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Strength aspect of concrete using stone dust as a partial replacement of sand

MD. NURUZZAMAN[1], MD. SAIFUL ISLAM[2], M. SALAUDDIN[1], MD. SAIFUL ISLAM[1]
[1]*Department of Civil Engineering, Chittagong University of Engg. and Technology, Chittagong, Bangladesh*
[2] *PEB Steel Alliance, Dhaka, Bangladesh*
Email: *mnzshuvo@gmail.com*

Abstract: Due to the auspicious attribute of concrete such as durability, availability, versatility, good compressive strength, it is one of the most commonly used building materials throughout the world. The demand for infrastructural facilities is increasing day by day which creates a tremendous pressure on concrete as well as on natural aggregates. Apparently it becomes unavoidable to look for alternative materials. On the other hand, disposal of stone dust generated from stone crusher is becoming a problem. Substituting sand by stone dust will serve the waste management as well as the alternative material in concrete. The present research's aim is to find out the strength aspect of concrete by using stone dust as a partial replacement of sand. The test specimens were made from three different grades of concrete i.e. mix ratios 1: 1.5: 3, 1: 2: 4, 1: 2.5: 5 and both compressive as well as tensile strength tests were conducted. The basic strength properties of concrete were investigated by replacing natural sand by Stone dust at replacement levels of 0%, 10%, 20%, 30%, 40%, 50% & 60%. For the different grades of concrete studied, the value of the compressive strength are observed to be maximum at 30% replacement level of sand whereas the maximum tensile strength occurs at 20% replacement level. The result shows that the maximum increase in compressive and tensile strength are 15% and 12% respectively in comparison to normal concrete (0% sand replacement level) for the concrete mix-ratio 1: 1.5: 3.

Keywords: *Stone Dust, Concrete, Compressive Strength, Tensile Strength.*

1. Introduction:

Among all the man-made materials, concrete is the mostly used one (Lomborg, 2001). Every year around 7.5 km^3 of concrete is being made (Hendrik and van Oss, 2007). To prepare this huge amount of concrete it needs a lot of sand, which is one of the prime constituent of concrete. As a result, the natural sources of sand are getting depleted (Palaniraj, 2003). Therefore, an alternative material of sand is needed to be explored. Stone dust is such a material which can be used to substitute sand as a fine aggregate in concrete (Nagabhushana and Sharada bai, 2011; Mahzuz *et al.* 2011; Balamurugan and Perumal, 2013; Muhit *et al.* 2014). Moreover, stone dust from stone quarries or stone crusher treated as wastage creates a great problem for disposal (Reddy *et al.* 2015). Different researchers took different initiatives at different time to find out a proper way to dispose waste (Kameswari *et al.*, 2001; Sanchez *et al.* 2002; Shih and Lin, 2003). Hence, the use of stone dust in concrete will not only serve as an alternative of natural sand but also reduce the environmental burden.

In different parts of the world, researchers have conducted different study to find out the effect of stone dust in concrete. Shukla *et al.* (1998) and Nagabhushana and Sharada bai (2011) have concluded their report by saying that up to 40% replacement of sand by crushed rock powder, the strength of concrete is not affected. Reddy and Reddy (2007) reported an increasing compressive strength and Hammed and Sekar (2009) reported an increasing flexural strength of concrete by the use of crushed stone dust. Again, quarry rock dust concrete acquires 10-12% more compressive strength than normal concrete of similar mix (Illangovana *et al.* 2008). It has been found by Ahmed *et al.*, 2010 from their research that the stone dust concrete acquired around 15% higher strength than conventional concrete. Mahzuz *et al.* (2011) examined the effect of stone powder as fine aggregate in concrete and they have reported that the strength of concrete from stone powder is 14.76% higher than normal concrete. Mogaveera *et al.* (2011) have pursued a study on sand replacement in concrete for different mix proportions by quarry dust and they have drawn a result by saying that up to 20% - 25%, sand can be replaced by quarry dust effectively. Some other researchers have also drawn an outline in their reports that replacing sand by stone dust improved the compressive strength of concrete (Nagpal *et al.* 2013; Sukesh *et al.* 2013). Balamurugan and Perumal (2013) revealed that concrete gives maximum compressive strength at 50% sand replacement by quarry dust. It has been scrutinized by Kumar and Singh, 2015 from their experimental study that at 20% and 50% sand replacement by stone dust the increase of compressive strength of concrete is 8-10%.

The present study is aimed at utilizing stone dust as fine aggregate in concrete by replacing natural sand at relatively smaller percentages. The current study is intended to determine the compressive strength and tensile strength of concrete on different replacement level of natural sand by stone dust with different concrete mix-ratios.

2. Experimental Program:

The experimental program was planned to study the effect of replacement of fine aggregate with supplementary material stone dust on the strength of

hardened cement concrete. Fine aggregate i.e. natural sand replacement at various percentage levels were used in investigation to observe the effects of different stone dust levels on concrete in developing strength at different curing ages.

2.1 Materials used:

Concrete test specimens were cast using ASTM type-I Ordinary Portland Cement (OPC), crushed stone chips as coarse aggregate, natural river sand and stone dust as fine aggregate. Table 1 provides the physical properties and the chemical compositions of the ordinary Portland cement (Aziz, 1995; Hossain and Seraj, 1985).

The coarse aggregate used was crushed stone with a maximum nominal size of 12.5 mm; the fine aggregate was river sand and stone dust. The grading of aggregates is shown in Table 2. Further, the physical properties of aggregates are shown in Table 3.

***Table 1**: Physical properties and the chemical compositions of ordinary Portland cement*

Sl.No	Characteristics	Value obtained	Value specified as
1	Fineness (#200 sieve)%	95%	>90%
2	Blain specific surface (cm^2/gm)	3300	>2800
3	Normal consistency (%)	24.5%	22%-30%
4	Setting times-Vicat test (minutes) Initial Final	 135 190	 >45 <375
5	Specific gravity	3.15	
6	Compressive strength (MPa) 3 days 7 days 28 days	 15.4 19.8 30.2	 >12.4 >19.3 >27.6

***Table 2**: Grading of aggregates*

Coarse aggregate		Fine aggregate (Stone Dust)	
Sieve size (mm)	Cumulative percentage retained	Sieve size (mm)	Cumulative percentage retained
25	0	4.75	0
12.5	0	2.36	5.24
9.5	55	1.18	28.62
4.75	100	0.6	75.20
-	-	0.3	85.90
-	-	0.15	92.84
-	-	Pan	100

***Table 3**: Physical properties of Aggregates*

Properties	Coarse aggregate	Fine aggregate	
		River sand	Stone dust
Specific Gravity	2.7	----	2.51
Unit Weight (kg/m^3)	1603.3	1709.2	1606.8
Fineness Modulus	6.45	----	2.88
Absorption Capacity (%)	1	----	0.31

2.2 Variables Studied:

(a) Mix Proportions: Three different mix proportions of concrete were used in the program which are 1:1.5:3, 1:2:4 and 1:2.5:5 those gives concrete of three grades namely M35, M28 and M23 respectively.

(b) Exposure Period: Test specimens were tested periodically after the specified curing periods of 7 days, 14 days, 28 days and 90 days in plain water.

(c) Size of specimens: Cube specimens were used in this program in which each side of the cube is 101.6 mm long.

(d) Percent level of sand replacement by stone dust: In this program the percent levels of sand replacement by stone dust were 0%, 10%, 20%, 30%, 40% and 50% which are denoted in different figures as SD0, SD10, SD20, SD30, SD40 and SD50 respectively.

(e) Test: Two tests namely compressive strength test and tensile strength test were conducted in this program.

2.3 Experimental Procedures:

2.3.1 Compressive strength:

The concrete specimens were tested for compressive strength at the ages of 7, 14, 28, 90 days in accordance with the BS EN 12390-3:2009. At each case, the reported strength is taken as the average of three tests results.

2.3.2 Tensile strength:

The concrete specimens were tested for tensile strength at the ages of 7, 14, 28, 90 days in accordance with the BS EN 12390-3:2009. At each case, the reported strength is taken as the average of three tests results.

3. Results and Discussions:

3.1 Compressive Strength:

The compressive strength of normal and stone dust concrete of three different grades M35, M28 and M23 has been graphically presented in Fig.1, Fig.2 and Fig.3. Also for the ease of comparison, the relative compressive strengths are plotted in Fig.4, Fig.5 and Fig.6. From the early age of curing, stone dust concretes achieve relatively higher compressive strength as compared to normal concrete.

Test result shows that 7 days compressive strength of M35SD10, M35SD20, M35SD30, M35SD40 and M35SD50 concrete is 17%, 20%, 28%, 15% and 20% higher than normal concrete i.e. M35SD0. From the

initial age of curing, compressive strength is seen to increase with the increase of stone dust content as a partial replacement of fine aggregate i.e. natural sand.

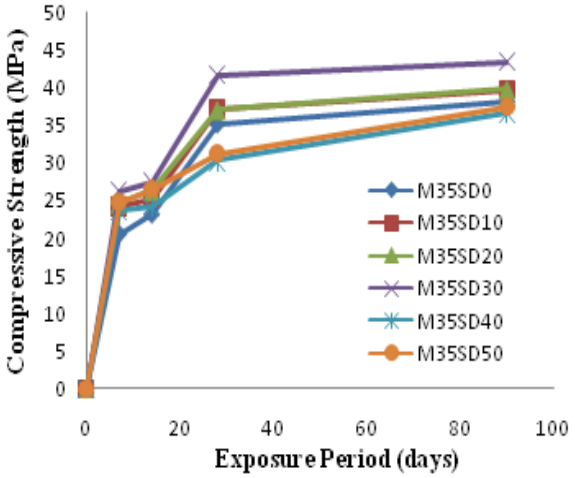

***Figure 1**: Compressive strength of M35 concrete*

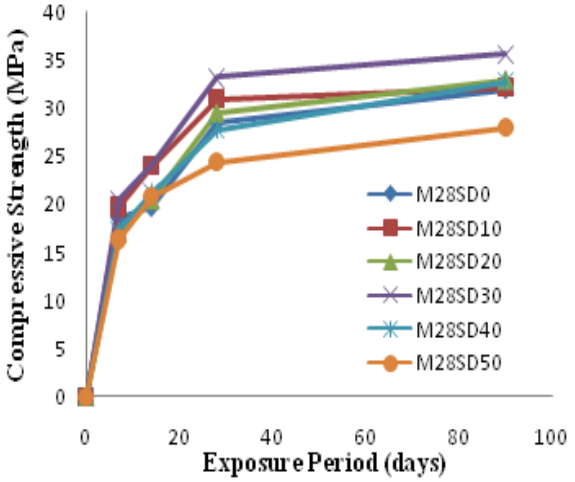

***Figure2:** Compressive strength of M28 concrete*

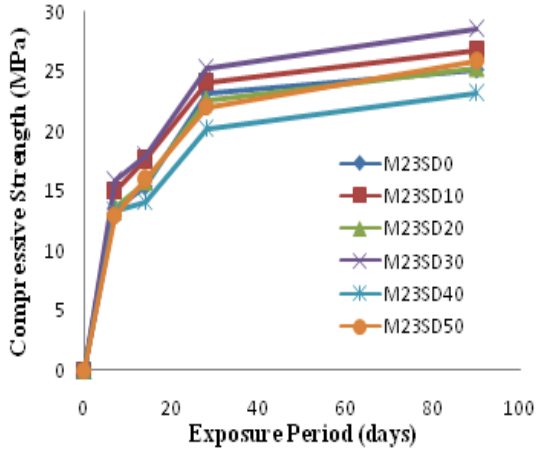

***Figure3**: Compressive strength of M23 concrete*

**M35SD10 denotes M35 grade concrete in which sand is replaced by 10% stone dust*

14 days compressive strength of normal concrete of M28 grade is lower by around 21%, 4%, 22%, 7% and 5% respectively for M28SD10, M28SD20, M28SD30, M28SD40 and M28SD50 concrete. Similarly, 28 days compressive strength of normal concrete of M23 grade is lower by around 4% and 9% respectively for M23SD10 and M23SD30 concrete, whereas the same value is reported to be higher by around 3%, 13% and 5% for M23SD20, M23SD40 and M23SD50 concrete respectively.

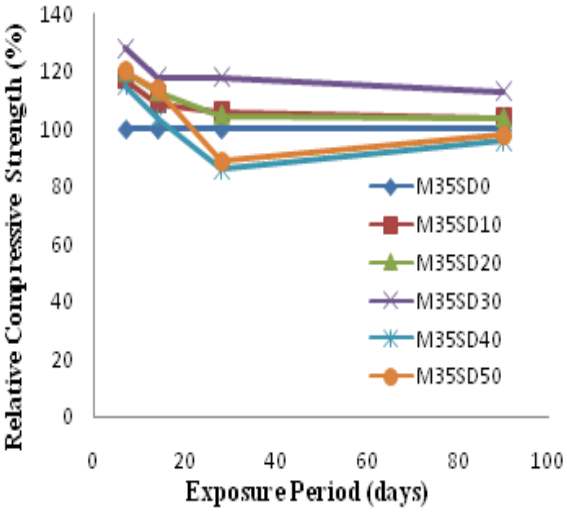

***Figure4**: Relative Compressive strength of M35 concrete*

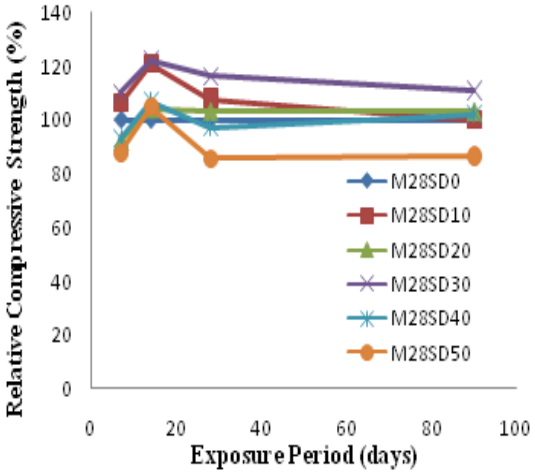

***Figure5**: Relative Compressive strength of M28 concrete*

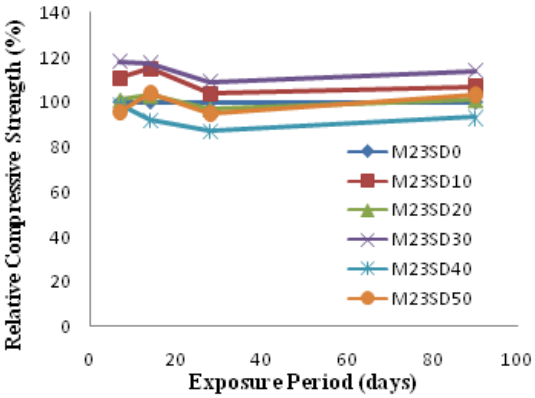

***Figure6**: Relative Compressive strength of M23 concrete*

From the test consequence it is found that the 90 days compressive strength of M35SD10, M35SD20 and M35SD30 concrete is 4%, 4% and 13% higher than normal concrete but at the same curing duration the compressive strength of M35SD40 and M35SD50 concrete is 4% and 2% lesser than normal concrete.

Concrete normally gains its maximum percentage of strength within 28 days. Now with respect to 28 days M35SD0 concrete the compressive strength of 7 days and 14 days M35SD30 concrete is lower by 25% and 22% respectively, whereas for 28 days and 90 days M35SD30 concrete is higher by 18% and 23% respectively.

Rate of strength attainment for different types of concrete is observed to vary with the grade of concrete. Gain in strength is higher for the higher grade of concrete. Among all the concrete studied, 28 days compressive strength is increased by about 6%, 5% and 18% for concrete M35SD10, M35SD20 and M35SD30 respectively as compared to 28 days M35 grade normal concrete, whereas the same value is increased by about 8%, 3% and 16% for concrete M28SD10, M28SD20 and M28SD30 respectively than M28 grade normal concrete, similarly the assessment is conducted for M23 grade concrete also and the same value is found to be increased by 4%, -3% (i.e. decreased by 3%) and 9% than the normal concrete. So it can be concluded that strength gaining is relatively faster for higher grade concrete as compared to lower grade concrete.

The value of compressive strength of concrete is observed to be optimum for 30% sand replacement level. The compressive strength of concrete is around 15% higher than normal concrete for 30% sand replacement by stone dust. The compressive strength of concrete is observed to be maximum for M35 grade concrete. For different sand replacement level, the minimum compressive strength of concrete is found at 40% sand replacement level.

4.2 Tensile Strength:

The tensile strength of normal and stone dust concrete of three different grades M35, M28 and M23 has been graphically presented in **Fig.7, Fig.8** and **Fig.9**. Also for the ease of comparison, the relative tensile strengths are plotted in **Fig.10, Fig.11** and **Fig.12**. From the early age of curing, stone dust concretes achieve relatively higher tensile strength as compared to normal concrete.

Test result shows that 7 days tensile strength of M35SD10, M35SD20, M35SD30, M35SD40 and M35SD50 concrete is 18%, 25%, 10%, 25% and 21% higher than normal concrete i.e. M35SD0. From the initial age of curing, tensile strength is seen to increase with the increase of stone dust content as a partial replacement of fine aggregate i.e. natural sand.

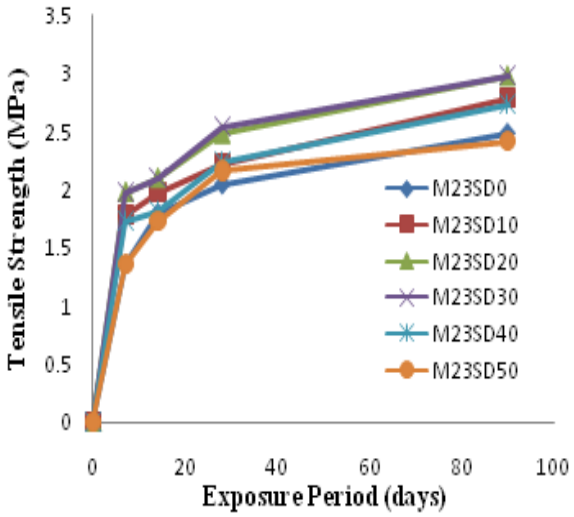

Figure9: *Tensile strength of M23 concrete*

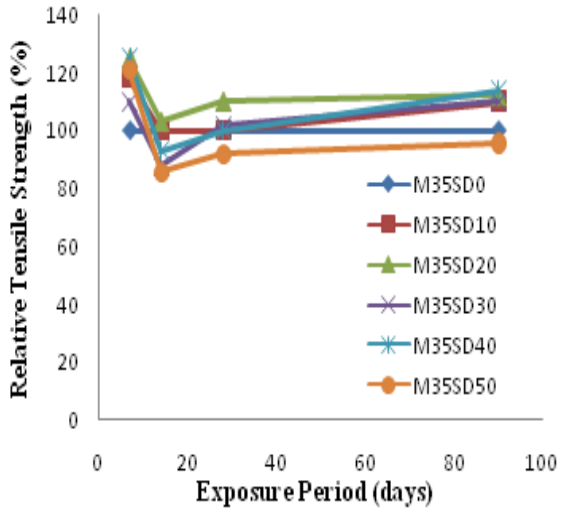

Figure10: *Relative Tensile strength of M35 concrete*

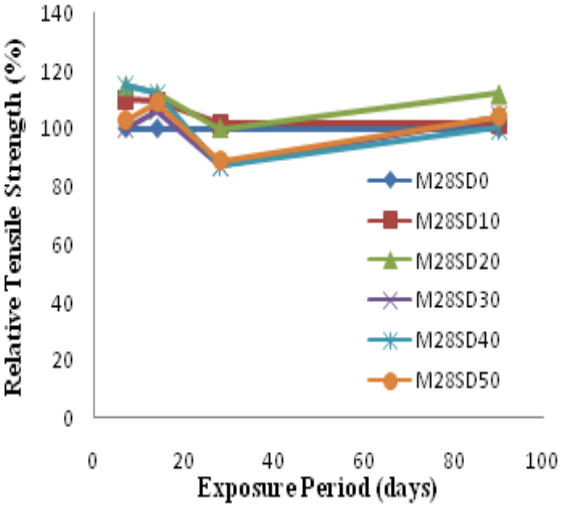

Figure11*: Relative Tensile strength of M28 concrete*

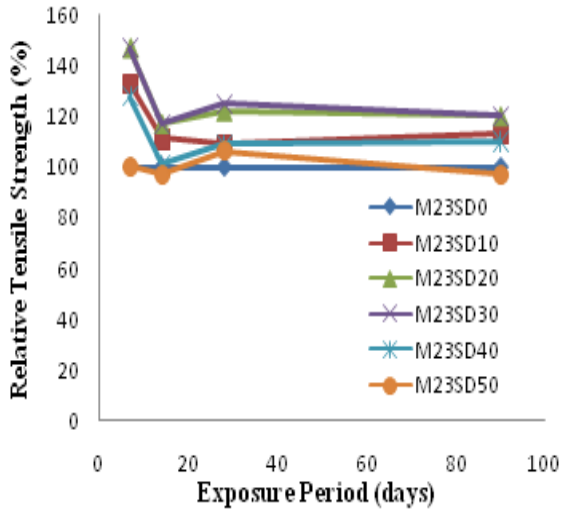

Figure12: *Relative Tensile strength of M23 concrete*

Furthermore, 14 days tensile strength of normal concrete of M28 grade is lower by around 9%, 12%, 6%, 12% and 9% respectively for M28SD10, M28SD20, M28SD30, M28SD40 and M28SD50 concrete. Similarly, 28 days tensile strength of normal concrete of M23 grade is lower by around 9%, 22%, 25%, 9% and 6% respectively for M23SD10, M23SD20, M23SD30, M23SD40 and M23SD50 concrete.

From the test consequence it is found that the 90 days tensile strength of M35SD10, M35SD20, M35SD30 and M35SD40 concrete is 10%, 12%, 10% and 14% higher than normal concrete but at the same curing duration the tensile strength of M35SD50 concrete is 4% lesser than normal concrete.

Concrete normally gains its maximum percentage of strength within 28 days. Now with respect to 28 days M35SD0 concrete the tensile strength of 7 days and 14 days M35SD20 concrete is lower by 29% and 10% respectively, whereas for 28 days and 90 days M35SD20 concrete is higher by 10% and 16% respectively.

Rate of strength attainment for different types of concrete is observed to vary with the grade of concrete. Gain in strength is higher for the higher grade of concrete. Among all the concrete studied, 90 days tensile strength is increased by about 10%, 12% and 10% for concrete M35SD10, M35SD20 and M35SD30 respectively as compared to 28 days M35 grade normal concrete, whereas the same value is increased by about 2%, 12% and 4% for concrete M28SD10, M28SD20 and M28SD30 respectively than M28 grade normal concrete, similarly the assessment is conducted for M23 grade concrete also and the same value is found to be increased by 13%, 20% and 20% than the normal concrete. So it can be concluded that strength gaining is relatively faster for higher grade concrete as compared to lower grade concrete.

The value of tensile strength of concrete is observed to be optimum for 20% sand replacement level. The tensile strength of concrete is around 12% higher than normal concrete for 20% sand replacement by stone dust. The tensile strength of concrete is observed to be maximum for M35 grade concrete. For different sand replacement level, the minimum tensile strength of concrete is found at 50% sand replacement level.

4. Conclusions:

The result of this study has great significance for providing high strength as well as durable concrete by using stone dust. This paper presents the compressive and tensile strength of concrete for 7 days, 14 days, 28 days & 90 days curing periods. On the basis of different concrete mix-ratios, sand replacement level by stone dust and exposure periods, the following conclusions can be drawn:

- The value of compressive strength of concrete is observed to be maximum for 30% sand replacement and the corresponding compressive strength is around 15% higher than normal concrete (0% sand replacement level) of similar mix.
- Among the various concrete mix studied, the compressive strength of concrete is observed to be maximum for mix ratio 1: 1.5: 3
- The value of tensile strength of concrete is observed to be maximum for 20% sand replacement and the corresponding tensile strength of concrete is around 12% higher than normal concrete (0% sand replacement level) of similar mix.
- Among the various mix studied the tensile strength of concrete is observed to be maximum for mix ratio 1: 1.5: 3.

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References:

[1] Ahmed, A.A.M., Mahzuz, H.M.A. and Yusuf, M.A. (2010), Minimizing the stone dust through a sustainable way: a case study of stone crushing industry of Sylhet, Proc. International Conference on Environmental Aspects of Bangladesh (ICEAB10), Japan.

[2] Aziz, M.A., (1995), Engineering Materials, Z and Z Computer and Printers, Dhaka, Bangladesh.

[3] Balamurugan, G. and Perumal, D.P. (2013), Use of Quarry Dust to replace Sand in Concrete- An experimental study, International Journal of Scientific and Research Publications, Vol. 3.

[4] Hameed, M. S. and Sekar A. S. S., (2009), Properties of green concrete containing quarry rock dust and Marble sludge powder as fine aggregates, ARPN journal of Engineering and applied Science, Vol.4(4), pp. 83-89.

[5] Hendrik, G. and van Oss (2007), Mineral Commodity Summaries- Cement. US Geological Survey, 40-41.

[6] Hossain, T. and Seraj, S.M. (1985), Laboratory Mannual on CE-202 Material Sessional. Department of Civil Engineering, Bangladesh University of Engineering and technology, Dhaka, Bangladesh.

[7] Ilangovana, R. Mahendrana, N. and Nagamanib, K., (2008), Strength and durability properties of concrete containing quarry rock dust as fine aggregates, ARPN Journal of Engineering and Applied Science, Vol.3(5), pp. 20-26.

[8] Kameswari, K.S.B., Bhole, A.G. and Paramasivam, R. (2001), Evaluation of Solidification (S/S) Process for the Disposal of Arsenic Bearing Sludge in Landfill sites. Environ. Eng. Sci., 18: 167-176.

[9] Kumar, L. and Singh, A. (2015), A study on the Strength of Concrete using Crushed Stone Dust as Fine aggregate, International Journal for Research in Applied Science & Engineering Technology (IJRASET), Vol. 3, pp. 308-316.

[10] Lomborg, B. (2001), The Skeptical Environmentalist: Measuring the Real State of the World. Cambridge University Press, UK.

[11] Mahzuz, H.M.A., Ahmed, A.A.M. and Yusuf, M.A. (2011), Use of Stone powder in Concrete and Mortar as an alternative of Sand, African Journal of Environmental Science and Technology, Vol. 5(5), pp. 381-388.

[12] Mogaveera, G., Sarangapani, G., and Anand, V. R. (2011), Experimental investigation on the effect of partial replacement of sand by quarry dust in plain cement concrete for different mix proportions, Proc Emerging Trends in Engineering, NMAMIT, Nitte, pp. 812-817.

[13] Muhit, I.B., Raihan, M.T., Nuruzzaman, M. (2014), Determination of Mortar Strength using Stone Dust as a Partially replaced material for Cement and Sand, Advances in Concrete Construction, Vol. 2, No. 4, pp. 249-259.

[14] Nagabhushana and Sharada bai, H. (2011), Use of Crushed Rock Powder as replacement of Fine aggregate in Mortar and Concrete, Indian Journal of Science and Technology, Vol. 4, No. 8.

[15] Nagpal, L., Dewangan, A., Dhiman, S. and Kumar, S. (2013), Evaluation of Strength Characteristics of Concrete using Crushed Stone Dust as Fine Aggregate, International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol.2, Issue. 6.

[16] Palaniraj, S. (2003), Manufactured sand. Intl. Conf. on Recent trends in Concrete Technology and Structures, (INCONTEST), Coimbatore.

[17] Reddy, M.V. and Reddy, C.N.V.S., (2007), An experimental study of rock flour and insulator ceramic scrap in concrete, Journal of Institute of Engineer (India), Vol-88, pp. 47-50.

[18] Reddy, M.V.S., Mrudula, D., Seshalalitha, M. and Hariprasad, P. (2015), The effect of Crushed Rock Powder and Super plasticizer on the fresh and hardened properties of M_{30} grade Concrete, International Journal of Civil, Structural, Environmental & Infrastructure (IJCSEIERD), Vol. 5, pp. 25-30.

[19] Sanchez, F., Garrabrants, A.C., Vandecasteele, C., Moszkowicz, P. and Kosson D.S. (2002), Environmental Assessment of Waste Matrices Contaminated with Arsenic. J. Hazard. Mater., 96: 229-257.

[20] Shih, C.J., Lin, C.F. (2003), Arsenic Contaminated Site at an Abandoned Copper Smelter Plant: Waste Characterization and Solidification/ Stabilization Treatment. Chemosphere, 53: 691-703.

[21] Shukla, M., Shau, A.K. and Sachan, A.K. (1998), Performance of stone dust as fine aggregate in Portland replacing Sand on concrete and mortar, National seminar on advances in special concretes, Indian concrete institute, banglore, India, pp 241248.

[22] Sukesh, C., Krishna, K.B., Teja, P.S.L.S. and Rao, S.K. (2013), Partial replacement of sand with Quarry dust in Concrete, International Journal of Innovative Technology and Exploring Engineering (IJITEE), Vol.2, Issue. 6.