

Suitability of Soil Washed Sand as Fine Aggregates to Replace River Sand in the Concrete

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Abstract

This paper presents a study on suitability of replacing river sand with soil washed sand as fine aggregate in concrete. The study was based on a comparison of concrete performance produced from river sand and soil washed sand obtained from four locations in Sri Lanka; Homagama, Rathnapura, Anuradhapura and Bandarawela. Several standard tests including Sieve analysis, Slump test and Compressive strength were conducted in order to check the workability, particle size distribution and compressive strength of M25 grade concrete. From the test results, it was found that percentages of coarse sand, medium sand and fine sand present in soil washed sand are higher than that of river sand, while highly coarse sand percentage was higher for the soil samples extracted from Rathnapura and Bandarawela areas compared to river sand. Slump test results showed that the concrete produced from river sand has a lower slump value compared to that of concrete produced from soil washed sand, suggesting that washed soil sand could possess higher workability. Test results showed that specimen cubes have achieved the target strength of M25 grade concrete even though compressive strength of concrete produced from soil washed sand was about 10% lesser compared that of river sand at 7 days, 14 days and 28 days' strength.

Keywords: Fine aggregates; washed soil; concrete.

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1. Introduction

Quality of construction is one of the most important aspect considered in construction industry. Sand is one of the dominant component in concrete production, which is around 35 % by volume of the concrete [1-3]. River sand is widely used as fine aggregates in concrete production and over usage of river sand has resulted in many harmful effects such as lowering of water table in rivers, salinity intrusion into rivers and increase in river bed depth [4–6]. These Environmental issues have forced researchers to study on alternatives for river sand such as fly ash, slag and limestone powder [7,8].

According to previous studies, researchers have studied on potential alternatives for river sand to use as fine aggregates in the concrete production. The authors in [6] have studied on the use of off shore sand as a fine aggregate for the concrete production. Their findings revealed that the concrete produced with off shore sand has its compressive strength within acceptable limits and other properties suitable for the concrete production. Thus, they concluded that off shore sand obtained from western coast of Sri Lanka can be used as an alternative to the river sand. The author in [5] investigated the suitability of Crushed granite fine (CGF) to replace river sand in concrete production. He performed slump test, compressive and indirect tensile strength tests for fresh and hardened concrete as methods of studying the performance of CGF based concrete. Based on the findings, he revealed that the CGF is suitable for production of concrete. The authors in [9] have studied on the effect of replacing natural sand with quarry dust on mechanical properties using M30 grade concrete with 10, 20 and 30 % of quarry dust as a replacement for natural sand. They found that physical and chemical properties of the quarry dust have satisfied the requirements in the standards. Furthermore, The authors in [10] have studied on strength of concrete made with quarry rock dust and washed gravel. They revealed that above materials can be used as a full replacement for conventional granite and natural river sand, although the aggregate/ cement ratio was found to be lower compared to conventional concrete. Apart from these, The authors in [11–16] have carried out their studies on finding the suitability of alternatives such as crushed discarded beverage glass, sea sand, robosand, quarry dust, copper slag and washed copper slag, and crushed cow bones to replace the use of river sand in the concrete production. However, there is a dearth of literature on studies to find the suitability of using washed soil as a partial or full replacement for river sand as the fine aggregates in concrete production. Thus, there is a knowledge gap related to performance of washed soil as a fine aggregate in concrete in terms of strength, workability and durability.

The objective of this study is to find the performance of washed soil in terms of compressive strength, workability and particle size distribution to replace river sand as fine aggregates in concrete production. Thus, to find solution for scarcity of river sand and environmental concerns arising over this scarcity in river sand.

2. Materials and methods

2.1. Study area

For this study, soil samples were collected from four different locations in Sri Lanka. They are Anuradhapura, located in North-central province, Rathnapura, located in Sabaragamuwa province, Bandarawela, located in Uva province, and Homagama, located in Western province. These sampling locations are shown in the map given in

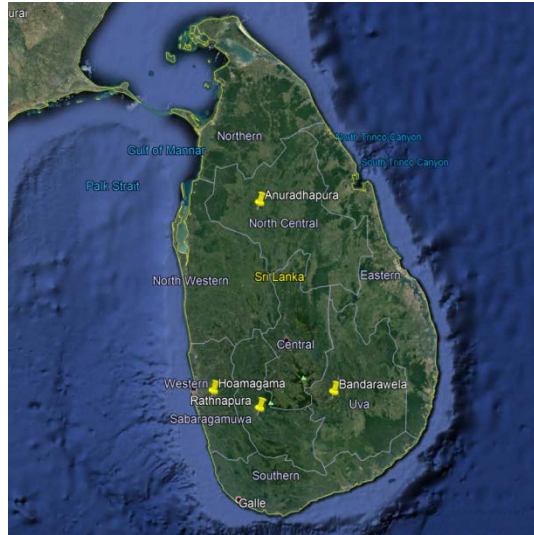


Figure 1 : Locations of collected samples.

2.2. Materials

Ordinary Portland cement and water conforming to BS EN 197-1:2000 and BS EN 1008 respectively were used to prepare the concrete mix. Crushed coarse aggregates of size 10mm and 20mm were used. For the fine aggregates, river sand and soil washed sand obtained from washing plants were used.

2.3. Mix design

For this study, M25 grade concrete was produced using following mix design to investigate the impact of using soil washed sand for the concrete production. The control mixture was designed to have a 28-day target compressive strength of 25 N/mm² with a water cement ratio of 0.52 [18–20]. Table 1 shows the mix proportions of the materials used after computation.

Table 1: Mix proportions and ratios for M25 concrete.

Material	Cement	Fine aggregates	Coarse aggregates	Water
Quantity (kg/m ³)	368.42	741.39	1192.42	191.58
Ratio	1	2.01	3.23	0.5

2.4. Sieve analysis test

Prior to casting of concrete, all the collected samples were tested for sieve analysis to identify the gradation of samples. It determines the required paste for workable concrete since the amount of void requires to be filled by the same amount of cement pastes in a concrete mixture. Sieve analysis was carried out in compliance with the standards provided in the BS 812.

2.5. Slump test

Slump test was used to compare the workability of fresh concrete produced from soil washed sand against that of river sand. Slump tests were carried out for each of the six concrete mixtures produced for different sampling locations. The slump test was carried out accordance with BS EN12350-2: [21,22].

2.6. Preparation and casting of test specimens

Forty-five cubes were used, where nine sample cubes of size $150 \times 150 \times 150$ mm were casted for each of the sand samples. These prepared cubes specimens were cured for specific period prior to compressive strength test at 7, 14 and 28 days.

2.7. Compressive strength test

Most important aspect of concrete is the ability to withstand the compressive loads, which is known as compressive strength. Compressive strength test is one of the most common methods used to determine the compressive strength of the concrete. That is the application of a load at a constant rate on a cube sized $150 \times 150 \times 150$ mm until the failure of the sample specimen. During this study, compressive strength test was carried out in compliance to BS 1881-108: 1983. Compression testing apparatus was used to determine the strength at 7, 14 and 28 days using Equation (1) where f_c is the compressive strength of concrete, P is the maximum load applied (kN) and A is the cross sectional areas of the sample (mm²) [23–26].

$$f_c = \frac{P}{A} \quad (1)$$

3. Results and discussion

3.1. Particle size distribution

The following test results given in Figure 2 were obtained from the sieve analysis experiment carried out for the soil samples obtained from Anuradhapura, Rathnapura, Bandarawela and Homagama compared to river sand sample. According to the particle size distribution curve and BS812: Part 103 standards, collected samples from all four areas belonged to C graded fine aggregates and river sand also belongs to grade C fine aggregates [27].

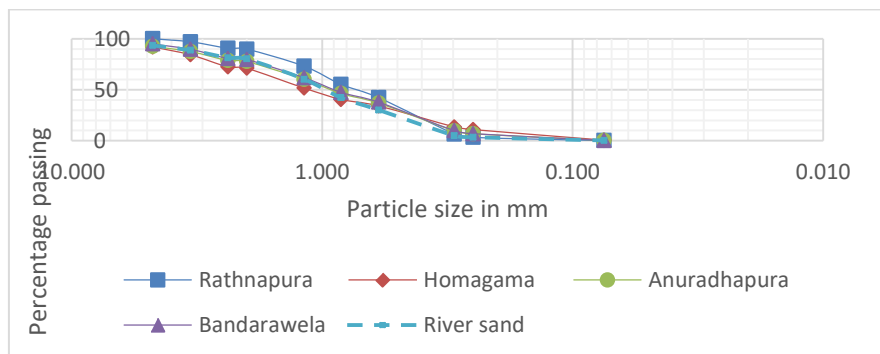


Figure 2: Particle size distribution curve

However, it can be observed that the highly coarse sand percentage in soil samples collected from Rathnapura and Bandarawela is higher than that of river sand tested, while Homagama and Anuradhapura samples possess lower percentages of highly coarse sand. Nevertheless, percentages of coarse sand, medium sand and fine sand for the all samples are higher than that of river sand as per the grading chart [28].

3.2. Slump test

The Table 2 shows the obtained results for the slump test for the test samples.

Table 2: Slump test results

Sample	Test 1 (mm)	Test 2 (mm)	Test 3 (mm)	Average (mm)
River Sand	65	69	70	68
Homagama	85	87	84	85.33
Anuradhapura	76	77	78	77
Rathnapura	78	75	80	77.67
Bandarawela	70	72	74	72

According to the results shown in Table 2, it can be observed that workability of concrete produced from washed soil sand is comparatively higher to that of concrete produced from river sand. However, this observation could be due to higher water requirement for river sand to lubricate its sand particles. Thus, it could result in higher slump values for concrete produced from soil washed sand [29].

3.3. Compressive strength

Nine cubes casted for each of the concrete batch produced from different sand samples were tested for the compressive strength test at 7 days, 14 days and 28 days. Test results for variation of strength are given in the Table 3, Table 4 and Table 5, and Figure 3 illustrates the average strength for the compared sand types.

Table 3: 7 day cube strength test results

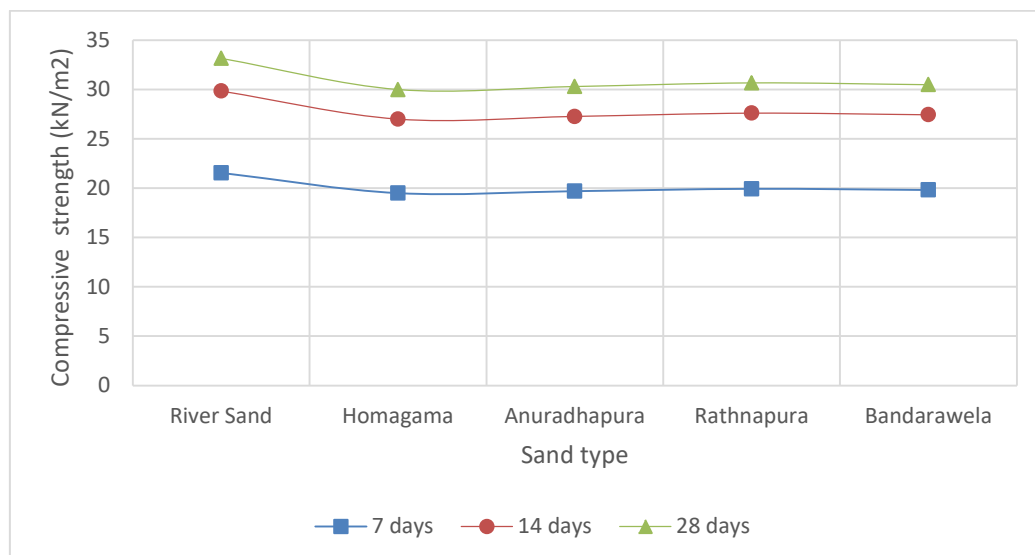
Sand type	Compression force at failure (kN)			Average	
	Cube 01	Cube 02	Cube 03	Force (kN)	Strength (kN/m ²)
River Sand	446.55	469.80	537.99	484.78	21.546
Homagama	476.33	428.02	408.76	437.71	19.495
Anuradhapura	467.69	435.62	425.94	443.08	19.693
Rathnapura	459.05	443.22	443.12	448.46	19.931
Bandarawela	463.37	439.42	434.53	445.78	19.812

Table 4: 14 day cube strength test results

Sand type	Compression force at failure (kN)			Average	
	Cube 01	Cube 02	Cube 03	Force (kN)	Strength (kN/m ²)
River Sand	618.30	650.50	744.92	671.24	29.833
Homagama	659.54	592.65	565.98	606.06	26.994
Anuradhapura	647.58	603.17	589.77	613.50	27.267
Rathnapura	635.62	613.69	613.56	620.96	27.598
Bandarawela	641.60	608.44	601.67	617.24	27.433

Table 5: 28 day cube strength test results

Sand type	Compression force at failure (kN)			Average	
	Cube 01	Cube 02	Cube 03	Force (kN)	Strength (kN/m ²)
River Sand	687.00	722.78	827.69	745.82	33.148
Homagama	732.82	658.50	628.87	673.40	29.993
Anuradhapura	719.53	670.19	655.30	681.67	30.297
Rathnapura	706.24	681.88	681.73	689.95	30.664
Bandarawela	712.89	676.04	668.52	685.82	30.481

**Figure 3:** Average compressive strength

As per Figure 3, similar pattern can be observed for 7 days, 14 days and 28 days' compressive strength of the concrete produced. Whereas, from the charts it is clear that with 14 days' time concrete cubes has attained more

than 90 % of the specified cube strength of M25 grade concrete. However, results clearly show that washed soil sand has a lower compressive strength compared to that of concrete produced from river sand. That is average compressive strengths of concrete produced from soil washed sand are 9.52 %, 9.51 % and 9.91 % lower to compressive strength of concrete casted from river sand at 7 days, 14 days and 28 days respectively. However, compressive strength of concrete produced from sand obtained from soil collected from four sampling locations showed similar values at all three tests with slightly lower values were observed for samples collected from Homagama and highest test results were shown for Rathnapura soil samples. Nevertheless, it can be seen that the concrete produced from washed soil sand reaches grade specified strength with time as river sand based concrete.

4. Conclusions and future recommendations

Based on these results, it is conclusive that percentages of coarse sand, medium sand and fine sand present in soil washed sand are higher than that of river sand. Furthermore, from the test results of slump test, it is certain that workability of concrete produced is slightly greater than the workability of concrete produced from river sand. Test results showed that specimen cubes have achieved the target strength of M25 grade concrete despite the compressive strength of the concrete produced from soil washed sand was found to be about 10% lower to that of concrete produced from river sand. Thus, further studies are required to promote the use of soil washed sand as a full replacement of river sand as fine aggregates in concrete. Future studies are recommended to carry out to find the suitability of partial replacement of soil washed sand for river sand. In addition, more test parameters such as splitting tensile strength, chemical properties and factors affecting the durability are proposed to study in future literature as this study was only based on workability, particle distribution and compressive strength. In future studies, proper economic feasibility studies can be done to find the financial, social and environmental advantages of replacing river sand with soil washed sand.

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