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Role of marine shell (*Meretrix casta*: Bivalve) in cement mortar preparation: An experimental study

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Abstract - Marine shells are suitable for mixing with cement as a replacer of cement. Fly ash, blast furnace slag, silica fumes, etc., are proposed as cement replacement materials. In this study *Meretrix casta* (bivalve) shell powder has experimented as a partial replacement in cementitious mortar compositions. Seven (E1toE7) specimens of the cement mortar cubes were prepared with various combinations and proportions. E1 specimen made with conventional mortar without any replacement. E2 with 12.5% of fly ash replacement, E3 toE7 specimens made with *Meretrix casta* shell powder (MCSP) as partial replacement for cement in the cement mortar with 8.33%, 8.75% and 8.75% of the cement weight. Seven and twenty-eight days compressive strengths of cured mortar cube specimens were analyzed. The compressive strength results of E7 sample exhibits higher strength of 41.80 MPa and 56.8 MPa, for seven and twenty-eight days respectively. The experimental investigations ofE1, E2, E3 and E5 samples show nearly the similar values of compressive strength. E4 sample exhibits lower compressive strength than others, the blend is oblivious in response; it discharges the CSH gel gradually over a time period in that mix.

***Keywords* — meretrix casta (bivalve), shell powder, replacement, mortar, compressive strength.**

I. INTRODUCTION

Mineral resources are very vital for any country's infrastructural development and economic growth. In recent years, minerals are used in larger quantities than ever before and in an increasingly diverse range of applications, particularly to meet the requirements of new technologies [26]. According to [20] mineral consumption is growing faster than population as more consumers enter the market for minerals and as the global standard of living increases. Further, he states that world demand for minerals will be affected by three general factors - uses for mineral commodities, the level of population that will consume these mineral commodities, and the standard of living that will determine just how much each person consumes. In addition to using minerals in far greater quantities, modern technology employs a considerably more diverse suite of metals [26]. The problem of increasing demand for mineral resources has a much wider dimension today and more extensively the world is discussing the issue with respect to the security of raw materials [5]. Scientific and Technological Community will have to play a major role to find out substitute or alternative materials for the mineral resources because they are non-renewable and finite.

Among the minerals, the limestone has wide industrial applications. Limestone consumed by many industries including cement, iron and steel, glass, agriculture, sugar, paint, etc. The limestone demand is mainly concentrated in the cement industry, which consumes around 65-70% of the total limestone production in India whereas the steel sector requires around 15-20%, the balance being consumed in the chemical and other small-scale industries [8]. As limestone becomes a limited resource, employment and construction associated with the concrete industry will decline. Therefore, those involved with these industries must develop new techniques for creating concrete with minimal use of limestone [29].The alternative materials are to optimize the mix for the best use of available raw materials. In this regard, locally available minerals, recycled materials and (industry, agriculture and domestic) waste may be suitable for blending with OPC as a substitute, or in some cases replacement, binders [35]; [7]; [2]; [24]; [18].

Marine shells are a rich source of calcium carbonate, the chemical composition of shells > 90% calcium carbonate ($CaCO_3$) by weight [19]; [10]; [27]; [11] this composition is similar to limestone powder or dust-like stone powder from grinding limestone to produce Portland cement [23]. Several experimental studies were done with seashells as additive or replacement material to produce concrete and mortar [25]; [38]; [31]. Estuaries and coastal seas have been focal points of human settlement and marine resource use throughout history [21]; [6]. Marine bivalves are abundant in coastal and estuarine waters of India [32]. Clams are harvested commercially, and discarded shells are a high-quality raw material for the production of $CaCO_3$ [30].

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A fresh water Meretrix casta, (Chemnitz) belongs to phylum Mollusca and class Bivalvia, they contain hard shells. This hard shell is mainly composed of calcium carbonate crystals in the form of aragonite [36]. In this paper, utilization of Meretrix casta Shell powder (MCSP) as partial replacement of cement mortar, According to [9] to manufacture one tonne of Ordinary Portland Cement (OPC), 1.1 tonnes of earth resources are needed. The production of Portland cement is one of the most notorious agents of CO2 emission into the atmosphere. Since the OPC causes serious environmental damages due to higher CO2 emission, it can be partially replaced with green materials which have pozzolanic characteristics [12]; [37]; [39]; [22].

II. STUDY AREA

The Study area Vellar Estuary falls in the Pichavaram Mangrove ecosystem in the Tamil Nadu Coast of India. The Vellar estuary is one of the prominent estuaries along the Southeast Coast of India.It has fishing activities and landing centers. The study area comes under the Parangipettai Block of Cuddalore District, Tamil Nadu, India.For the present study, the chosen areal extent of velar estuary is around 0.625 km^2. It falls in the Latitudes 11˚25' to 11˚30' north and the Longitudes 79˚45' to 79˚50' east in the Survey of India (SOI) toposheet No.58M/15 of 1:50000 scale. The Vellar estuary is an open type of ocean and it has connections with the adjoining sea throughout the year. The Vellar River originates from the Shervarayan Hills, Salem District, Tamil Nadu. It joins the Bay of Bengal at Parangipettai and is said to be a 'true estuary' as there is no complete closure of the mouth. This estuary has been demarcated into marine, gradient, tidal and freshwater zones based on salinity characteristics [33]. The study area map is shown in Fig. 1.

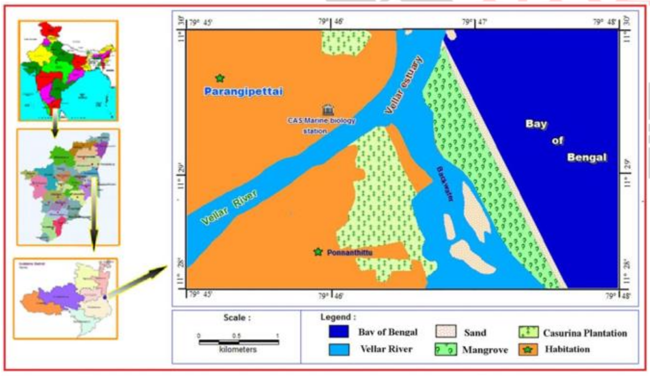

Fig.1. Location map of the study area.

III. MATERIALS AND METHODS

1. Materials

The Ordinary Portland Cement (OPC) of 53 grades confirming to IS 12269:53 [15] was used in this study. The OPC cement was used as the main binder. River sand confirming to grading zone II of IS 383 [16] was used as a fine aggregate. For the 75mm mortar cube, sand was passed through IS test sieve, range between 600µm to 1.18mm. The *Meretrix casta* (bivalve) shell powder was used for the replacement of cement, it also has passed through 90 µm same fine as cement conforming to the IS 12269: 53 [15]. Fly ash was collected from NLC India Ltd, Tamil Nadu and sieved before use, as confirming to IS 3812 (part I) [13]. Potable water (drinking water) confirming to IS 3025 [17] having pH value 7.0 is used for mixing and curing purposes.

2. Preparation of Meretrix casta shell powder

Dead *Meretrix casta* shells were obtained from Vellar Estuary banks. The collected shells cleaned with fresh water and dried in sunlight (Fig. 2) for five days approximately at a temperature range of 25-30°C. Then, the shells, crushed, grounded with a mortar and pestle and passed through a 90µm sieve fine powder (Fig. 3) was used for cement replacement study.

Fig. 2. *Meretrix casta* shells, dried in the sunlight.

Fig 3. Image shows the heap of the sieved *M. casta* shell powder.

3. Proportion of materials

The proportion of cement to fine aggregate ratio is 1:3 (by weight) and the Water/Cement ratio was taken as liter/m3, for example, 230ml (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. Cement has been partially replaced with 0%, 5%, 8.33%, 8.7% and 12.5% fly ash and *Meretrix casta* shell powder (MCSP) of the total volume of the mortar. For the study, totally seven proportions were executed. The normal 53

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grade OPC cement used for mortar cubes. The first combination (E1) is without any replacement in cement; in the second combination (E2), 12.5% of cement was replaced with fly ash. The third combination (E3), 12.5% of cement was replaced with burned *Meretrix casta* shell powder (MCSP). The fourth combination (E4) consists of an equal amount of 8.33% of cement, fly ash, and MCSP; the fifth combination (E5) with 12.5% of cement and MCSP in equal amount. The sixth combination consists of 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 1 shows the proportion of cement, fly ash, shell powder along with aggregates.

Table 1. Mixing proportion of cement, fly ash and MCSP for mortar cubes

Specimens	Cement		MCSP		Fly ash		Sand		W/C
	Kg/m^3	Wt. %	Kg/m^3	Wt. %	Kg/m^3	Wt. %	Kg/m^3	Wt. %	
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 (burned)	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	0	1710	75	0.40

4. Mixing and casting

As an initial step, partially replacing materials are mixed well with cement and fine aggregate in dry condition with a ratio of 1:3 (by weight) and added the water with a W/C ratio 0.40 Typically, water/cement ratio of 0.4 according to Abram's law [34]; [1] was used for making the fresh cement mortar mix. With this ratio 75x75x75 mm cube mould was chosen for the casting, for the compressive strength test, a minimum of three cubes was prepared for each combination for the best results. Each experiment, six cubes were made for 7 and 28 days compressive strength test.

Before placing of mortar, the cube mould should be oiled for the ease of mortar specimens stripping. A care was taken during oiling the moulds, to avoid the stains left on the moulds. Tamping has been done uniformly using the tamping rod while placing of fresh mortar into the moulds, to reduce the honeycombing. The moulded specimens were kept at room temperature for 24 hours after that the specimens have been demoulded from the mould and separate numbers given for clear identification of specimens.

5. Curing

The curing process is an important process to avert the mortar specimens from moisture at the time of obtaining its required strength. Curing has a strong influence on hardened cement products (mortar and concrete) by improving strength, volume stability, permeability resistance and durability. Improper curing or lack of adherence to best standard practices could significantly affect strength properties of concrete and mortar [4]. The demoulded cube specimens were submerged in the curing tank with a controlled temperature of 25 ºC. After fulfilling 7 and 28 days of curing, the mortar cube specimens were removed from the curing container and dried it in the sunlight for a few hours, subsequently the specimens were measured and weighed.Finally, the specimens were undergoing for compression test to determine the compressive strength of the mortar cubes.

6. Compression test

Compression test is the most common test conducted on hardened concrete, 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 [28]. The compressive strength test was conducted using a digital compression testing machine capacity of 3000 kN, Model ASEW-107. In order to understand the compressive strength of mortar, the hardened 75 mm mortar cube specimens were placed in the center of chamber plate, a loading rate of 2.5 cm/s was applied as per IS 1199 [14]. The digital display indicated results of compression values are in kN/s.

IV. RESULT ANALYSIS

Varied ratios of *Meretrix casta* shell powder (MCSP) were replaced in the mortar in addition to fly ash. A total of seven sets of specimens was tested and the results are deliberated in a chart diagram (Fig. 4). A compressive strength test was conducted at the age of 7 and 28 days using a digital compression testing machine. The compressive strength is high in E7 at the age of 7 and 28 days of 41.80 and 56.8 MPa respectively. The E7 combination consists of cement 20% + MCSP 5% + sand 75%, which demonstrates slightly higher at the age of 7 and 28 days strength, it could be due to the chemical reaction between MCSP and cement paste as a mortar. The E4 experiment results evidence the lowest

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compressive strength of 32.42 and 47.42 MPa at the age 7 and 28 days. This specimen consists of cement, MCSP and fly ash in an equal portion of 8.33% apart from 75% of fine aggregate. This indicates that such combinations having a poor binding capacity ultimately decrease the compressive strength, which shows that the admixtures act as fillers, only.A review of the literature shows that mineral and chemical admixtures control the strength and durability properties of concrete. From a chemical standpoint, it is important to accelerate the hydration rate of tricalcium silicate (C3S), which is responsible for the production of calcium silicate hydrate (CSH)—the main hydration product responsible for enhanced strength and durability [3]. The experiment E1 shows the standard compressive strength and this combination has no replacement in cement. The specimens E2, E3 and E5 show nearly the same values of compressive strength ranging from 50 to 52.40 MPa. These specimens illustrate that cement, fly ash and MCSP combinations are not having enough binding capacity in mortar in order to fulfil the strength test.

The specimen E6 indicates that good compressive strength for the age of 7 and 28 days, i.e. 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 increases the pole size and subsequently decreases strength in mortar cubes. The experimental study also evidenced that there is no much variation in the compressive strength values between the burned and unburned MCSP (E3 and E5).

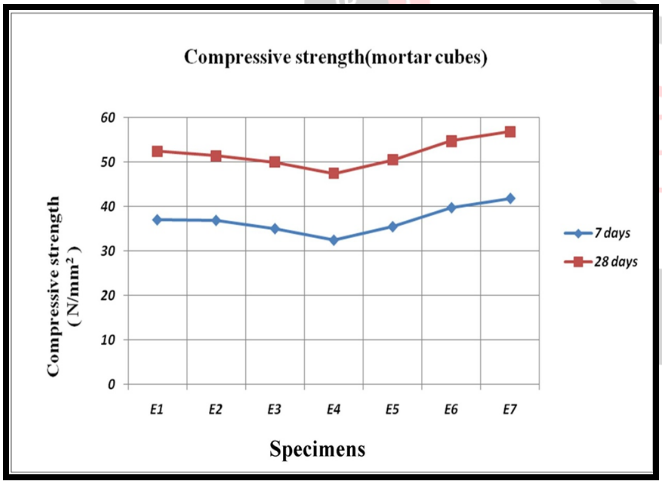

Fig. 4. Compressive strength of mortar cubes.

V. CONCLUSION

The experimental study reveals that *Meretrix casta* shell powder (MCSP) plays a significant role as a replacing material in the mortar. However, it is noticed that a higher ratio of replacement increases the pore size and subsequently decreases strength in mortar cubes. MCSP with 5 to 8% of replacement in the mortar will give the high compressive strength.

REFERENCES

[1] Abd Elaty MAA (2014). Compressive strength prediction of Portland cement concrete with age using a new model. HBRC. J. 10(2): 145-155. https://doi.org/10.1016/j.hbrcj.2013.09.005

[2] Akindahunsi AA, Uzoegbo HC (2015). Strength and durability properties of concrete with starch admixture. Int. J. Conc. Struc. and Mater.9(3): 323–335. http://dx.doi.org/10.1007/s40069-015-0103-x

[3] Byung W J, Muhammad AS, Sumit C, Zafar B (2017). Strength and durability assessment of portland cement mortars formulated from hydrogen-rich water. Adv. in Mater. Sci. and Engi. 2017(3):1-10. https://doi.org/10.1155/2017/2526130

[4] Bediako M, Kevern JT, Amankwah EO (2015). Effect of curing environment on the strength properties of cement and cement extenders. Mater. Sci. Appln. 6: 33-39. http://dx.doi.org/10.4236/msa.2015.61005

[5] Dubiński J (2013). Sustainable development of mining mineral resources. J. Sust. Min. 12(1):1-6 https://doi.org/10.7424/jsm130102

[6] Dugan JE, Airoldi L, Chapman MG, Walker SJ, Schlacher T (2011). Estuarine and coastal structures: environmental effects, a focus on shore and nearshore structures. Treat. Estuar. Coast. Sci. 8: 17-41. https://doi.org/10.1016/B978-0-12-374711-2.00802-0

[7] Fairbairn EMR, Americano BB, Cordeiro GC, Paula TP, Filho RDT, Silvoso MM (2010). Cement replacement by sugar cane bagasse ash: CO2 emissions reduction and potential for carbon credits. J. Enviro. Manage. 91(9): 1864-1871. https://doi.org/10.1016/j.jenvman.2010.04.008

[8] Ghose AK, Dhar BB (2000). Mining challenges in 21st century, APH Publishing Corporation, pp. 47-59, ISBN:8176481580.

[9] Gowsika D, Sarankokila S, Sargunan K (2014). Experimental investigation of eggshell powder as partial replacement with cement in mortar. Int. J. Eng. Trends Tech. 14(2): 65–68. https://doi.org/10.4445/22315381/IJETT-V14P214

[10] Hamester MRR, Balzer PS, Becker D (2012). Characterization of calcium carbonate obtained from oyster and mussel and incorporation of polypropylene. Mater. Res. 15(2): 204-208. http://dx.doi.org/10.1590/S1516-14392012005000014

[11] Hou Y, Shavandi A, Carne A, Bekhit AA, Ng TB, Cheung RCF (2016). Marine shells: Potential opportunities for extraction of functional and health-promoting materials. Crit. Rev. Environ Sci. Tech. 46(11): 121047-1116. https://doi.org/10.1080/10643389.2016.1202669

[12] Imbabi MS, Carrigan C, McKenna S (2012). Trends and developments in green cement and mortar technology. Int. J. Sustain. Built. Environ. 1, 194–216. https://doi.org/10.1016/j.ijsbe.2013.05.001

[13] IS 3812 (part I) (2013). Pulverized Fuel Ash - Part 1: For use as Pozzolana in cement. Cement Mortar and Concrete.

 DOI : 10.18231/2454-9150.2018.0077

Bureau of Indian Standards. Government of India, New Delhi.

[14] IS 1199 (1959). Methods of sampling and analysis of mortar [CED 2: Cement and Mortar]. Bureau of Indian Standards. Government of India, New Delhi.

[15] IS 12269 (2013). 53 grade ordinary Portland cement [CED 2: Cement and Mortar] Bureau of Indian Standards. Government of India, New Delhi.

[16] IS 383 (1970). Specification for coarse and fine aggregates from natural sources for mortar [CED 2: Cement and Mortar] Bureau of Indian Standards. Government of India, New Delhi.

[17] IS 3025 (1986). Methods of sampling and test (physical and chemical) for water and wastewater: Part 24 Sulphates [CHD 36 (Water Quality)] Bureau of Indian Standards. Government of India, New Delhi.

[18] Islam GMS, Rahman MH, Kazi N (2017). Waste glass powder as partial replacement of cement for sustainable concrete practice. Int. J. Sustain. Built Environ. 6: 37-44. https://doi.org/10.1016/j.ijsbe.2016.10.005

[19] Kamba SA, Ismail M, Ibrahim TAT, Zakaria, ZAB (2013). Synthesis and characterization of calcium carbonate aragonite nanocrystals from cockle shell powder (Anadara granosa). J. Nanomaterials, 2013:1-9, Article ID 398357. http://dx.doi.org/10.1155/2013/398357

[20] Kesler SE (1994). Mineral resources, economics and the environment. Macmillan. New York. 396 p, ISBN 0-02-362842-1.

[21] Knottnerus OS (2005). History of human settlement, cultural change and interference with the marine environment. Helgol. Mar. Res. 59(1): 2-8. https://doi.org/10.1007/s10152-004-0201-7

[22] Krishna KN, Sandeep S, Mini KM (2016). Study on concrete with partial replacement of cement by rice husk ash. IOP Conf. Ser. Mater. Sci. Eng. 149:1-11. https://doi:10.1088/1757-899X/149/1/012109

[23] Lertwattanaruk P, Makul N, Siripattarapravat C (2012). Utilization of ground waste seashells in cement mortars for masonry and plastering. J. Environ. Manage. 111:133-141. https://doi:10.1016/j.jenvman.2012.06.032

[24] Letelier V, Tarela E, Moriconi G (2017). Mechanical properties of concrete with recycled aggregates and waste brick powder as cement replacement. Procedia Eng. 171: 627-632. https://doi:10.1016/j.proeng.2017.01.396

Liang CF, Wang HY (2013). Feasibility of pulverized oyster shell as a cementing material. Adv. Mater. Sci. Tech. 2013:1-7 Article ID 809247. https://dx.doi.org/10.1155/2013/809247

[25] Lusty PAJ, Gunn AG (2014). Challenges to global mineral resource security and options for future supply. Geol. Soc. London. Spec. Pub. 393(23): 265-276. https://doi.org/10.1144/SP393.13

[26] Mohamad SFS, Mohamad S, Jemaat Z (2016). Study of calcination condition on decomposition of calcium carbonate in waste cockle shell to calcium oxide using thermal gravimetric analysis. ARPN J. Eng. and App. Sci. 11(16): 9917- 9921.

[27] More RA, Dubey SK (2014). Effect of different types of water on compressive strength of mortar. Int. Jour. On Emerging Tech.5(2): 40-50.

[28] Naik TR (2008). Sustainability of concrete construction. Pract. Period. Struct. Des. Constr. 13(2): 98-103. https://doi.org/10.1061/(ASCE)1084-0680(2008)13:2(98)

[29] Nelson DJ, Rains TC, Norris JA (1966). High purity calcium carbonate in freshwater clam shells. Science. 152(3727):1368-1370. https://doi.org/10.1126/science.152.3727.1368

[30] Olivia M, Mifshella AA, Darmayanti L (2015). Mechanical properties of seashell concrete. 5th Int. Conf. of. Euro. Asia. Civil. Eng. Forum. (EACEF-5). Procedia Eng.125:760-764. https://doi.org/10.1016/j.proeng.2015.11.127

[31] Pawar PR, Al-Tawaha ARMS (2017). Species diversity and distribution of marine bivalves from coastal transitional ecosystem of Uran, Navi, Mumbai, India. Adv. Environ. Biol. 11(4): 1-11.

[32] Ramamoorthi, K. (1954) A preliminary study of the hydrology and fauna of Vellar estuary. Proceedings of the Indo-Pacific Fisheries Council, 9th Session, Karachi, Pakistan, Section I. IPFC Secretariat, FAO Regional Office for Asia and the Far East, Bangkok, pp. 299.

[33] Sear LKA, Dews J, Kite B, Harris FC, Troy JF (1996). Abrams law, air and high water-to-cement ratios. Constr. Build. Mater. 10(3): 221–226. https://doi.org/10.11016/0950-0618(95)00079-8

Shao Y, Lefort T, Moras S, Rodriguez D (2000). Studies on concrete containing ground waste glass. Cem. Concr. Res. 30(1): 91-100. https://doi.org/10.1016/S0008-8846(99)00213-6

[34] Shoba K, Senthilkumar GR (2014). Geochemical aspects of *Meretrix casta* (bivalve) shells of Vellar estuary, southeast coast of India. 13(20): 2090-2094. https://doi.org/10.5897/AJB2014.13615

[35] Turner LK, Collins FG (2013). Carbon dioxide equivalent (CO2-e) emissions: A comparison between geopolymer and OPC cement concrete. Const. Build. Mat. 43: 125–130. http://dx.doi.org/10.1016/j.conbuildmat.2013.01.023

[36] Yao Z, Xia M, Li H, Chen T, Ye Y, Zheng H (2014). Bivalve shell: not an abundant useless waste but a functional and versatile biomaterial. Criti. Rev. Environ. Sci. Tech. 44(22): 2502–2530. https://doi.org/10.1080/10643389.2013.829763

[37] Yu R, Spiesz P, Brouwers HJH (2014). Effect of nano-silica on the hydration and microstructure development of ultra-high performance concrete (UHPC) with low binder amount. Elsevier, constr. and build. mater. 65: 140-150. http://dx.doi.org/10.1016/j.conbuildmat. 2014.04.063 0950-0618.

 DOI : 10.18231/2454-9150.2018.0077