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DREDGED OFFSHORE SAND AS A REPLACEMENT FOR FINE AGGREGATE IN CONCRETE

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ABSTRACT

This paper deals with the study on the extent of using off shore sand as a partial replacement for fine aggregate in concrete. Experiments conducted in this investigations involved sieve analysis, gap grading, determinations of compressive strength, flexural strength test, Rapid chloride penetration test, water absorption test and alkalinity test. After the result of sieve analysis as per IS383-1970 the graph shows that the grading curve for the offshore sand was found to be far away from river sand. The chloride content present in sample was 0.014% by weight after being exposed to rain and atmospheric conditions for nearly one year. The structural properties of off shore sand were found to be improving after replacing the finer particles of offshore sand with the river sand. The offshore sand replaced with 30% of fine particles from river sand gave satisfactory results when compared to river sand.

I. INTRODUCTION

To meet the ever rising demand for fine aggregate in the construction industry, river sand has been exploited unconditionally in various parts of our country. This has led to various environmental issues. Hence we have to restrict river sand mining, mainly from rivers in which water level is decreasing. As a remedial measure, the government has imposed various restrictions on the extraction, but all of these leads to instability of the construction industry.

The research reported here is on offshore sand, which is considered the most viable alternatives to river sand, with respect to availability, ease of extraction, environmental impact and cost. The offshore sand for this research work was obtained from the coastal areas of Cochin. The offshore sand was dredged to increase the sea bed depth of the Cochin port for the accessibility of mother ships. Nearly 21 million cubic meters of offshore sand should be dredged from Cochin port every year. The offshore sand obtained for this project work was subjected to rain and atmospheric conditions for a year.

Many countries like Sri Lanka, China and America are following the practice of using off shore sand as fine aggregate for different concrete works. The studies shows that offshore sand collected from 2 to 7 km away from the Western coast of Sri Lanka, soon after dredging can be used as an alternative to river sand [1]. Experiments conducted on offshore sand collected from European and American coasts shows that this material can be used for construction of base and sub base pavements [2],[5],[6]. Materials collected from marine deposits at coasts of Great Britain are already used for concrete production for a long time [3]. In China, sea sand is used in local concrete works due to convenience and lower costs [4]. After sieve analysis marine Sand samples shows that the sediments consist of more than 98% of sand content [7].

II. MATERIALS, METHODOLOGY AND EXPERIMENTS

2.1 Materials used

The offshore sand for this research work was collected from Cochin sea port, in Kerala, which was dredged from the sea bed around 2 Km from the shore. The cement used for making concrete was ordinary Portland cement of grade 53. The river sand and course aggregate was collected from Coimbatore. The size of course aggregate used for making test specimens was 20 mm. The mix designs for M20, M25and M30 grades were calculated using IS 10262- 2009 specifications. For M20 grade the mix proportion used was 1:1.74:3.37 and water cement ratio was 0.55.For M25 grade the mix proportion used was 1:1.56:3.02 and water cement ratio was 0.50and for M30 grade the mix proportion used was 1:1.37:2.65and water cement ratio was 0.45.

2.2 Sieve analysis

In order to determine grading pattern of offshore sand, the sieving of sand was done by using sieve shaker and the particle size distribution curve was drawn according to Indian standards 383-1970 specification. The sieves used were10mm, 4.75mm, 2.36mm, 1.18mm, 600 micron, 300 micron and150micron.

Table 1 Standard values for different zones for fine aggregate

IS Sieve size in mm	Percentage passing for			
	Zone I	Zone II	Zone III	Zone IV
10	100	100	100	100
4.75	90-100	90-100	90-100	95-100
2.36	60-95	75-100	85-100	95-100
1.18	30-70	55-90	75-100	90-100
0.60	15-34	35-59	60-79	80-100
0.30	5-20	8-30	12-40	15-50
0.15	0-10	0-10	0-10	0-15

2.3 Compressive strength

The concrete specimens of grade M20, M25and M30 were made. The cube moulds of size 150 x 150 x 150mm were filled and tamped 25 times using tamping rod at three different layers and it was cured for 28 days. The Concrete cylinders of size 150mm diameter and 300mm height were cast as same and were also cured for 28 days. The cubes and cylinders were tested in Universal Testing Machine by applying axial load to get the compressive strength.

2.4 Flexural strength

The different concrete mixes like M20, M25andM30 were made and filled inside the mould of size 100 x 100 x 500mm and these were cured for 28 days. The beams were tested for flexure strength in the Universal testing machine using the two point loading method.

2.5 Rapid chloride penetration test

The concrete specimens were made using standard moulds of 100mm diameter and 50 mm height. The specimens were placed inside the vacuum desiccators for removing the air content inside the pores of the concrete sample and then the desiccator is filled with water till the specimen got submerged. The specimens were then fixed inside the diffuser cell consisting of two chambers. The first chamber was filled with sodium chloride solution and the other was filled with sodium hydroxide solution. The diffuser cells were connected to electric current of 60V. The readings were taken at an interval of 30 minutes for 6 hours.

Average current (I) flowing through one cell is calculated by the formulae,

$$I = 900 \times (I_0 + I_{360}) \times 2\,(I_{cummulative})$$

$$I_{cummulative} = I_{30} + I_{60} + I_{90} + I_{120} + I_{150} + I_{180} + I_{210} + I_{240} + I_{270} + I_{300} + I_{330}$$

Where, I: average current passing, I_0, I_{30}, I_{60} ,….: are current passing at Particular intervels at 0,30,60,…. in minutes.

2.6 Water absorption

Concrete cubes of size 100x100x100mm were cast and oven dried at 100ºC for 24 hours and then dry weight was taken. The specimens were then immersed in water for 24hours and its wet weight was taken.
Then the percentage water absorption can be calculated by the formulae

$$\%\ water\ absorption = \left(\frac{wet\ weight - dry\ weight}{dryweight} \right) \times 100$$

2.7 Alkalinity test

From the concrete specimens the coarse aggregate was removed and a part of the mortar was taken. The mortar was ground by compaction and sieved through the 150 micron sieve. 10 grams of the material passing through the above sieve was taken and mixed with the 50 ml of distilled water in a glass beaker. The water in the beaker was stirred well and the particles were allowed to settle down for 24 hours. Then the clear water was tested for alkalinity using pH meter.

2.8 Method adopted for improving the quality of off shore sand

The off shore sand was found to contain about 40% of particles of size less than 300 microns. These finer particles are undesirable for use in concrete and it causes poor grade zone. Hence the particles less than 300 microns were removed from the offshore sand, and 10%, 20% and 30% of river sand passing through 300 microns were mixed with the off shore sand there by improving the grading properties of the offshore sand.

III. RESULTS AND DISCUSSIONS

3.1 Grading of offshore sand

The graphs were drawn between %finer of sand and sieve size to study the grading of fine aggregate. Fig.1 shows the curves of off shore sand with Indian standard curves for zone III and zone IV for a comparative study. From the graph it was found that the curve for off shore sand deviate much from the limits specified by the curves obtained for Indian standards 383-1970 specifications in the sieve size less than 300 microns. The grading of offshore sand was found to be closer to zone IV thus making it unsuitable for construction purposes.

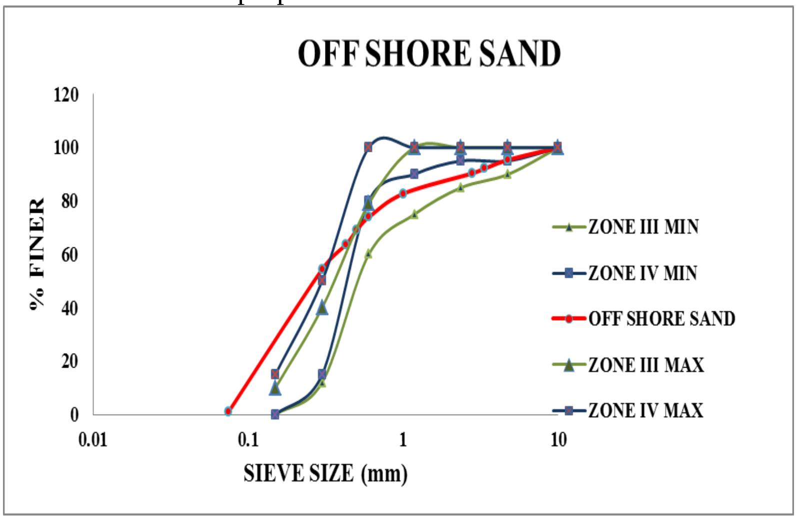


Fig. 1 Particle size distribution curve for off shore sand.

3.2 Grading of river sand

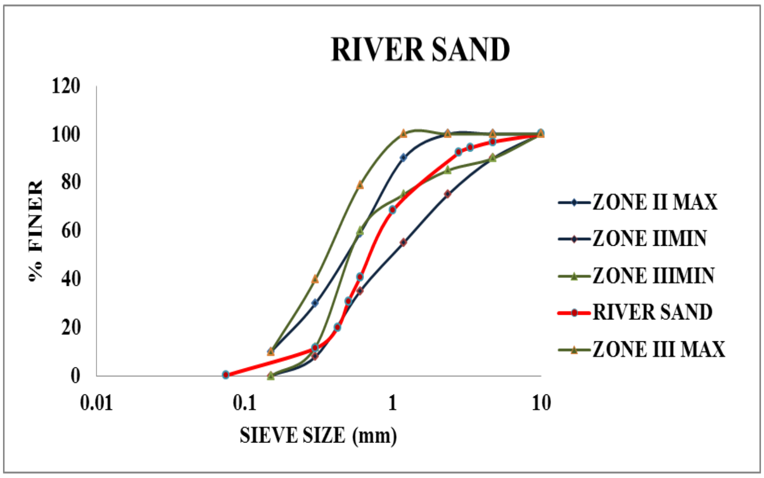
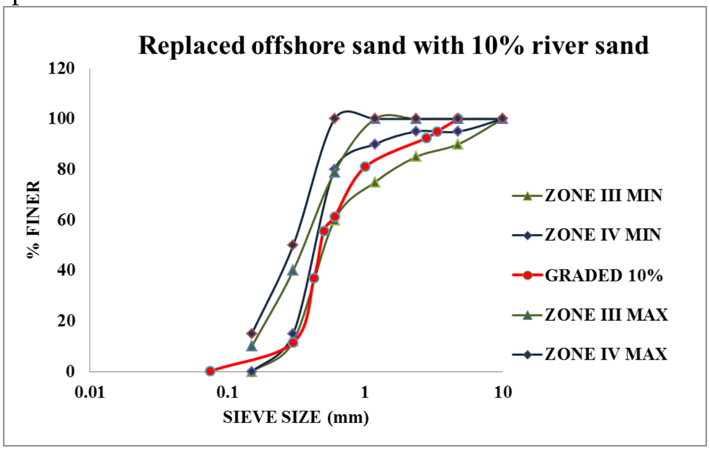


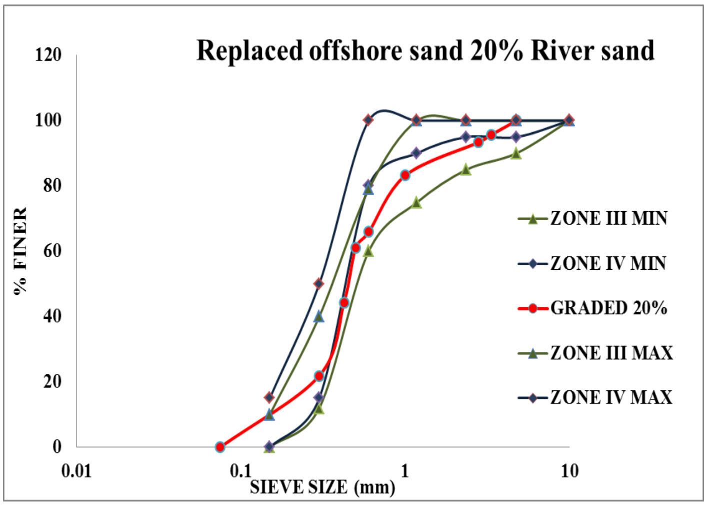
Fig. 2 Particle size distribution curve for river sand.

3.3 Partial Replacement of Offshore Sand with River Sand

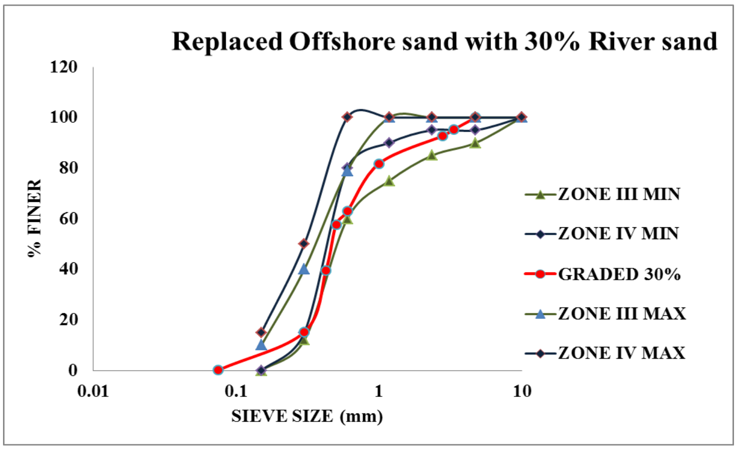
The offshore sand retained up to 300 microns was mixed with the river sand passing through the 300 micron sieve in proportions of 10%,20% and 30% and again sieve analysis were carried out to compare the new compositions of sands.



(a)



(b)



(c)

Fig. 3 Particle size distribution curve for gap graded sand (10%, 20%, and 30%)

After partial replacement of offshore sand with river sand the particle size distribution curves in **Fig. 3** (a), (b) and (c) were found to be within the Zone III as prescribed in the Indian standards.

3.4 Compressive strength

The compressive strength of the different samples was determined by conducting tests on universal testing machine. **Table 2** shows the results for compressive strength of cube and cylinder specimens.

Table 2: 28 days compressive strength of cubes and cylinders

Specimen	Mix	28 days compressive strength in N/mm^2 for	
		Cube	Cylinder
River sand	M 20	23.54	17.60
River sand	M 25	29.20	24.21
River sand	M 30	39.12	30.29
Offshore sand	M 20	14.31	10.87
Offshore sand	M 25	14.76	12.84
Offshore sand	M 30	18.89	17.10
Offshore and 10% river sand	M 20	21.71	18.32
Offshore and 10% river sand	M 25	26.87	23.13
Offshore and 10% river sand	M 30	34.18	28.21
Offshore and 20% river sand	M 20	22.21	16.41
Offshore and 20% river sand	M 25	27.58	21.52
Offshore and 20% river sand	M 30	34.38	26.60
Offshore and 30% river sand	M 20	25.43	20.44
Offshore and 30% river sand	M 25	30.23	23.54
Offshore and 30% river sand	M 30	39.34	32.46

From the results it was found that the graded sand with 30% replacement of river sand with off shore sand has shown higher value of compressive strength. In this attempt more than 30 % replacement was not made. Hence the optimum replacement could not be established. The maximum increase in percentage of compressive strength was found to be 77.7% in M20 grade concrete, 104.8% in M25 grade concrete and 108.26% in M30 grade concrete. Therefore the off shore sand can be effectively utilized in concrete with the partial replacement of river sand up to 30%. In case of cylinder also it was found that the graded sand with 30% replacement of river sand shows higher value of compressive strength.

3.5 Flexural Strength

The flexural strength of different samples was determined by conducting two point loading test. The **Table 3** shows the flexural strength of the different samples.

Table 3 Flexural Strength after 28 days

Mix	28 days flexural strength in N/mm^2 for				
	River sand	Offshore sand	Graded sand 10%	Graded sand 20%	Graded sand 30%
M 20	4.21	3.53	3.82	3.73	4.66
M 25	4.43	3.60	4.16	3.82	4.81
M 30	5.12	3.67	4.51	3.92	4.91

Flexural strength of graded sand with 30% river sand was found to be more nearer to the flexural strength of the river sand.

3.6 Rapid Chloride Penetration Test (R.C.P.T.)

The average current passed through various concrete samples was calculated using rapid chloride penetration testing equipment.

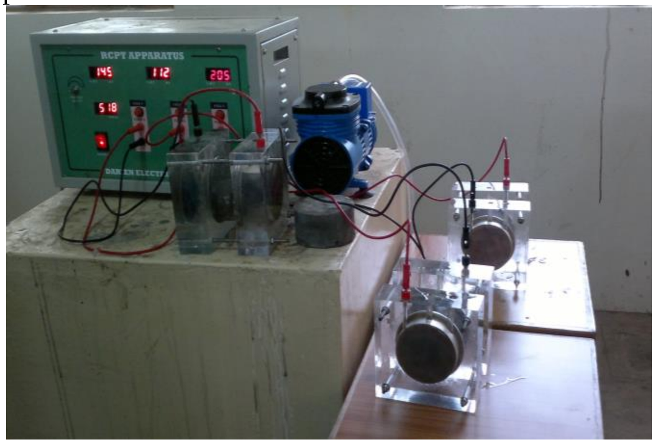


Fig. 4 Rapid chloride penetration testing arrangement.

The test results of different samples are shown in **Table 4**.

Table 4 R. C. P. T. result after 28 days

Mix	Average current passing in Coulombs for				
	River sand	Off shore sand	Graded with 10% river sand	Graded with 20% river sand	Graded with 30% river sand
M 20	989	1998	1219	1202	1250
M 25	1024	2314	1374	1365	1423
M 30	1058	2630	1534	1529	1583

The Average current flowing through the conventional concrete specimen was at the range of 1000 to 4000 as per ASTM C 1202. From the above experimental results it was found that all the specimens satisfy the ASTM requirements. Hence the chloride penetration properties of concrete made with offshore sand are well within the limits.

3.7 Water absorption

The percentage of water absorbed by various specimens was determined and the results are shown in Table 4.

Table 5 Water absorption result after 28 days

Mix	Water absorption in % for concrete made with				
	River sand	Offshore sand	Graded with 10% river sand	Graded with 20% river sand	Graded with 30% river sand
M 20	4.52	5.41	3.51	3.18	4.09
M 25	3.83	4.50	3.48	3.14	4.01
M 30	3.52	3.69	3.47	3.12	3.96

The water absorption of concrete should not be greater than 5% as per ASTM C 140 standards. The water absorption in concrete made with river sand and graded sand are found to be well within the ASTM limits. In the case of offshore sand for the lower grade of concrete (That is for M 20 grade of concrete) the water absorption value was found to be higher. For M25 and M30 grade of concrete the water absorption value was found to decrease when offshore sand was used for concrete.

3.8 Alkalinity test

The alkalinity of different samples was calculated. Table 5 shows the alkalinity test result of concrete samples after 28 days of curing. The alkalinity of concrete must be within the range of 9 to 12 as per ASTM D 4262.

Table 6 Alkalinity test result after 28 days

Mix	Alkalinity in pH for concrete made with				
	River sand	Offshore sand	Graded with 10% river sand	Graded with 20% river sand	Graded with 30% river sand
M 20	11.51	11.36	11.78	11.41	11.46
M 25	11.46	11.37	11.71	11.42	11.43
M 30	11.38	11.35	11.67	11.38	11.42

The alkalinity values of all samples satisfy the ASTM limits.

IV. ANALYSIS OF TEST RESULTS

4.1. Percentage of water absorption and compressive strength

Based on the test results, for offshore sand replaced with river sand by 10,20 and 30% an equation was obtain to show the variation of % of water absorption with respect to the cube compressive strength. The equation is

$$\%\ water\ absorption = -56 \times 10^{-4} f_{ck} + 3.72$$

On substituting the experimental value of cube compressive strength (fck), to determine the % water absorption in the above equation it was found that the theoretical and experimental values were found to be agree with each other.

At the same way for offshore sand replace with river sand by 10,20and 30% an equation was obtain to show the variation of % of water absorption with respect to the cylinder compressive strength. The equation is

$$\%\ water\ absorption = -65 \times 10^{-4} f_{ck} + 3.70$$

On substituting the experimental value of cylinder compressive strength (fck), to determine the % water absorption in the above equation it was also found that the theoretical and experimental values were agree with each other.

V. CONCLUSION

(1) Partial replacement of offshore sand with river sand improved the grade of aggregate for use in concrete.

(2) The compressive strength of concrete specimens made with offshore sand was very less compared to river sand. The strength of concrete made with 30% graded sand was found to be nearer to the strength of concrete made with the river sand.
(3) The flexural strength of concrete made with offshore sand was very less compared to the concrete made with the river sand. The flexural strength of concrete made with 30% graded sand was found to be nearer to the flexural strength of concrete made with river sand.
(4) The R.C.P.T. results had shown the average current passing through the off shore sand was within the range specified by ASTM for conventional concrete. Hence the possibility for corrosion is less.
(5) The percentage of water absorption for concrete made with off shore sand was high and the concrete made with 30% graded sand shows less water absorption compared with concrete specimens made with 10% and 20% graded sand.
(6) The alkalinity of all the specimens was within the permissible limits. Hence the possibility of corrosion is less.

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