AN EXPERIMENTAL STUDY ON OFFSHORE SAND WITH PARTIAL REPLACEMENT OF RIVER SAND IN CONCRETE

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Abstract - *In the construction industry, Concrete is the popular and most wanted building material in the world. River sand has been the most popular choice for the fine aggregate in the concrete. Now, the scarcity of river sand leads to found the alternate material. Over usage of the river sand has led to environmental concerns, depleting of securable river sand deposits and adorable price increase of the material. Therefore, it is desirable to obtain cheap, environmentally friendly substitute for river sand that is preferably offshore sand. The Land Reclamation & Development Board plans to popularize the use of offshore sand as an alternate to river sand. This study has made an attempt to partially replace the offshore sand in place of river sand. The River sand passing through 300 microns were mixed in proportion of 10%, 20%, 30% with offshore sand separately there offshore sand was graded with River sand as partial replacement to enhance the properties of fine aggregate in concrete. The study revealed that offshore sand can be used as an alternative to River sand, which is considered the most viable off all alternatives, in terms of availability, ease of extraction, environmental impact and cost.*

Key Words: Concrete, Offshore sand, River sand, Fine aggregate.

1. INTRODUCTION

River sand is becoming very scares and sand mining from rivers has become objectionably excessive. It is exhausting very fast and the government has put ban on lifting sand from river beds. In order to restrict river sand mining, it is necessary to introduce alternatives to river sand if we have to carry on with the construction industry smoothly for the years to come. It should be noted that offshore sand extracted from below around 15 m of ocean depth would not affect the coastal sediment budget. Harvesting of beach sand is clearly unacceptable, not only because it would directly contribute to coastal erosion, but also because the aggregate may have high chloride contents due to repeated wetting and drying cycles. The offshore sand for the research work was obtained from the coastal areas of Pondicherry. As river sand also is a commodity in demand it was attempted to use as partial replacement with offshore sand for enhancing its property for making a good concrete.

1.1 Offshore sand in construction industry

The mining of sand in the rivers for construction purposes has been identified for many years as a major environmental, social and economic problem. In order to restrict river sand mining, it is necessary to introduce some alternatives for river sand to meet the demand. There are river sand alternatives such as offshore sand, dune sand, quarry dust and pit sand. Some of these such as dune sand and quarry dust are already in use but they do not satisfy existing depressed demand. Offshore sand has been identified as one of the cheapest forms of fine aggregates. However, the presence of such impurities as salts and shells made see dredged sand less popular in construction use. Well drained sea aggregates could be used in reinforced concrete without washing by fresh water. However if it is required to control the chlorides contents to very low levels offshore sand could be washed after pumping to the shore. This washing will lead to additional costs. Therefore the cost and prices of offshore sand without washing and with washing are presented separately.

1.2 Objectives of the project

- To review the literature on using offshore sand in construction, focusing especially on the use of lower grade concretes in warm climates, with particular reference to the effect of chlorides on reinforced concrete.
- To measure the relevant properties of offshore sand, namely grading, shell content and chloride content, examining also the effects of draining and simulated rain on the chloride content.
- To study the corrosion properties of reinforced cement concrete containing offshore sand with various chloride contents, using corrosion testing.

2. PREVIOUS STUDY

J. Limeira, L. Agullo, M. Etxeberria, 3rd December 2009 - The aim of this work is to find the suitability of dredged marine sand by an experimental section of a harbor a pavement. The influence of dredged marine sand from port of SantCarles de la Rapita as a fine aggregate on the production of concrete was analyzed. Describes three experimental sections of a harbor pavement made with three different concretes.

C1: control concrete,
C2: concrete made with DMS as corrective fine sand,
C3: concrete made with DMS as corrective fine sand & reinforced with plastic fibers. Concrete harbor pavements produced with DMS obtained adequate properties according to water penetration depth under pressure.

A. R. Dolage, M. G. S. Dias and C. T. Ariyawansa, 4th May 2010 - The aim of this study is to test the relevant properties of offshore sand obtained soon after dredging and to examine the effects on chloride levels of offshore sand when fresh water is drained to simulate average monthly rainfalls. The findings are valid for offshore sand that does not require washing particularly to remove organic matter and other contaminants. As per the results of sieve analysis, grading of the offshore sand is within the limits specified in BS 882:1992. The compressive strength of grade 25 concrete which is the mostly used structural concrete is also within the acceptable limits.

J. Limeira, M. Etxeberria, L. Agullo, D. Molina, 19th April 2014 - The process of depletion of sources of natural aggregates challenges the production of technically and environmentally adequate concrete. Alternative material from marine sources, especially for concrete maritime structures, could represent an acceptable solution for this problem and it might also be of great interest for port management. They concluded that dredged marine sand can be successfully used as a fine aggregate for concrete production. The results indicate a good quality of concretes and, therefore, they verify the appropriate behavior of these materials in the short term in comparison with the reference mixture.

From the above literature it can be seen that many experiments have been conducted to study the suitability of offshore sand as a fine aggregate for concrete production. In most of the experiments offshore and river sand is used together for concrete production. The chloride content in the sand is removed only through natural rain water washing. In this project the chloride content is removed through some chemical process and by artificial washing.

3. TESTING METHODS AND RESULTS

3.1 General

An experimental program was carried out using the samples obtained from port area, Pondicherry. The extracted for the project was extracted from areas 2-7 km offshore of the project and is exposed to rain for more than a year. The test methods are mainly divided into two, a) physical and chemical properties of offshore sand, b) structural properties of offshore sand.

3.2 Grading

Grading is the representation of the particle size in a sample of aggregate. Good grading implies that a sample of aggregate contains all standard fractions in required proportion. For the grading of fine aggregates, the limits were given in table 4 of IS 383-1970.

Table - 1: Grading limits for fine aggregate

IS Sieve	Percentage passing for			
Designation	Grading Zone 1	Grading zone 2	Grading zone 3	Grading zone 4
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	90-100
1.18 mm	30-70	55-90	75-100	90-100
600 microns	15-34	35-59	60-79	80-100
300 microns	5-20	8-30	12-40	15-50
150 microns	0-10	0-10	0-10	0-15

3.2.1 Grading of offshore sand

In order to determine grading pattern of sand the relevant test was conducted. The sieves used were 4.75mm, 3.35mm, 2.80mm, 1.00mm, 600 micron, 500 micron, 425 micron and 75 micron. Table 3.1 displays the displays the result of sieve analysis of the offshore sand sample which weighed 1000 g.

Table - 2 : Grading of offshore sand

Sieve	Aperture	Weight	% of weight	Cumulative %	% of finer
4.75	4.75	0.044	4.40	4.40	95.60
3.35	3.35	0.024	2.40	6.80	93.20
2.80	2.80	0.005	0.50	7.30	92.70
1.00	1.00	0.046	4.60	11.9	88.10
600	0.60	0.079	7.90	19.8	80.20
500	0.50	0.009	0.90	20.7	79.30
425	0.425	0.096	9.60	30.3	69.70
75	0.075	0.688	68.8	99.1	0.90
Pan	pan	0.009	0.90	100	0

3.2.2 Grading of river sand

Grading displays the result of sieve analysis of the river sand sample which weighed 1000 g.

Table – 3: Grading of river sand

Sieve	Aperture	Weight	% of weight	Cumulative %	% of finer
4.75	4.75	0.044	4.40	4.40	95.60
3.35	3.35	0.024	2.40	6.80	93.20
2.80	2.80	0.005	0.50	7.30	92.70
1.00	1.00	0.046	4.60	11.9	88.10
600	0.60	0.079	7.90	19.8	80.20
500	0.50	0.009	0.90	20.7	79.30
425	0.425	0.096	9.60	30.3	69.70
75	0.075	0.688	68.8	99.1	0.90
Pan	Pan	0.009	0.90	100	0

3.3 Determination of chloride

Chlorides are widely distributed as salts of calcium, sodium and potassium in water and wastewater. In potable water, the salty taste produced by chloride concentrations in different and it depend on the chemical composition of water. The major taste producing salts in water are sodium chloride and calcium chloride. The salty taste is due to chloride anions and associated cations in water. In some water which is having only 250mg/L of chlorides may have a detectable salty taste if the cation present in the water is sodium. On the other hand, a typical salty taste may be absent even if the water is having very high chloride concentration for example 1000 mg/L.

Table - 4: Determination of chloride in offshore sand

Sl No	Volume of sample (mL)	Burette Reading (mL)		Volume of AgNO3 (mL)
		Initial	Final	
1	20	0	1.6	1.6
2	20	0	1.6	1.6
Blank	20	0	0.2	0.2

Table - 5: Determination of chloride in river sand

Sl No	Volume of sample (mL)	Burette Reading (mL)		Volume of AgNO3 (mL)
		Initial	Final	
1	20	0	0.5	0.5
2	20	0	0.5	0.5
Blank	20	0	0.2	0.2

3.4 Shell content in offshore sand

The shell content of offshore sand samples was measured separately for the aggregate sizes greater than 5mm and less than 10 mm, as per BS 882: 1992. This was measured from a sample weighing 1000 g. The shell content greater than 5 mm was measured by 'handpicking' method.

Table - 6: Shell content in offshore sand

Grading	Shell content	Limit as a percentage
>5mm	1.1 %	Finer than 10 mm and coarser than 5 mm- 20 %
		Coarser than 10 mm- 8 %
<5mm	1 %	Not recommended

3.5 Determination of specific gravity

Table - 7: Observation of specific gravity

Calculation	Offshore	M sand	River sand
Weight of pycnometer (W1)	0.664	0.664	0.667
Weight of pycnometer + sand (W2)	1.114	1.053	1.128
Weight of pycnometer + sand + water (W3)	1.818	1.792	1.758
Weight of pycnometer + water (W4)	1.542	1.542	1.526
	2.58	2.79	2.65

4. IMPROVING TECHNIQUES

4.1 Method adopted for improving the quality of offshore sand

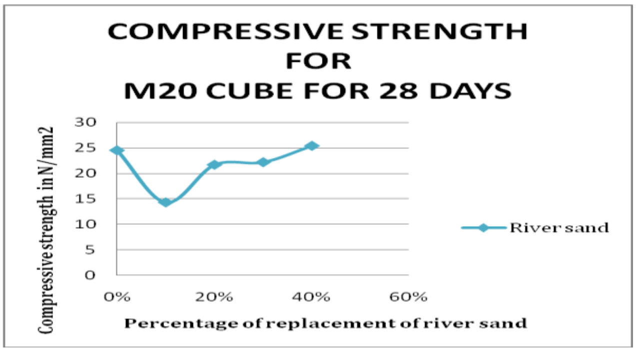
The offshore sand was found to contain about 50% of particles of size less than 300 microns which are the undesirable for the use in concrete. Hence the particles less than 300 microns were removed from the offshore sand. In the place of discarded particles and River sand passing through 300 microns were mixed in proportion of 10%, 20%, 30% with offshore sand separately there offshore sand was graded with River sand as partial replacement to enhance the properties of fine aggregate in concrete.

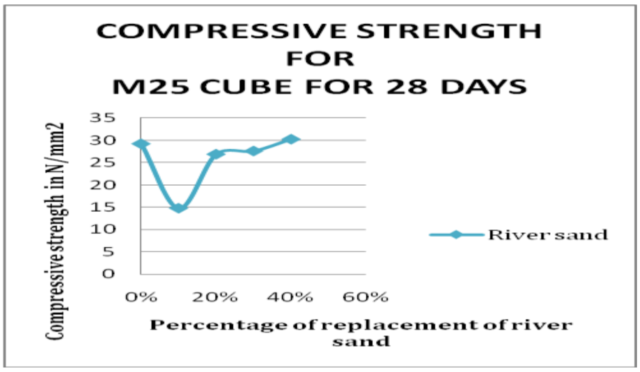
The offshore sand retained up to 300 microns was mixed the River sand passing through the 300 microns sieve separately and again sieve analysis were carried out to compare the new compositions of the sand.

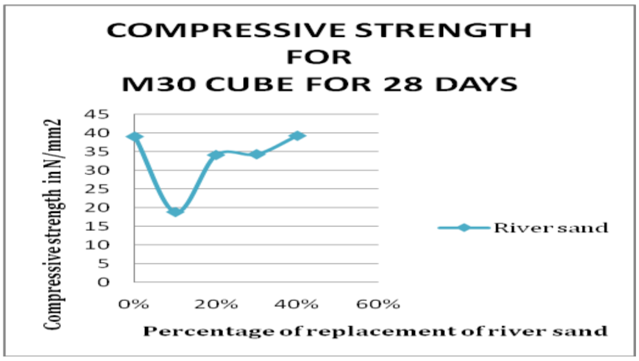
4.2 Compressive strength of concrete

Table - 7: Compressive strength of cube for 28 days

Mix	M20	M25	M30
River Sand	24.54	29.20	39.12
Offshore Sand	14.31	14.76	18.89
10% of River Sand	21.71	26.87	34.18
20% of River Sand	22.21	27.58	34.38
30% of River Sand	25.43	30.23	39.34





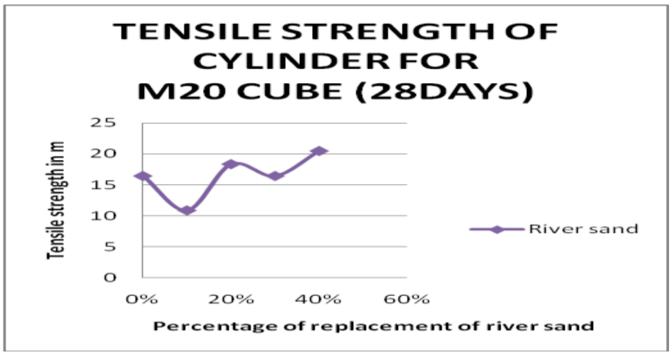


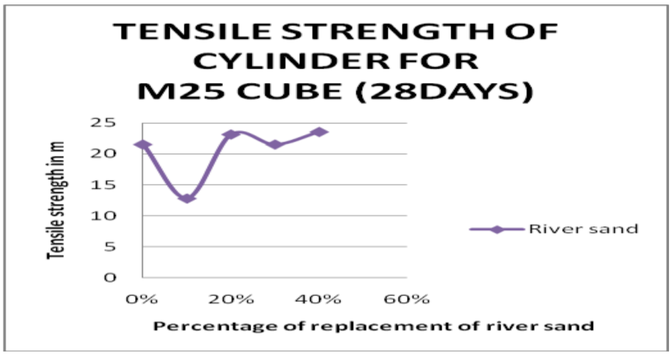
From table it was found that the graded sand replaced with River sand has shown higher value of compressive strength. The maximum increase in percentage of compressive strength was found to be 85.64% for both graded River in M20 concrete, 83.56% for both graded River in M25 grade concrete, 80.87% for both graded River sand in M30 grade concrete. Therefore the offshore sand can be effectively utilized in concrete with partial replacement of River sand.

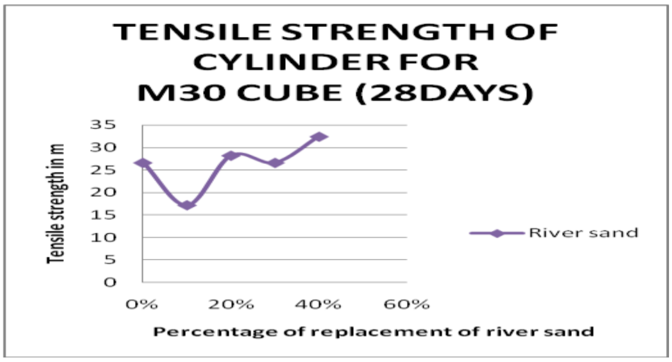
4.3 Split Tensile Test

Table - 8: Split Tensile Test of Cylinder for 28 days

Mix	M20	M25	M30
River Sand	4.52	3.83	3.52
Offshore Sand	5.41	4.5	3.69
10% of River Sand	3.2	3.01	2.83
20% of River Sand	3.46	3.11	2.76
30% of River Sand	1.19	1.11	1.01







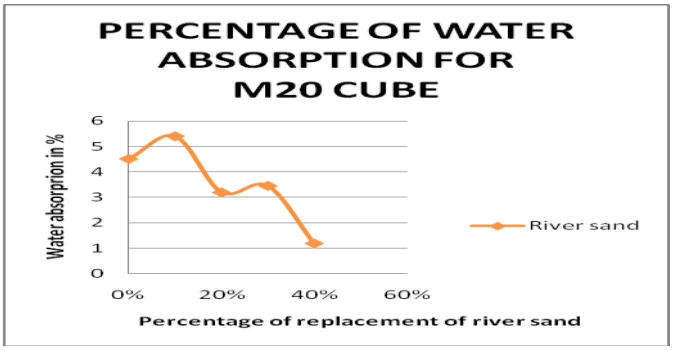
From table 8, it was found that the graded sand replaced with river sand has shown higher value of compressive strength. The maximum increase in percentage of compressive strength was found to be 85.64% for graded River sand in M20 concrete, 83.56% for graded River sand in M25 grade concrete, 80.87% for graded river sand in M30 grade concrete. Therefore the offshore sand can be effectively utilized in concrete with partial replacement of River sand.

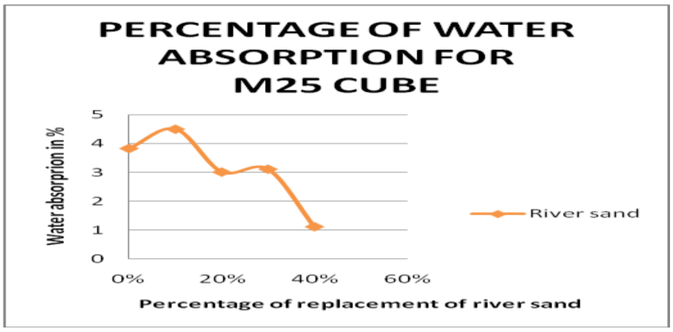
4.4 Water absorption test

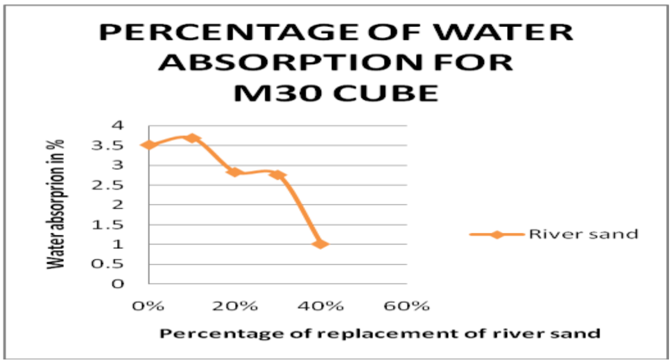
The water absorption of concrete shall not be greater than 5% as per ASTM C 140 standards. The water absorption in concrete made with River sand and graded sand are found to be well within the ASTM limits. In case of offshore sand for the lower grade of concrete (i.e for M20 grade of concrete) the water 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 in concrete.

Table - 9: Percentage of water absorption

Mix	M20	M25	M30
River Sand	16.41	21.52	26.6
Offshore Sand	10.87	12.84	17.1
10% of River Sand	18.32	23.13	28.21
20% of River Sand	16.41	21.52	26.6
30% of River Sand	20.44	23.54	32.46







5. ANALYSIS OF TEST RESULTS

5.1 Percentage water absorption and cube compressive strength

The test results for offshore sand replaced with river sand by 10%, 20%, 30% an equation was obtained to show variation of percentage of water absorption with respect to cube compressive strength. The equation is Percentage of water absorption

$$= - 0.25\ln(f_{ck}) + 5.06$$

On substituting the experimental values of cube compressive strength (fck) to determine the percentage water absorption using the above equation it was found that that both the theoretical and experimental values were found to agree with each other.

Percentage of water absorption = $- 0.25\ln((f_{ck}) + 5.06$

Table -10: Experimental Vs Theoretical Results for Percentage of water absorption

	Experimental results			Theoretical results		
Mix	10% of R Sand	20% of R Sand	30% of R Sand	10% of R Sand	20% of R Sand	30% of R Sand
M20	3.2	3.46	1.19	3.34	3.2	1.45
M25	3.01	3.11	1.11	3.12	3.08	1.34
M30	2.83	2.76	1.01	2.98	2.94	1.23

5.2 Tensile strength & compressive strength

Based on the test results for offshore sand replaced with River sand by 10, 20, 30% an equation was obtained to show different values of the flexural strength with respect to cube compressive strength. The equation is

Flexural strength = $f_{cr} = \sqrt{(f_{ck})}$

On substituting the experimental value of cube compressive strength (f_{ck}) to determine the flexural strength using the above equation it was found that that both the theoretical and experimental values were found to agree with each other.

Table -11: Experimental Vs Theoretical Results for Percentage of water absorption

	Experimental reslts			Theoretical results		
Mix	10% of R Sand	20% of R Sand	30% of R Sand	10% of R Sand	20% of R Sand	30% of R Sand
M20	3.82	4.16	4.51	3.26	3.62	4.09
M25	3.72	3.82	3.92	3.29	3.67	4.10
M30	4.66	4.81	5.05	3.52	3.84	4.39

6. CONCLUSIONS

By partial replacement of offshore sand and River sand the grade of the offshore sand was improved. The chloride content in offshore sand was 0.014% by weight which is marginally higher than limits specified by BS 882:1992 which may be ignored. The shell content in the offshore sand are finer than 5mm and coarser than 10 mm is 1.1% which is less than the limits specified by BS 882:1992.The characteristic compressive strength of offshore sand was very less compared to River sand. The strength of offshore sand was improved by the partial replacement with River sand. The tensile strength of concrete made with offshore sand was very less compared to the concrete made with river sand. The tensile strength of concrete made with 30% graded sand was found to be nearer the flexural strength of concrete made with River sand. The percentage of water absorption for concrete made with offshore sand was high. The concrete made with 20% graded sand shows less water absorption compared with 10% and 30% graded sand. The study revealed that offshore sand can be used as an alternative to River sand, which is considered the most viable off all alternatives, in terms of availability, ease of extraction, environmental impact and cost.

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