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INDIGENOUS FINE AGGREGATE SUBSTITUTE FOR SLS 107 STRENGTH COMPLIANCE TESTING OF ORDINARY PORTLAND CEMENT

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INTRODUCTION

Cement is the most versatile and extensively used binder material in the construction industry. The versatility stems from the ability of cement to develop the binding capability even under water, which entitles it the name 'Hydraulic Cement'. Though there are many varieties of hydraulic cements, the most commonly and extensively used type is the Ordinary Portland Cement (OPC).

At present the cement requirement of the Sri Lankan industry is fulfilled by local manufacture as well as imports from various origins, though there was a time when it was completely addressed through local manufacture by the State Cement Corporation. With the expansion of the infrastructure development and import liberalization policies of successive governments, it was inevitable that cements reaching the consumer originated from many sources. Specifically the OPC consumed in the local construction works is both locally produced by a few manufacturers and imported in many forms such as clinker, ground clinker, bulk cement and bagged cement, by several dealers.

Since the main binding property of cement is highly sensitive to the exposure to humidity (high perishability) and being a manufactured product from different raw material sources, it is essential to ensure conformity to specification in cements so that its performance in the intended role is not impaired. To this end, quality assurance/control tests are essential to safeguard the consumer in terms of product quality. This is further accentuated by the fact that in the national interest, achieving a high level of safety, integrity and useful life from constructed facilities is a matter of very high importance.

In order to ensure that quality assurance tests are carried out with out hindrance on cements, they should be economically viable. As developed through the following section, the objective of this study is to identify a locally available sand to be used for strength compliance testing of cements, without depending on the imported standard sand which is both expensive and difficult to obtain.

REVIEW ON LITERATURE AND OBJECTIVES OF THE STUDY

The specification for OPC in Sri Lanka is primarily based on the Sri Lankan Standard SLS 107 which had been derived from the British Standard BS 12. In the context of marketability in Sri Lanka, all OPCs used are legally required to conform to the stipulations of SLS 107. This standard clearly specifies the conformity criteria and relevant tests to satisfy these stipulations for conformity.

Conformity tests on cements as stipulated in the standards could be broadly divided into two categories of mechanical properties and chemical properties related to composition. Table 1 gives a listing of the physical and chemical properties to be considered to arrive at a overall assessment of a cement. Though the chemical composition of a cement plays a significant role in the

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durability and strength development characteristics of that cement based construction materials such as concrete and mortar, mechanical properties, especially compressive, tensile and shear strengths are more significant and relevant aspects to be considered in ensuring quality.

Physical Properties	Chemical Properties
Fineness	Insoluble residue
Soundness	Loss on Ignition
Initial Setting Time	Aluminium Oxide Content
Final Setting Time	Iron Oxide Content
Compressive strength	Sulphate Content

Table 1 - SLS 107 Stipulated Conformity Tests on OPCs

The physical characteristics of compressive, tensile and shear strengths can be easily correlated to the compressive strength of a cement bound matrix, which is the reason for the standards to specify the determination of compressive strength only. The cement bound matrix for the purpose of testing compressive strength should be formed using a homogeneous non reactive material with cement, in order for the test to be an unbiased compliance test.

Both Sri Lankan and British standards stipulate the use of a homogeneous closely graded rounded particle sand, which is chemically inert to cement and its hydration products, as the basis for the cement bound matrix. These standards specify a mortar cube made of a particular mix proportion and a water cement ratio, made out of such a sand and the cement in question to be cast cured and tested at a given maturity for determination of compressive strength by crushing.

In particular, these standards specify a proportion of 1:3, cement:sand with water:cement ratio of 0.4 for the mortar to be compacted, by a stipulated amount of tamping, into custom made cast iron cube moulds of 70.7 mm dimension, maintained in moist curing for three days. At the lapse of the curing period the cube has to be crushed on a compression testing machine and the resulting compressive strength should not be less than 20 N/mm^2 to satisfy compliance.

The natural silicate sand recommended by the standards and widely used in application is known as 'Leighton Buzzard Sand' borrowed in England. Since it is an imported material, use of this sand in cement testing would naturally make the strength testing process substantially expensive and pose a deterrent to employing this most important compliance test on cements used in Sri Lanka.

Consequently, the objective of this study is to identify a locally available fine aggregate that would fulfil the requirements of the 'standard sand' and could be used as a substitute for the imported 'Leighton Buzzard Sand' (LB sand).

METHODOLOGY

The methodology adopted in this study to achieve the objective is a stage wise screening of locally available sands to fulfil the requirements. The preliminary selection of sand samples for the study is based on general particle shape, size and colour. The initial stage of screening of the selected samples is governed by the gradation or the particle size distribution of the sample. In the final stage, controlled strength tests using a conforming cement, is used to identify the best candidate fine aggregate for the purpose.

RESULTS AND DISCUSSION

Shape and grading requirements for the 'standard sand' are stipulated in the standards as spherical in shape and particle size between 1.18 mm and 0.6 mm.

For the initial stage of screening, five sand types were used, identified based on general particle shape, size and colour. These were dune sand from *Nattandiya*, pit sand from *Puttalama*, river bank sand from upstream *Kelani Ganga*, river bank sand from downstream *Kelani Ganga* and dune sand from *Jaffna*. Sea sand was not considered as particle shapes of screened samples were not in conformity with the stipulations. Since all sand samples had appreciable fraction of particles larger than 1.18 mm, a prepared sub sample passing 1.18 mm sieve, from each type of sand were used to analyze the suitability. Results of the sieve analysis of the sand samples are given in Table 2 which includes LB sand for comparison.

Sand Type	**Dune Sand** *Nattandiya*	**Pit Sand** *Puttalama*	**River Sand US** *Kelani*	**River Sand DS** *Kelani*	**Dune Sand** *Jaffna*	**LB Sand**
% passing 1.18 mm	100	100	100	100	100	100
% passing 0.6 mm	0	80	0	0	100	0

Table 2 - Sieve Analysis of Selected Sand Samples

From Table 2 it is clear that two sand samples, pit sand from *Puttalama* and dune sand from *Jaffna* are too fine as indicated by a high fraction passing through 0.6 mm sieve. Due to this fact, these two sands have to be eliminated from consideration at the initial stage.

To assess the performance of sands for the final stage, mortar cubes were made and tested using the remaining sand types following the guidelines given in the standards. As the control cement for this procedure, a fresh well protected sample of an OPC from a leading manufacturer was used. As a control test, samples made using the LB sand were also tested. Individual and average compressive strength test results of these tests are given in Table 3.

Sand Type	**Three day Compressive strength (N/mm^2)**				
	Sample 1	Sample 2	Sample 3	Sample 4	**Average**
Dune Sand Nattandiya	20.57	19.79	21.08	20.10	20.39
River Sand US Kelani	11.72	10.88	11.82	11.10	11.38
River Sand DS Kelani	15.92	11.60	14.36	15.45	14.33
LB Sand	22.79	18.65	22.82	22.55	21.70

Table 3 - Compressive Strength Results for Selected Sand Samples

It is clearly evident from the results in Table 3 that sands from both US and DS locations of the *Kelani Ganga* fall substantially short from the targeted 20 N/mm^2 compressive strength required of a 'standard sand', which would eliminate both samples from consideration. However, though one individual result is lower, the compressive strength achieved by dune sand from *Nattandiya*, on average has given a strength above the target while comparing favourably with that of the original LB sand.

CONCLUSIONS/RECOMMENDATIONS

From the investigation presented in the preceding sections, it can be concluded that a sample of sand extracted by collecting the fraction passing 1.18 mm sieve, from dune sand occurring in *Nattandiya*, could be a viable substitute fine aggregate for compressive strength testing of cements for conformity with SLS 107. This particular fluvially deposited and agitated sand of rounded particles which occurs in the form of dunes in the *Nattandiya* area is available in adequate quantities to be utilized for the purpose of cement testing. Further, this sand is not generally preferred for other construction operations as it is deemed to be too fine. Consequently, it can further be concluded that the imported, 'Leighton Buzzard Sand' which entails a substantial expense, could be effectively replaced by this indigenous alternative.

Recent developments in cement testing for compliance, as depicted in later editions of the standard BS 12 indicate a trend towards more stringent as well as specific apparatus and material based techniques. Though these new methods undoubtedly result in more accurate evaluation of cement properties, the cost of administering such testing would be in many folds of the present values. However, if conforming to international norms would necessitate the adoption of these new testing procedures, it would be preferable if a local alternative could be found for the new 'standard sand' technically known as EN 196 which essentially is a graded fine sand as compared to 'Leighton Buzzard Sand' which is a single sized sand.

REFERENCES

Specification for Ordinary Portland Cement – SLS 107 :1995, Sri Lanka Standards Institution, Sri Lanka.

Specification for Portland Cement – BS 12 :1996, British Standards Institution, England.