 3025-1986 [11]having pH value 7.0 is used for mixing and curing purposes.

Preparation of *Meretrix casta* shells

Meretrix casta shells obtained from Yadayanthittu Estuary, formed as the result of the disintegration of dead animals. The collected shells cleaned with clean water and dried in sunlight for five days approximately at a temperature range of 25-30°C. The shells, then hand crushed, grounded with mortar and pestle and passed through a 90µm sieve fine powder was used for cement replacement study.

Proportion of materials

The proportion of cement to fine aggregate ratio is 1:3 (by weight) and the Water/Cement ratio was taken as litre/m^3, for example, 230m1 (water) / 570g (cement) = 0.40, used for making the mortar specimens. As per the 1:3 ratio, cement and sand have been taken 570g and 1710g respectively. In that 570g of cement, we replaced 0%, 5%, 8.33%, 8.7% and 12.5% with fly ash and *Meretrix casta* shell powder (MCSP). In this Study, totally seven proportions were prepared.

The normal 53 grade OPC cement used for mortar Cubes. The first combination is without any replacement in the mortar (El). 12.5% of Fly ash was replaced with cement (E2) as a second combination. In the third combination, a proportion of 12.5% of burned *Meretrix casta* shell powder (MCSP) was replaced (E3). In the fourth combination an equal amount of 8.33% of cement, fly ash, and MCSP was mixed together along with fine aggregates (E4). The fifth combination (E5) with 12.5% of cement and MCSP in equal amount. The sixth combination consists 16.25% of cement and 8.75% of MCSP mixed with aggregates (E6). The last and seventh combination ratio is 20% of cement and 5% of MCSP (E7). Table 2 showing the proportion of cement, fly ash and MCSP percentages.

Table 2: Mixing proportion of cement, fly ash and MCSP for mortar cubes

Experiments	Cement		MCSP		Fly ash		Sand		W/C
E1	570	25	0	0	0	0	1710	75	0.40
E2	285	12.5	0	0	285	12.5	1710	75	0.40
E3	285	12.5	285	12.5	0	0	1710	75	0.40
E4	190	8.33	190	8.33	190	8.33	1710	75	0.40
E5	285	12.5	285	12.5	0	0	1710	75	0.40
E6	370	16.25	200	8.75	0	0	1710	75	0.40
E7	456	20	114	5	0	0	1710	75	0.40

Mixing and casting

As an initial Step, Partially replacing materials are mixed well with cement and fine aggregate in a dry condition in a ratio of 1:3 (by weight) and added the water with a W/C ratio 0.40 was used for making the fresh cement mortar mix. In this proportion, 75X 75 X 75mm cube mould was chosen for the casting, for the compressive strength test, minimum of three cubes was prepared for each combination for the best results. For each experiment, Six cubes were made for 7 and 28 days Compressive strength test. The fresh concrete mix was placed in the cube moulds. Before placing of concrete, the cube mould must be oiled for the ease of mortar specimens stripping. Special care was taken during the oiling of the moulds, so that there are no concrete stains left on the moulds. During the placing of fresh concrete into the moulds, tamping was done uniformity using the Tamping rod in order to reduce the honeycombing. The moulded specimen was kept at room temperature for 24 hours, and then the specimens were demoulded from the mould, given separate numbers for identification of the proportions.

Curing

Curing is an important process to prevent the concrete specimens from of moisture while it is gaining its required strength. Lack of curing will lead to an improper gain in the strength[16]. The

demoulded cube specimen was submerged in the curing tank with a controlled temperature of 25 ºC. After 7 and 28 days of curing, the mortar cube specimens were removed from the curing tank, dried in sunlight.

Compression test

Compression test is the most common test conducted on hardened concrete, mortar, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive Strength[14]. The compressive strength was determined using a digital compression testing machine capacity 3000 kN, Mode, No. ASEW-107. For the compressive strength test, the hardened 75 mm mortar cube specimens were placed the in center of chamber plate, a loading rate of 2.5 kN/s was applied as per IS: 51 6-1959. From the compression test machine, the failure load of the hardened specimen was indicated on the digital display, the indicated results of compression values as kN/s. the specimen cracked on its form in the time of their failure load. The compressive strength results of all specimens at the age of 7 and 28 are tabulated and given in Table 3.

Table 3: Compressive strength results of cubic specimens at the ages of 7 and 28days

Experiments	Replaced combination (in %)				Compressive strength (MPa)	
	Cement	MCSP	Fly ash	Sand	7 days	28 days
E1	25%	--	--	75%	37.00	52.40
E2	12.5%	--	12.5%	75%	36.86	51.86
E3	12.5%	12.5% (Burned)	--	75%	35.00	50.00
E4	8.33%	8.33%	8.33%	75%	32.42	47.42
E5	12.5%	12.5%	--	75%	35.44	50.44
E6	16.25%	8.75%	--	75%	39.72	54.72
E7	20%	5%	--	75%	41.80	56.80

RESULTS AND DISCUSSION

Various ratios of *Meretrix casta* shell powder (MCSP) were partially replaced in the cement. A total of seven experiments was conducted and the results are deliberated in a chart diagram. Compressive strength tests conducted at the age of 7 and 28 days using a digital compression testing machine. 56.8 Pa respectively. Hence this combination of (cement 20%+ MCSP 5%+sand 75%) demonstrates slightly higher at the age of 7 and 28 days strength, it could due to a chemical reaction between MCSP and cement paste as a concrete. The E4 experimented results shows the lowest compressive strength of 32.42 and 47.42 at the age 7 and 28 days. This experiment consists of cement, shell powder and fly ash in an equal portion of 8.33% apart from 75% of fine aggregate. This experiment indicates that such combinations having a poor binding capacity ultimately

decrease the compressive strength. The experiments (E1, E2, E3 and E5) show nearly the same values of compressive strength ranging from 50 to 52.40 MPa. These experiments illustrate that cement, fly ash and MCSP combination are not having enough binding capacity in concrete in order to fulfil the strength test.

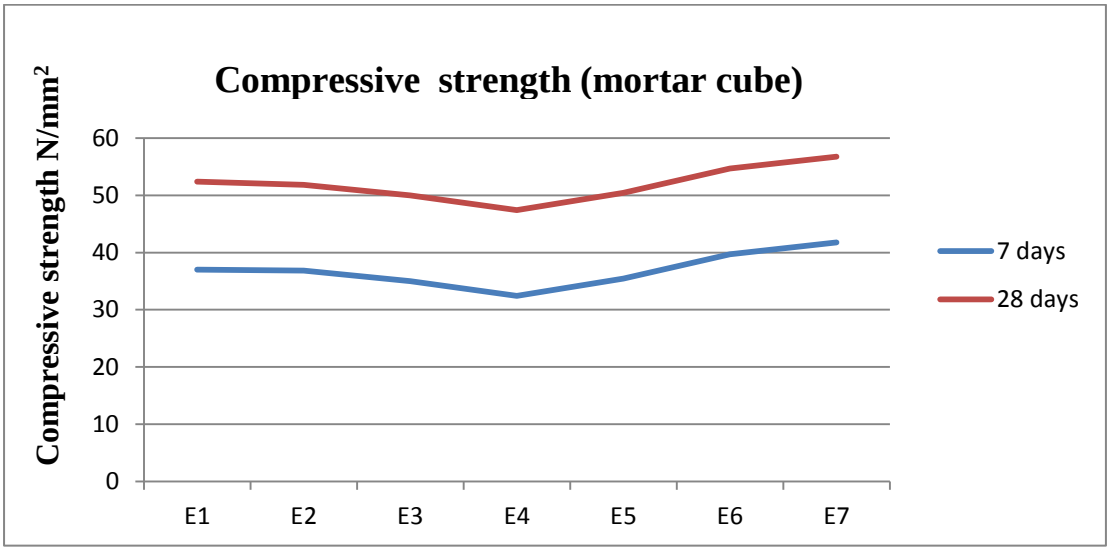

Figure 2: Exhibits that the compressive strength is high in E7 for the age of 7 and 28 days

The experiment E6 indicates good compressive strength for the age of 7 and 28 days, 16.75% of cement and 8.75 % of MCSP is a better combination of good strength. From the overall experimental study, it is noticed that a higher ratio of replacement increase the pole size and subsequently decreases strength in concrete cubes. The experimental study also evidenced (E3 and E5) there is no much variation in the compressive strength values between the burned and unburned MCSP.

SUMMARY AND CONCLUSION

Meretrix casta shells of Yadayanthittu Estuary reveals that the average of CaO content is (54.47%). The remaining oxide constituents less than 2% of total oxides constituents. The rare oxides of scandium (Sc_2O_3) and rhenium oxide (Re_2O_7) also presented in the shell. From the seven studies, the results are determined by digital compression testing machine, The compressive strength is high in E7 for the ages of 7 and 28 days by 41.80 and 56.8 MPa respectively. This combination (cement 20%+ MCSP 5% + sand,75%) demonstrates slightly higher strength at the age of 7 and 28 days, it could be due to a chemical reaction between MCSP and cement paste as in the concrete. The E4 experimented result shows the lowest compressive strength of 32.42 and 47.42 MPa, at the age of 7 and 28 days respectively. This experiment consists cement, shell powder and fly ash in equal the proportion of 8.33% apart from 75% of the fine aggregate. This experiment indicates that such

combinations having a poor binding capacity ultimately decrease the compressive strength. The experiments (E1, E2, E3, and E5) show nearly the same compressive strength values, the values are ranging from 50 to 52.40 MPa. The experiments illustrate that the cement, fly ash and MCSP combinations are not having enough binding capacity in the concrete. The experiment E6 indicates good compressive strength for 7 and 28 days. From the overall experimental study, it is noticed that a higher ratio of replacement increase the pore size and subsequently decreases strength in concrete cubes. The experimental study also evidenced that there is no much difference in the compressive strength test result between the burned and the unburned MCSP (E3 and E5).

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