UTILISATION OF 'AS GENERATED' QUARRY DUST AS A FINE AGGREGATE IN CONCRETE

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INTRODUCTION

The use of quarry dust as an alternative to traditionally used fine aggregate in concrete has drawn the attention of researchers and investigators over the last several years (Rajapaksha and Sooriyaarachchi,2009; Ilangovana et al. 2008, Ho et al. 2001). Aspects such as cement requirement, workability, compressive strength and the cost of quarry dust concrete have been studied in the Sri Lankan context (Mathanraj et al., 2011, Rajapaksha and Sooriyaarachchi, 2009 and Nishanthie and Dias, 2010). Nevertheless, in Sri Lanka, there is still a hesitation to use quarry dust as a fine aggregate due to the presence of a high content of finer particles in fresh quarry dust. Moreover, the samples of quarry dust that were used in the testing programmes of these studies are the ones in which particles size distribution (PSD) curves are well placed within the upper and lower bounds according BS 882 recommendations for fine aggregates. This necessitates further studies which tests properties of concrete using, 'as generated' (or rather 'as supplied') quarry dust.

Quarry dust is a by-product formed particularly when metal is produced from rubble in metal crushers. There are two types of crushers in use of which the crushing mechanism differs. They are namely the jaw crusher and the cone crusher. With the jaw crusher, trubbles are placed between the jaws and crushed through an impact, whereas with cone crusher, rubble is crushed due to the rotation of cones. In no crusher site, quarry dust which is the by-product of metal is sieved before being piled up for disposal. There is no evidence of a study carried out in Sri Lanka to investigate the variance of the PSD of quarry dust in relation to crusher type. This is important on account of the difference of crushing techniques which could lead to varying gradations.

This study aims to check the feasibility of substituting river sand with 'as generated' quarry dust with as a fine aggregate in nominal concrete mixes. The objectives of the study are as follows:

1. To determine the PSD of 'as generated' quarry dust obtained from crusher plants in the Western and Eastern provinces.
2. To investigate the feasibility of using 'as generated' quarry dust in nominal concrete mixes without the removal of fines by washing or re-gradation.

METHODOLOGY

Fresh 'as generated', quarry dust samples were collected from sixteen different crushers in the Western and Eastern provinces. In total, 16 crushers were visited eight each in the Western Province (WP) and Eastern Province (EP). The samples were collected from piles of quarry dust dumped at each crusher location and labeled WP1-WP8 and EP1-EP8. In order to draw a PSD curve for each sample, sieve analysis was performed and the PSD curves of only four samples were drawn on one chart to avoid cluttering. The eight samples collected from each province were divided into two groups in this manner. To account for the variation of gradation among quarry dust samples, each taken from a separate crusher was tested in four groups. The purpose was to see how the PSD curves of the samples fit within the lower and upper bounds as per BS 882. From each group, the least suitable sample was selected for the

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preparation of mixes since the aim of the study was to test the feasibility of using 'as generated' quarry dust.
The three grades of concrete considered for the study are namely 20, 25 and 30, which are widely used in structural concrete. The concrete used for the casting of cubes was prepared using volume batching. The nominal mixes were prepared according to the mixes specified in Table 4.4 of ICATD publication SCA /4/1 which in turn is based on BS1881, Part 116. A total of 72 test cubes were cast with quarry dust as the fine aggregate and 18 were cast with river sand as the fine aggregate. They were both tested for compressive strength in 7 and 28 days.

RESULTS AND DISCUSSION

The locations and type of crusher from which the samples were generated are depicted against the sample name in Table 1. While in the Western province both types of crushers are equally popular, in the Eastern province, 75 per cent of the crushers are of the Jaw type; samples have been selected to be representative of the crusher prevalence.

Table 1: Details of samples collected from Western and Eastern provinces

Western			Eastern		
Sample	**Location**	**Type of crusher**	**Sample**	**Location**	**Type of crusher**
WP1	Malvana	Jaw	EP1	Ampara	Jaw
WP2	Kirindiwela	Jaw	EP2	Hingurana	Cone
WP3	Delgoda	Cone	EP3	Ugana	Jaw
WP4	Kotadeniyawa	Cone	EP4	Mahiyangana	Cone
WP5	Hokandara	Cone	EP5	Velikanda	Jaw
WP6	Kotadeniyawa	Cone	EP6	Kantalai	Jaw
WP7	Matugama	Jaw	EP7	Kantalai	Jaw
WP8	Matugama	Jaw	EP8	Valathapitiya	Jaw

The least suitable sample in each group (namely, WP1 to WP4, WP5 to WP8, and EP1 to EP4 and EP5 to EP8) with respect to gradation, was used as the fine aggregate in preparing test cubes. Figures 1 to 4 depict the PSD curves of four groups of samples. In the Western province, the two groups of samples WP3 and WP8 are the least suitable with respect to gradation. The PSD curve for sample WP3 lies outside the lower bound curve for smaller sieve sizes. However, the PSD curve for sample WP8 lies within the upper and lower bounds throughout. As for the samples from the Eastern province, the two least suitable samples are EP2 and EP7, and the PSD curves of both these lie within the upper and lower bounds.

The standard concrete cubes cast with the least suitable quarry dust samples and sand were tested for compressive strength; the results are compiled in tables 2 and 3. According to tables 2 and 3, mixes with quarry dust as fine aggregate records higher compressive strength than those that had sand as a fine aggregate for both grades 25 and 30. Quarry dust being a generated material rather than a natural aggregate is well graded and has a rougher surface texture due to crushing. While the property of 'well gradedness' offers increased bonding, rougher surface texture offers friction to movement between particles, both effects contributes to increased compressive strength.
Nevertheless, for grade 20, this is vice versa. As can be expected, this phenomenon is common for both 7 and 28 days compressive strength. It is also observed that this increase in strength is far higher for grade 25 than for grade 30. Since quarry dust contains a higher content of fines than sand, it has a greater specific surface area. As a result, quarry dust concrete will require a higher content of cement paste to cover the surface. Since Grade 20 concrete contains relatively low cement content, this situation will result in less cement paste being available for bonding and thereby lower compressive strength. According to Rajapaksha and Sooriyaarachchi (2009), the difference in the recorded strength is greater for

higher grade concrete, grades 30 and 50 in particular. This situation is well demonstrated in figures 5 and 6, which use average values.

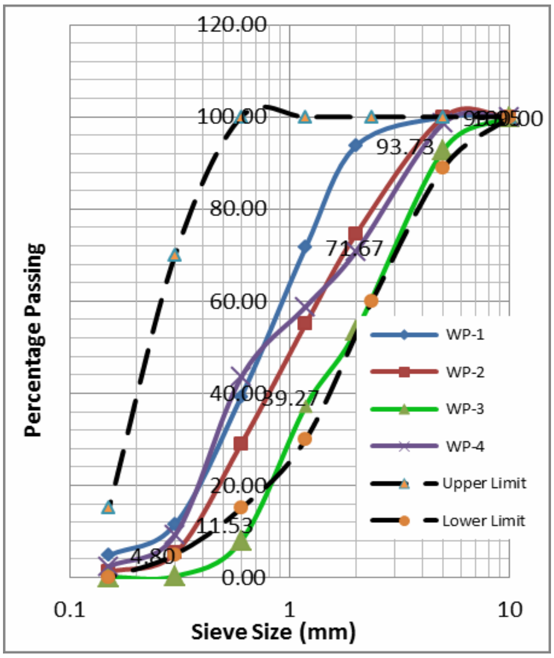

Figure 1: Particle size distribution for WP1–

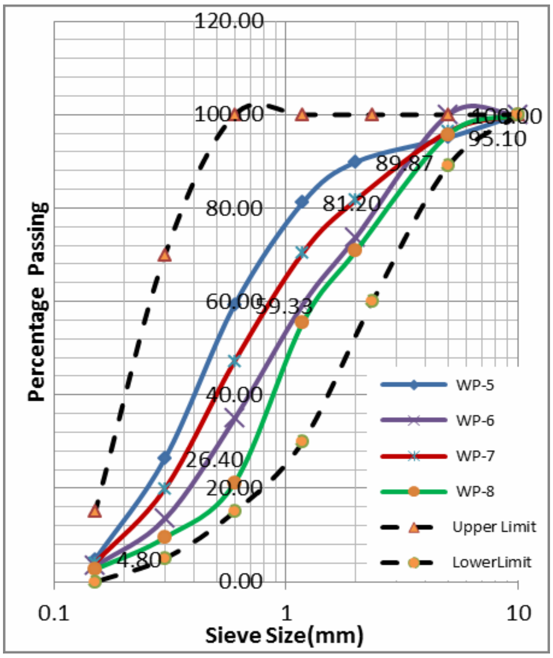

Figure 2: Particle size distribution for WP5–WP8

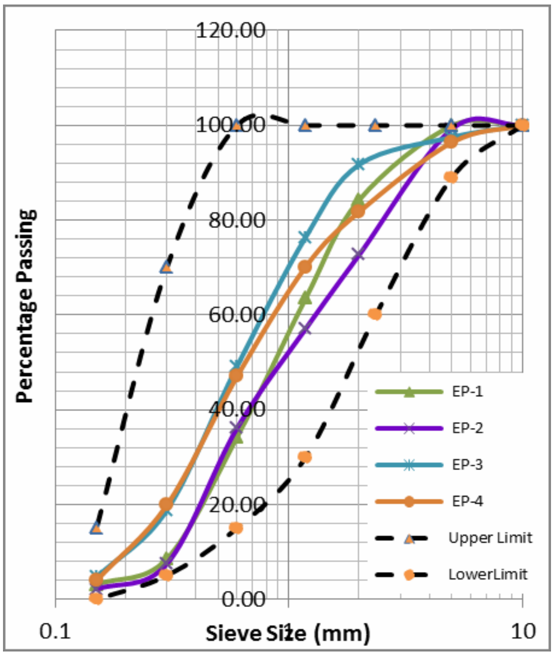

Figure 3: Particle size distribution for EP1–EP4

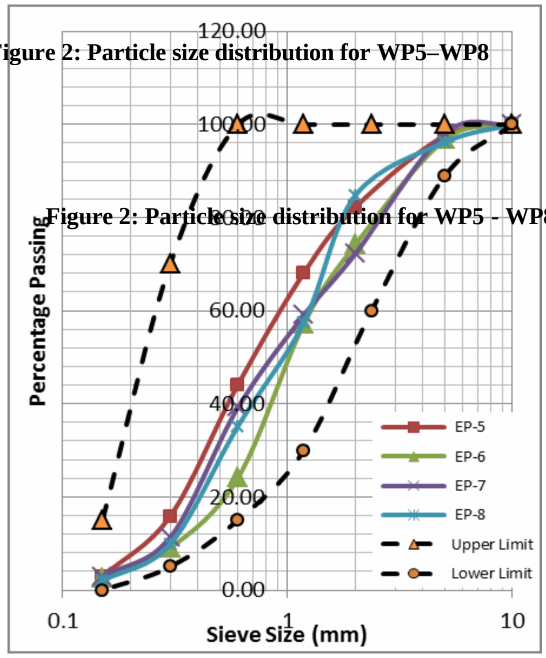

Figure 2: Particle size distribution for WP5 - WP8

Figure 4: Particle size distribution for EP5–EP84

Table 2: Compressive Strength of concrete at 7 and 28 days - quarry dust as fine aggregate

Specific Mix	Grade	Compressive strength at 7 days (MPa)					Compressive strength at 28 days (MPa)				
		WP3	WP8	EP2	EP7	AVG	WP3	WP8	EP2	EP7	AVG
1:1:2	30	26.67	26.44	26.69	26.43	26.56	39.56	36.89	4356	42.67	40.67
1:1.5:3	25	22.22	20.89	21.78	21.35	21.56	29.56	28.44	30.00	28.22	29.06
1:2:4	20	16.67	17.2	16.88	16.18	16.84	20.89	20.22	20.89	20.44	20.61

Table 3: Compressive Strength of concrete at 7 and 28 days - river sand as fine aggregate

Specific Mix	Grade	Compressive strength at 7 days (MPa)			Compressive strength at 28 days (MPa)				
		S1	S2	AVG	S1	S2	S3	S4	AVG
1:1:2	30	30	20.22	20.11	31.56	31.33	30.89	31.11	31.22
1:1.5:3	25	25	18.00	18.11	28.22	28.00	27.56	28.22	28.00
1:2:4	20	20	17.33	17.22	22.22	22.00	22.22	22.44	22.22

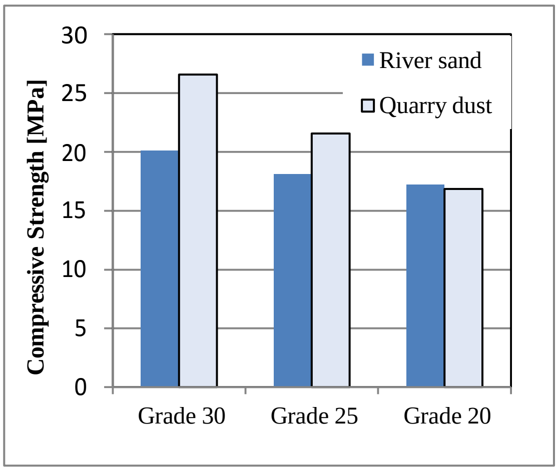

Figure 5: Compressive Strength - 7days

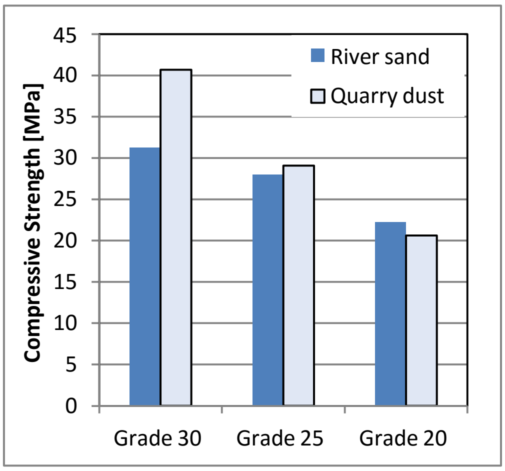

Figure 6: Compressive Strength - 28 days

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CONCLUSIONS

Based on the above discussion, the following conclusions are drawn:

- The difference in gradation among quarry dust samples in both provinces is not significant; out of the 16 samples, the PSD curve of one sample lied outside the lower bound.
- Concrete produced with quarry dust records an appreciably higher compressive strength than the same produced with river sand for grades 25 and 30 concrete. As for grade 20, quarry dust concrete records a lower compressive strength than river sand concrete.
- As generated quarry dust can be recommended to be used as a fine aggregate in structural concrete for higher grades.

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