

USE OF DUNE SAND AS AN ALTERNATIVE FINE AGGREGATE IN CONCRETE AND MORTAR

R. Sanjeevan¹, S. Kavitha², T.C. Ekneligoda³ and D.A.R. Dolage⁴

^{1,2,3,4} *Department of civil Engineering, The Open University Sri Lanka*

INTRODUCTION

River sand is the most widely used fine aggregate in civil engineering constructions in Sri Lanka. Traditionally river sand is extracted from rivers and streams. In the Jaffna peninsula there are no rivers or streams flowing through the area. Sand deposits in rivers are depleting in Sri Lanka, especially in the Southern region, as the annual demand for sand is very high due to rapid increases in civil constructions. The total demand of sand in Jaffna is met by the supplies of sand from the Southern region. This has led to large scale sand mining in the southern part of the country. As a result, most river banks have been eroded. Therefore, it is necessary to minimize sand mining, which is hazardous to environment.

One way to minimize this problem is to introduce an alternative material to river sand, such as dune sand, offshore sand and land based sand etc. Several studies have been conducted on dune sand in different countries to identify its suitability for concrete (Alhozaimy et al, 2013, Al-Harthy et al, 2007, Guettala and Mezghiche, 2011). Dune sand is the most widely available form of sand in the northern part of Jaffna.

The estimated total quantity of the dune sand that can be mined is 18.38 million cubic meters (Dias et al, 1999). This article describes the suitability of dune sand and quarry dust as fine aggregate in concrete and mortar instead of using river sand as fine aggregate.

TEST PROGRAMME

Sri Lankan experience in mix design together with the UK method described by Department of Environment for concrete mix design in the UK was used for the preparation of concrete mixes (Dias et al, 2002). It was decided to carry out testing for grade 25 concrete as that is the most widely used concrete in building construction. The OPC content of concrete was kept close to 340 kg/m³ (Dias, 2003). The rest of the materials were determined according to the guidelines provided by the UK Department of Environment. The target slump of the mixes was 120-150 mm. Although the addition of an air entrainer is common in warm climates to improve the workability, it was decided not to use an air entrainer in the mix as the production cost will increase (Shetty, 2010). As the objective is to minimize sand use, the fine aggregate phase was replaced with dune sand and quarry dust.

Five different types of mixes were prepared by partially replacing quarry dust with varying percentages of dune sand namely 10% (M-1), 30% (M-2), 50% (M-3), 70% (M-4) and 100% (M-5). 100% (M-5) dune sand consisted of a mix that represents the maximum percentage that can be used in the mix design. Adjustments were not made in the determination of water content due to the addition of dune sand which is common in modified mix design methods (Dias et al, 2002) as the mixture of dune sand and quarry dust acts against each other with respect to the water demand (see discussion).

Table 1 illustrates the mix proportions adopted for the concrete testing. The dune sand percentages were varied from 10 to 100%.

³ Correspondence should be addressed to Dr. T.C Ekneligoda, Department of Civil Engineering, Open University of Sri Lanka (email: thushan.e@gmail.com)

Table 1: Mix proportions (kg/m³) for grade 25 concrete

Sample/Results	M-5	M-4	M-3	M-2	M-1
Grade	25	25	25	25	25
Water/cement ratio	0.5	0.5	0.5	0.5	0.5
Cement content (kg/m ³)	341.66	341.66	341.66	341.66	341.66
Water content (kg/m ³)	170	170	170	170	170
Fine aggregate (kg/m ³)	726.7 (DS-726)	726.7 (DS-508)	726.7 (DS-363)	726.7 (DS-128)	726.7 (DS-73)
Coarse aggregate (kg/m ³)	1136.64	1136.64	1136.64	1136.64	1136.64

DS- Amount of dune sand

For mortar, the flow test and compressive strength test for cement block were performed and the mix proportions together with the measured values are presented in Table 2.

Compressive strength test

The compressive strength test was conducted according to BS 1881 for fifteen cubes pertaining to a batch. 150 x 150 x 150 mm cubes were cast for the compressive strength testing. All samples were cured after 24 hours. For each testing three cubes were tested. Compressive strength development was observed at 3, 7 and 28 days after casting. Early age strength is important in warm countries as thermal shrinkage cracks can cause damages in structures if the initial strength gain is low (Shetty, 2010). Such phenomenon is also common in concrete mixes with fly ash (Luo et al, 2013). Therefore, it was decided to measure the three-day strength after casting cubes to determine the early age strength.

Durability test

The durability test was carried out on specimens that had a size of 100 x 100 mm (diameter x height) and was cast in plastic moulds. The test was carried out for both concrete and mortar. Concrete durability was tested by using sorptivity (Dias, 2003). Sorptivity is an index of moisture transportation into unsaturated specimens. The experiment was carried out for 24 hours and the specimens were placed on sponges with the cast surface in a shallow tray of water.

Fresh state - Fluidity

The following tests were carried out for fresh stage properties of concrete.

Slump loss test for concrete

Slump test for concrete

Fluidity test for mortar

The fluidity test was carried out only for mortar. The slump test was performed according to BS 1881 and the flowability test was performed according to BS 1015.

RESULTS AND DISCUSSION

Fresh concrete properties

As the fresh stage properties slump, slump loss together with flowability experiments were carried out. The non agitated slump loss was carried out for 1 hour. The concrete used for the non agitated slump loss test was not returned to the concrete cube preparation. The highest slump value (180 mm) was demonstrated by the mix with 100% dune sand while the least

value (130 mm) of initial slump was demonstrated when the dune sand percentage was 10. The difference in slump values can be explained by considering the particle shape of dune sand. Due to the nature of formation of dune sand most particles possess a spherical shape. Therefore, the frictional force between particles becomes less and shows a higher flowability which is similar to ball bearing action (Nanayakkara, 2003). As a result, the mix of 100% dune sand exhibits the highest slump value. Arguing along that line, the least slump is given by the 100% quarry dust sample which has more angular particles and hence there are higher frictional forces between the particles. However, after 60 minutes (in the slump loss test) all the mixes gave similar slump values which indicate there was no impact from dune sand (Fig 1a).

The flow table values indicate that the addition of dune sand increases the flowability of mixes. A flow table value of 212.5 mm was demonstrated when the dune sand percentage of the mix was 100 (Table 2). This behaviour is also consistent with the explanation offered to the behavior of slump values.

Table 2: Flow table test results together with their mix proportion

Mix number	Dune sand % in mix	Quarry dust % in mix	X(mm)	Y(mm)	Flow value(mm)
1	100	0	230	200	215
4	70	30	150	150	150
6	50	50	140	140	140
8	30	70	125	143	134
10	10	90	120	120	120

Hardened state - Compressive strength of mortar

Figure 1b shows the compressive strength results of hardened concrete. Each value presented is the average of the three values of three samples for each mix type. The compressive strength is gradually increased with a dune sand percentage (Fig.1b). The highest compressive strength is recorded when the dune sand percentage of mix is equal to 50%. The strength variation indicates similar behavior in all three days (i.e 3, 7 and 28 days). Similar strength development can also be observed in mortar (Fig 1c). Compressive strength values of all mixes of 1:5 mortar satisfied the Sri Lankan standard (ICTAD specifications), which is greater than 5 N/mm². According to the results compressive strength of mortar is higher than 5 N/mm².

The marginal optimum point of the strength can be explained by considering the shape of the particles in the micro structure. As explained earlier dune sand contains more spherical particles. Although this helps for workability, micro level pores can be filled only by dune sand. Quarry dust has more angular shaped particles. These particles help to fill the micro pores to some extent. However, after increasing 50 % of quarry dust, angular particles dominate the micro structure reducing the workability, which affects the strength.

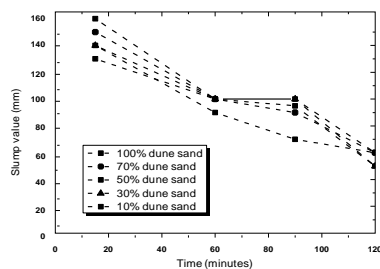


Figure 1a: The variation of slump loss

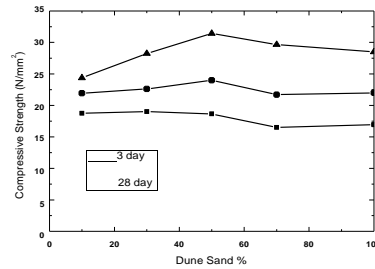


Figure 1b: The behaviour of compressive strength of concrete

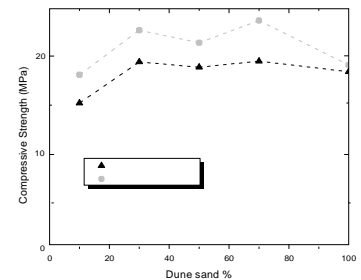


Figure 1c: The behaviour of compressive strength of mortar

Durability test

Figures 2a and 2b which represent the penetration depth change versus the square root of time demonstrate the approximate linear plot for each of the mixes (Fig 2a and 2b). According to figures 2a and 2b, the rate of water absorption for all mixes is less than 2×10^{-5} mm/ $\sqrt{\text{min}}$. However, the correlation coefficient (R) value for mixtures M5 and M4 are less than 0.98. All the other mixtures gave a correlation coefficient (R) that is greater than 0.98. The concrete produced with 50 % or above dune sand shows a clear difference of sorptivity both air cured (dry curing) and water cured. Increasing percentages of dune sand causes an increase in sorptivity in both air cured and water cured samples. However these values are marginally higher (less than 15%) than those that are produced by river sand (Dias, 2003).

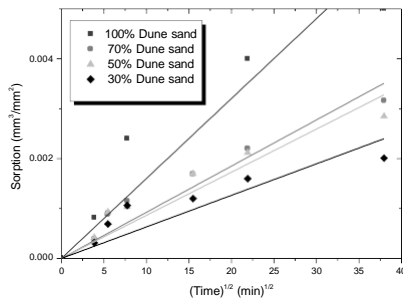


Figure 2a: Dry cured sorptivity values

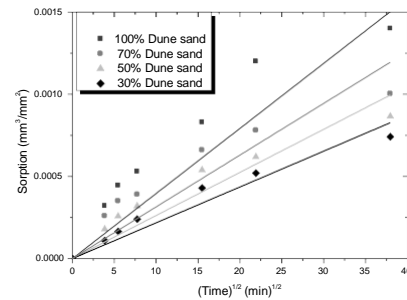


Figure 2b: Wet cured sorptivity variation

These phenomena can be explained considering the shape of dune sand. Circular shaped of dune sand causes opened pores at micro levels which cannot be filled. These micro levels pores help to conduct fluid. Therefore a higher percentage of dune sand causes the increment of sorptivity

CONCLUSIONS

This paper investigated the suitability of dune sand in concrete and mortar. Ball bearing action dominates the flow of dune sand mixed concrete. Marginal strength variation (less than 8%) occurs in the concrete when dune sand is used. The marginal strength variations are probably due to the combined effect of particle shape of dune sand and quarry dust. Mortar with dune sand satisfies the Sri Lankan strength requirement. The behavior of slump loss is same in all the mixtures. The drop of slump values after 2 hrs was approximately 60% for all the mixtures. The sorptivity parameter is closely related to the amount of dune sand. The highest sorptivity value was obtained when the dune sand percentage is 100.

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