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Alternatives for River Sand

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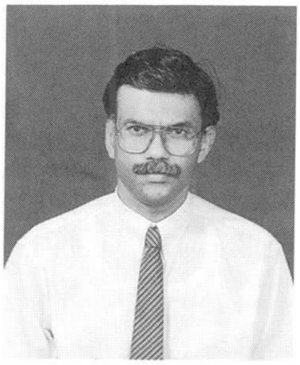

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Summary

Offshore sand, dune sand and land based sand have been identified as alternatives for river sand. Experimental investigations have been carried out to find their physical and chemical properties and properties of concrete made with these alternatives. It was found that all the offshore sand samples tested comply with the chloride limitation for normal reinforced concrete with OPC. However, it does not comply with that for prestressed concrete. In addition, it was found that chloride content of dune sand is extremely low and can be used for concrete without washing. The compressive strength results show that the concrete made with all three alternatives is as good as the concrete made with river sand.

1. Introduction

River sand is the most widely used fine aggregate in Sri Lanka. The average annual demand for sand is around 5 million cu.m and by the year 2000, the demand would be 9.6 million cu.m[1]. Due to large scale and uncontrolled river sand mining, there are environmental problems such as riverbank collapses, salt-water intrusion and coastal erosion. Because of these environmental problems, there is a necessity to reduce river sand mining especially at harmful locations. In order to restrict river sand mining, it is necessary to introduce some alternatives for river sand to meet the demand for sand. A few river sand alternatives such as offshore sand, dune sand, quarry dust and land based sand have been identified and some of these are already in use for various purposes. Out of the four identified alternatives, the quarry dust is widely used as a partial replacement of sands in concrete and other various applications. The properties of quarry dust and its performance are known to a greater extent. However, the other three alternatives are less known in Sri Lanka as alternatives for river sand specially for concrete. Therefore the experimental investigation is mainly focused on properties of offshore sand; dune sand and land based sand and their suitability for concrete.

2. Experimental Investigation

The physical properties of sand such as specific gravity, particle shape, particle size distribution, fine dust content were determined based on relevant British Standards[2]. The following tests were also carried out, based on relevant British Standards.

1. *Shell content*: BS 812:Part 106:1985 [3] describes the method for determining the shell content in coarse aggregate. This method was adopted for shells greater than 5 mm. Shell content in fine aggregate was determined by modifying the method given in the literature by Chapmen et al[4]. In this method, a representative oven dry sample of about 50 g is accurately weighed and standard hydrochloric acid solution is added to dissolve shells (calcium carbonate). Addition of hydrochloric acid is continued until there is no further reaction. The residue of the sand sample is carefully washed and the oven dried weight is obtained. The percentage loss of weight of the sample indicates approximately the shell content in the sample.
2. *Salt contamination (water soluble chlorides)* : Chloride content was measured using a method for determination of chloride content in drinking water [5]. In the case of offshore samples, a wet sample was used after draining the excess water under gravity to obtain the highest possible chloride content. About 500 g of the sample was weighed and placed in a bottle; 500 ml of distilled water was added and the sample was agitated in a shaker for 24 hrs. The filtrate was tested to determine the chlorides in the sand sample.
3. *Compressive strength of concrete*: Since the main objective of the investigation is to find out the suitability of the selected alternatives for concrete, properties of concrete made with offshore sand, dune sand and land based sand were obtained. The standard mix proportion for grade 20 concrete given in ICTAD specifications[6] was used in this test. The slump and compressive strength at 7 days and 28 days were obtained.

3. Sand Samples

3.1 Offshore sand

As an island surrounded by the sea, Sri Lanka has access for considerable amounts of offshore sand deposits, existing mainly in the continental shelf area. In Sri Lanka, offshore sand has been used in beach nourishment and land filling work. Offshore sand samples were collected from locations in the western reaches of the continental shelf close to Ratmalana, Wadduwa and Negombo. These locations are about 1 km to 6 km from the shoreline and at a depth of about 14 m. Some samples were collected from Muthurajawela area since offshore sea sand was used to fill that area.

3.2 Dune sand

In Sri Lanka, dunes exist along the north-west coast between Chilaw and Kalpitiya, across Mannar island and the Pooneryn peninsula, along the north-east coast between Pulmoddai and Point Pedro and in the south-east coast from east of Ambalantota to Timitar[7]. Six dune sand samples were collected from Puttalam and Chilaw Districts.

3.3 Land based sand

Soil samples were collected from the Kosgama, Puwakpitiya, Bulathsinhala and Horana areas. Sand was extracted from these soil samples by washing manually. A steel wire mesh of 0.3 mm was used to extract sand from the soil in case of soil from Kosgama and Puwakpitiya and washed water was allowed to settle in order to obtain the clay. Sand extracted from these two soil samples were tested to obtain physical and chemical properties as well as the properties of concrete made with those sands. Sand from other soil samples was extracted using a 0.075 mm square mesh and only the composition of soil and particle size distribution of sand were obtained.

4. Test Results

4.1. Specific gravity and particle shape

Table 1 gives the specific gravity of the offshore sand, dune sand and land based sand samples tested. It can be seen that the specific gravity of dune sand is higher than that of the offshore sand and land based sand because dune sands are composed of quartz grain with a relatively high proportion of heavy minerals[7]. The water absorption is fairly low except for one land based sample. Although there is no clear-cut relation between the strength of concrete and the water absorption of aggregate used, the pores at the surface of the particle affect the bond between aggregate and the cement paste, and may thus exert some influence on the strength. And also it can be seen from the results given in Table 1 that the clay, silt and dust content(i.e. amount of materials passing through 75μm sieve) of offshore sand as well as dune sand is less than 3%, which is the limit given in BS 882 [8] for clay, silt and dust content in sand. Clay, silt and dust content of land based sand samples depends on the efficiency of washing. Since thorough washing was carried out, clay, silt and dust content in washed land based sand is very low.

Table 1 - Physical properties of river sand alternatives

Sample		Specific gravity (SSD)	Water absorption (%)	Clay, silt and dust content(%)	Particle shape
Offshore sand	Muturajawela	2.68	0.30	-	Rounded Irregular
	Ratmalana	2.75	0.20	0.42	
	Wadduwa	2.66	0.14	0.47	
	Negombo	2.71	0.10	0.39	
Dune Sand	Daluwa	2.78	0.23	0.3	Irregular
	Sinnapadu	2.89	0.29	0.64	
	Chilaw	2.78	0.32	0.9	
Land based sand	Kosgama	2.68	0.78	1.6	Angular
	Puwakpitiya	2.67	0.12	0.07	

4.2. Sieve Analysis

Figures 1, 2 and 3 show the grading curves for the offshore, dune and land based sand samples tested respectively. It can be seen that most of the samples fall into the overall limits specified in BS 882 [8]. It can be noted that particle size distribution of offshore sand samples vary from the coarser zone C to the finer zone F, whereas all dune sand samples fall into finer zone F. The particle size distribution of land based sand is in the coarse zone C and there is a deficiency in very fine particles in the samples from Puwakpitiya and Kosgama. This is because of the use of a coarse mesh (0.3 mm) in the separation of sand from these two soil samples. Since large

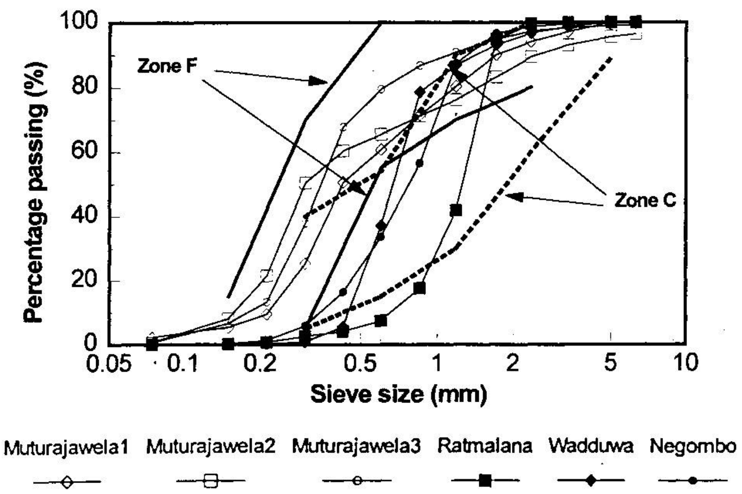

Fig.1 Particle size distribution of offshore sand

quantities of sand were needed for other tests such as strength properties of concrete, a coarser mesh was used to separate sand. The use of a finer mesh like a 0.075 mm square mesh is not practical in large scale washing because it is a time consuming process to separate very fine particles from clay manually. And also it was found that most of the soil samples contain sand around 50% (by wt) (i.e. particles less than 5 mm) and also a fairly high percentage of clay (i.e. about 40% by wt. of soil). However, it is important to note that grading alone is not a governing factor to reject aggregates as blending and/or adjustment of the coarse to fine aggregate ratio are possible remedies.

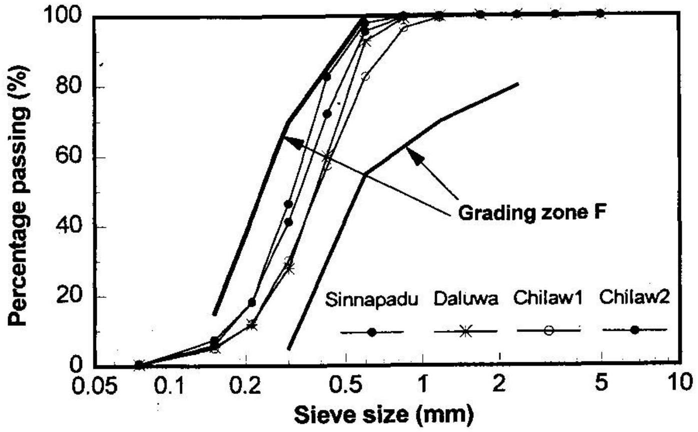

Fig.2 Particle size distribution of Dune sand

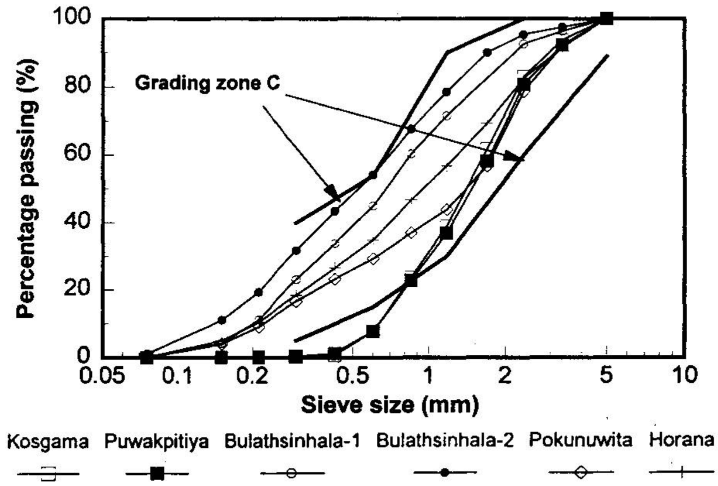

Fig.3 Particle size distribution of Land based sand

4.3. Shell Content

The shells larger than 5 mm was found to be in the range of 0.6% to 5.3% for offshore sand samples. The shell content of the fraction less than 5 mm was found to be in the range of 6.5% to 39.0%. There were no shells in the dune sand. The BS 882[8] gives no limits for shells in sand, but limits shell content to 20% by weight in 10-5 mm aggregate and to 8% by weight in sizes above 10 mm. The presence of a large shell content has no adverse effect on strength but workability of concrete made with aggregates having large shell contents is slightly reduced[9].

4.4. Chloride Content

The chloride content of offshore sand and dune sand is given in Table 2. The samples taken from Muthurajawela show very low chloride content because that sand was exposed to rain for over a year and salt must have been washed away. Similarly dune sand also shows very low chloride content because these dune sands have got accumulated over very long periods and salt deposits on the sand must have been washed away by rain water.

Table 2 - Chloride content in offshore sand and dune sand

	Offshore sand			(Offshore sand)		Dune sand		
	Wadduwa	Ratmalana	Negombo	Mutu-1	Mutu-2	Daluwa	Sinnapadu	Chilaw
Chloride Content(%)	0.14	0.13	0.14	0.001	0.001	0.0004	0.0005	0.0009

Mutu – Muthurajawela

Table 3 - Limits for chloride ion in British Standards

Type of concrete	Mandatory limit for concrete to comply with BS8110:1985- Table 6.4 (wt % of cement)	Guidance limit for aggregate* in BS 882:1983 Table 8 Appendix C (wt % of aggregate)
Prestressed concrete	0.1	0.02
Concrete with SRPC	0.2	0.04
Concrete with OPC	0.4	0.06

* The combined aggregates, i.e., coarse and fine aggregate combined in the proportion to be used in concrete.

Table 4 - Equivalent values of chloride content limits

Grade	Mix proportion (kg/m^3)			Maximum total chloride content in concrete expressed as a % of Cl$^-$ by *mass of sand*		
	C	S	G	Prestressed concrete	Concrete with SRPC	Concrete with OPC
20	350	788	962	-	0.066	0.155
25	390	765	935	-	0.076	0.178
30	430	743	908	0.029	0.087	0.202

C – Cement, S – Sand, G – Coarse agg.

BS 8110 [10] and BS 882 [8] specify the limits for total chloride ion content in concrete and aggregate respectively as given in Table 3. The limits on the chloride content of aggregates given in BS 882 are for guidance only, since they assume that only aggregates contribute to the chloride content of the concrete. In practice, however, cement and admixtures contain small amounts of chloride and allowance may need to be made for this by a corresponding reduction in the permissible levels of chloride in aggregates. Table 4 shows the above limits (i.e. BS 8110 limits) converted to equivalent values expressed as a percentage of chloride ions by mass of fine aggregate, based on the prescribed mixes for ordinary structural concrete given in ICTAD specifications for Building works[6]. When calculating the maximum chloride content in Table 4 , it is assumed that chloride ions are contributed by fine aggregate and cement only. In addition, the chloride content of cement is assumed to be at the maximum of the typical range of 0.01~ 0.05% for OPC[11]. From Table 4, it can be noted that all the offshore sand samples tested comply with the requirement for normal reinforced concrete with OPC. However, it does not comply with that for prestressed concrete. In any case, it is better to wash offshore sand, but it is not necessary to do so in the case of dune sand.

4.5 Compressive Strength of Concrete

Table 5 - Properties of concrete made with various types of sand

Sample		Workability	Compressive strength(N/mm^2)	
		Slump(mm)	7 day	28 day
River sand		20	19.5	28.2
Offshore sand	Ratmalana	collapse	19.4	25.8
	Negombo	10	18.4	24.1
	Muturajawela	20	17.6	26.0
Dune sand		25	20.3	29.8
Land based sand	Puwakpitiya	0	16.9	27.4
	Kosgama	3	15.7	26.0

Table 5 shows the workability and the 7 day and 28 day compressive strength of a standard 1:2:4 concrete mix (quantities per cubic meter of concrete: cement – 320 kg, sand – 0.44 m^3 , coarse agg. – 0.88 m^3 , w/c – 0.55)[6] with river sand, offshore sand, dune sand and land based sand. It can be seen from the results that the compressive strength of concrete made with all the alternatives for river sand is as good as the strength of concrete made with river sand. Furthermore, concrete with dune sand gave the highest strength as well as workability. However, all mixes, including the mix with river sand, displayed generally low workability. The mixes with land based sand gave zero slump, which may be due to a deficiency in fine particles or due to the angularity of particles.

5. Conclusions

It was found that all offshore sand samples tested comply with chloride limitation for normal reinforced concrete with OPC. However, it does not comply with that for prestressed concrete. Grading of offshore sand varies from fine to coarse. Offshore sand can be used even without washing for production of concrete with OPC for normal RC structures. After washing, it can be used even for prestressed concrete because washing will lower the chloride content to a very low level. Since chloride content in dune sand is very low, it can be used for any type of concrete. The quality of the land-based sand depends on the type of soil and method of washing. Sand obtained from this method is suitable for works where coarse sand is required. The compressive strength results show that the concrete made with all three alternatives is as good as the strength of concrete made with river sand.

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