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Use of Stone Powder with Sand in Concrete and Mortar: A Waste Utilization Approach

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ABSTRACT

Disposal of stone dust resulting from crushing activities has been become a crucial issue in Bangladesh. Sand is commonly used as a fine aggregate in Bangladesh. This study concentrates on the determination of the strength of mortar and concrete by using mixture of sand and powder sand in various ratios as fine aggregate so as to find an alternative of sand and to minimize and utilize waste. The objective of the study is to establish that the powder sand can be used as an alternative of sand or mixed with sand in making medium grade concrete and mortar where high strength is no required . The study has been conducted in different proportion of sand and powder sand in different mixing ratio for both mortar and concrete. In this study crushed stones are used to make concrete as coarse aggregate. The laboratory tests are made to find the strength for various ratios and then are compared to each other. The result shows that stone powder shows almost equivalent strength as shown by sand and can easily be used in low strength concrete and mortar works.

Keywords: *Mortar, concrete, fine aggregate, powder sand, compressive strength.*

1. INTRODUCTION

Concrete, is an artificial stone manufactured by combining a binding material, inert materials or aggregate with water, an attractive material for a wide range of structural applications (Aziz,1995; Mahzuz et al., 2011; Ferguson et al., 1988). It is considered as a chemically combined mass where the inert material acts as a filler and the bonding material acts as a binder (Aziz,1995). Cement is usually used as binding material (Aziz, 1995; Chamberlain, 1995). Mortar is also an important building a material. Mortar is composed of cement (as a binding material), fine aggregate and water etc. (Aziz,1995). In preparation of concrete sand is usually used as fine aggregate in Bangladesh (Ahmed and Yusuf, 2009; Aziz, 1995). In this study powder sand (i.e. stone dust) is used as fine aggregate in addition with sand and as an alternative of sand. Jaflong is a place of rare natural beauty. Not long ago visitors to this remote area would be confronted by a glorious triad of river, hills and brilliant blue sky that could have come straight out of an artist's canvas. The spot where most tourists gather is called Bollar (boulder) Ghat. Boulders have become Jaflong's bane (The Star, 2009; Haque and Masum, 2011). In Jaflong a huge numbers of stone crushers are available, as a result of these extensively labor oriented economic activities, a large number of low income workers live in Jaflong and its surrounding (Mahzuz et al., 2011; Haque and Masum, 2011). Generally powder sand is originated during stone crushing. Boulder stones are crushed in the stone crusher to produce different size of crushed stone which is used as coarse aggregate in preparation of concrete for different construction purposes. During this process powder sand is produced as by-product (Ahmed and Yusuf, 2009; Mahzuz et al., 2011; Haque and Masum, 2011). Powder sand is usually considered as waste (Mahzuz et al., 2011; Ahmed and Yusuf, 2009). Some of those are used in land filling, making bricks, hollow bricks; sanitary rings etc. but a large mass of powder sand are thrown in a stack (Haque and Masum, 2011).These improper disposals of powder sand are seriously threatening to public health, environment, agricultural land and beauty of the area (Mahzuz and Tajmunnahar, 2010; Haque and Masum, 2011). The study focuses on the utilization of the powder sand by engineering way and at the same time reducing the unplanned disposal of powder sand. The main objective of the study is to determine relative performance of the concrete and mortar made by mixing normal sand and powder sand (stone Powder) in different ratios where the coarse aggregate is crushed stone. Previously a research work in Civil and Environmental Engineering Department of SUST was conducted by Ahmed and Yusuf (2009) relating with the comparison of compressive strength of mortar and concrete by normal sand and powder sand. Villalobos et al., (2005) conducted several research works on the basis of alternative fine aggregate and admixture and a numerous research works have been carried out by researchers to get an fruitful alternative way of waste utilization and minimization therefore (Mahzuz et al., 2011; Mahzuz et al. 2009, Sanchez et al., 2002; Shih and Lin, 2003; Kameswari et al., 2001). In this study normal sands and powder sands were mixed in various ratios in preparation of mortar and concrete and their relative strengths were compared.

2. METHODOLOGY

The research methodology that has been undertaken during the conduction of the study includes field observation, collection of data/sample, data study, laboratory test, data analysis.

The powder sand was collected from Jaflong which is generated during the crushing of stone. Sand that

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has been used for this study was collected from Sari river known as sari sand and also known Sylhet sand. Crushed stones were used as coarse aggregate. After gathering these materials, the properties of the collected sample have been determined. Fineness modulus of sand and powder sand has been determined by ASTM method using sieve shaker and particle size gradation curve of coarse aggregate has also been determined.

To find out whether the powder sand can be uses with sand as a fine aggregate a certain amount of laboratory experiments have been conducted. The sand and powder sand was mixed with various ratios to prepare mortar and concrete and their strengths were compared with each other. For this purpose 50mm x 50mm (2" x 2") mortar block and concrete cylinder of 150mm diameter x 300mm height (6" diameter x 12" height) has been tested.

The ratios those are used for the mortar are shown in a tabular form below.

Table 1: Mixing ratios used for preparation of mortar

Cement : sand + powder sand	Cement : sand + powder sand
1:(3+0)	1:(2.5+0)
1:(2+1)	1:(1.75+0.75)
1:(1+2)	1:(0.75+1.75)
1:(0+3)	1:(0+2.5)

The mixing ratios those are used for concrete are shown in a tabular form below.

Table 2: Mixing ratios used for the preparation of Concrete

Cement : (sand + powder sand) : crushed stone	Cement : (sand + powder sand) : crushed stone
1: (2+0) :4	1: (1.5+0): 3
1: (1+1) :4	1: (0.75+0.75): 3
1: (0.5+1.5) :4	1: (0.5+1): 3
1: (0+2) :4	1: (0+ 1.5): 3

The mortar cubes and concrete cylinders were prepared by following the standard procedure. After preparation, the cube and cylinder specimens were stored undisturbed for 24 hours. After 24 hours those specimens were released from the mould and were further cured in water. After specific days the specimens were taken out from the water and dried for half an hour. The specimens were tested to determine the crushing strength by using universal compressive testing machine.

The peak load and strength was obtained from the machine and the obtained result is analyzed and compared to each other. Depending comparison of the results discussion was prepared.

3. RESULT AND DISCUSSION

a. Fineness Modulus of Sand

Table 3: Sieve analysis data of normal sand

Sieve no	Material retained gm	Percentage retain	Cumulative percentage retain
4	20.5	2.07	2.07
8	50.5	5.1	7.17
16	158.5	16.01	23.18
30	411	41.52	64.7
50	231	23.33	88.03
100	108.5	10.96	98.99
Pan	10	1.01	100
Sum	990	100	

Fineness modulus of sand = 2.84

b. Fineness Modulus of Powder Sand

Table 4: Sieve analysis data of powder sand

sieve no	material retained gm	percentage retain	cumulative percentage retain
4	0	0	0
8	3.5	0.35	0.35
16	193.5	19.55	19.9
30	201.5	20.35	40.25
50	180	18.18	58.43
100	314.5	31.78	90.21
Pan	97	9.79	100
Sum	990	100	

Fineness modulus of powder sand = 2.09

c. Compressive Strength of Mortar

From the laboratory experiment we found compressive strength of mortar (50 mm x 50mm) for 1:3 and 1:2.5 for the various mixing ratio of sand and powder sand. The obtained results are shown in a tabular from below.

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Table 5: Comparison of stresses (MPa) of mortar cube (50mm x 50 mm) for ratio 1:3

Mix ratio (cement :sand+ powder)	7 days				14 days				28 days			
	1	2	3	mean	1	2	3	mean	1	2	3	Mean
1: (3+0)	15.2	17.1	16.74	16.35	16.3	17.69	16.2	16.83	17.98	18.34	21.4	19.24
1: (2+1)	16.0	16.99	17.4	16.80	18.5	17.98	16.8	17.76	23.6	20.58	18.4	20.86
1: (1+2)	15.8	16.98	16.7	16.49	17.9	16.85	17.8	17.52	24.2	19.2	19.87	21.09
1: (0+3)	14.5	16.85	15.9	15.75	17.8	16.89	16.5	17.06	20.2	17.98	19.2	19.13

Table 6: Comparison of stresses (MPa) of mortar cube (50mm x 50 mm) for ratio 1:2.5

Mix ratio (cement :sand +powder)	7 days				14 days				28 days			
	1	2	3	mean	1	2	3	mean	1	2	3	Mean
1: (2.5+0)	17.93	16.3	17.6	17.28	19.62	18.3	16.5	18.14	20.71	21.26	19.59	20.52
1: (1.75+0.75)	18.2	17.34	17.24	17.59	18.5	18.3	18.70	18.50	22.60	21.94	20.4	21.65
1: (0.75+1.75)	20.32	18.5	17.93	18.92	20.24	18.6	18.9	19.24	24.48	22.30	19.87	22.22
1:0:2.5	18.6	16.4	14.3	16.43	17.8	16.5	18.69	17.66	20.6	19.93	19.2	19.71

d. Compressive Strength Of Concrete Cylinder

For the preparation of concrete, crushed stone was used as coarse aggregate and sand and powder was used as fine aggregate. The tests were made by changing the ratios of sand and powder under the mixing ratio of 1:2:4 and 1:1.5:3. The result obtained from the laboratory experiment shown in tabular form below.

Table 7: Comparison of strength (MPa) of concrete cylinder (300mm x 150 mm) for ratio 1:2:4

Mix ratio (cement:sand:powder:stone)	28 days		
	1	2	Mean
1:2:0:4	22.20	21.88	22.04
1:1:1:4	21.87	20.82	21.35
1:1.5:0.5:4	19.37	19.42	19.40
1:0:2:4	20.60	21.50	21.05

Table 8: Comparison of strength (MPa) of concrete cylinder (300mm x 150 mm) for ratio 1:1.5:3

Mix ratio (cement:sand:powder:stone)	28 days		
	1	2	Mean
1:1.5:0:3	22.09	27.63	24.86
1:0.75:0.75:3	19.94	18.74	19.34
1:0.5:1:3	20.90	21.36	21.13
1:0:1.5:3	21.83	22.14	22.99

e. Graphical Representation

From the study it is evident that the compressive strength for the powder sand mortar and for the mixture of sand and powder sand is quite similar to that of sand mortar for the ratio 1:3 and 1:2.5.

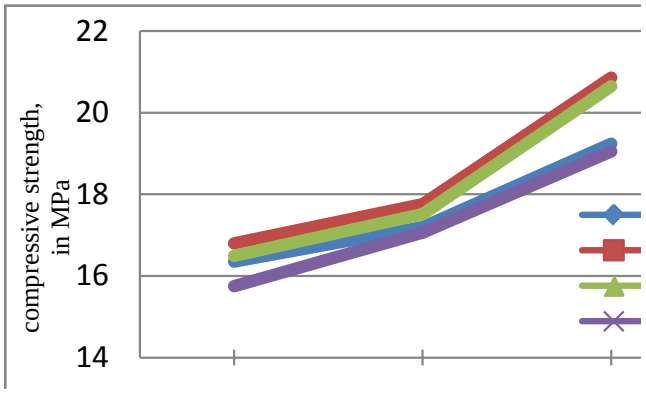

Fig 1: Compressive Strength vs. Duration for the mortar of 1:3

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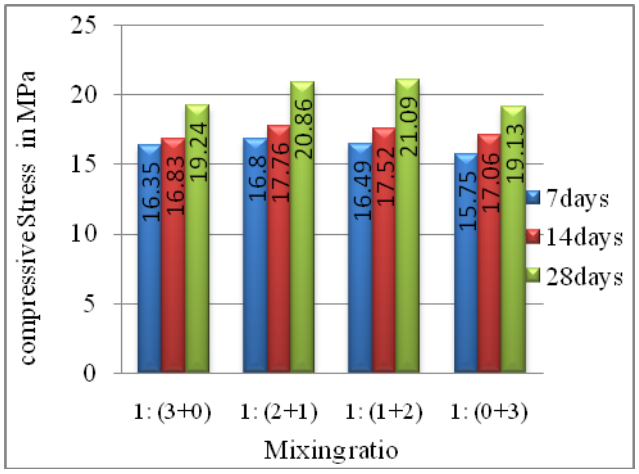

Fig 2: Compressive Strength of mortar (1:3) for various mixing ratio

Fig 1 and 2 shows the compressive strength of the mortar of ratio 1:3 with various mixing proportion of sand and powder sand. It can be seen that after 7 days the compressive strength of mortar (50mm x 50mm) for the ratio of 1: (3+0)) is 16.35 MPa and that for a ratio of 1: (0+3) is 15.75 MPa. The strength for the ratio 1: (2+1) is found 16.8 MPa and that for 1: (1+2) is found 16.49 MPa. The differences between these values are very small. The difference between the maximum value and minimum is 6.25%. After 14 days the maximum strength is obtained for 1: (2+1) is 17.76 MPa and minimum value is obtained for 1: (3+0) is 17.06 MPa. The compressive strength is increased by 4.1% from 1: (3+0) to 1: (2+1). It can be seen that after 28 days the maximum strength is obtained for 1: (2+1) is 20.86 MPa and minimum strength is obtained for 1: (0+3) is 19.05 MPa and for the sand mortar (1:3+0) the strength is found 19.24 MPa. For the ratio 1: (2+1) stress is increased by 8.42% from 1: (3+0) and 9.5% from 1: (0+3).

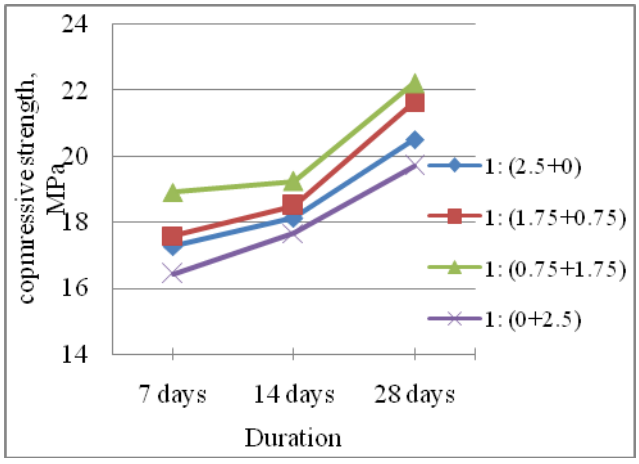

Fig 3: Compressive Strength vs. Duration for the mortar of 1:2.5

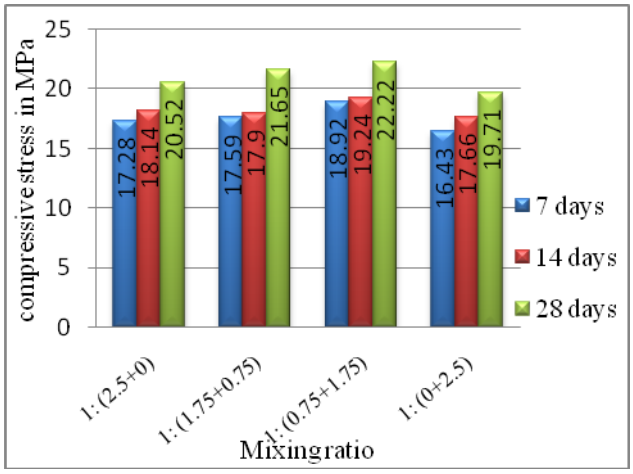

Fig 4: Compressive Strength of mortar (1:2.5) of various mixing ratio

Fig 3 and 4 shows the compressive strength of mortar of 1:2.5 with various mixing proportion of sand and powder sand. From the figure it is evident that after 7 days the maximum strength is found for the ratio 1: (0.75+1.75) is 18.92 MPa and minimum value is obtained for 1: (0+2.5). The difference between maximum and minimum is 15.15%. After 14 days the strength for 1: (0.75+1.75) is found 19.24 MPa, which increased by 6.1% from 1: (0+2.5) and 8.9% from 1: (2.5+0). It can be seen that after 28 days the maximum strength is found for 1: (0.75+1.75) is 22.22 MPa which is increased by 8.3% from 1: (2.5+0) and 12.7% from 1: (0+2.5).

After analyzing these data found from the laboratory experiment it has been seen that the strength of mortar and concrete for various ratios were very close to each other. The highest compressive strength for the mortar is found for the ratio 1: 0.75+1.75 and is 22.22 MPa and without sand it is found 19.71 MPa and only for sand it is found 20.52 MPa. So mortar can be prepared without using sand and only by the powder sand as the difference of strengths are very minor. If sand and powder sand are mixed together it will give a better result.

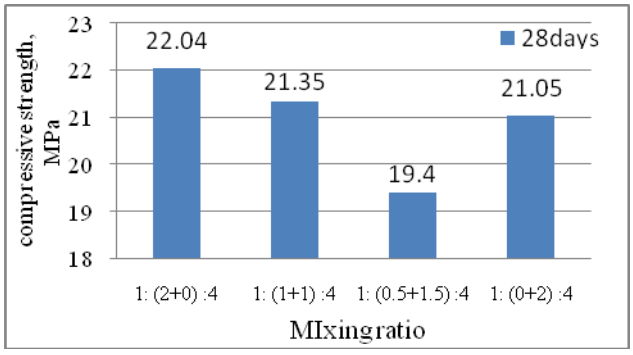

Fig 5: Compressive Strength of concrete cylinder of 1:2:4 at 28 days

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Fig 5 shows the compressive strength for concrete cylinder (300mm x 150 mm) after 28 days for the ratio of 1:2:4. It is evident that the compressive strength is gradually decrease as the quantity of powder sand is increased from 1: (2+0) :4 to 1: (0.5+1.5) :4 from a value of 22.04 MPa to 19.4 MPa and then increase for 1: (0+2) :4 is 21.05 MPa.

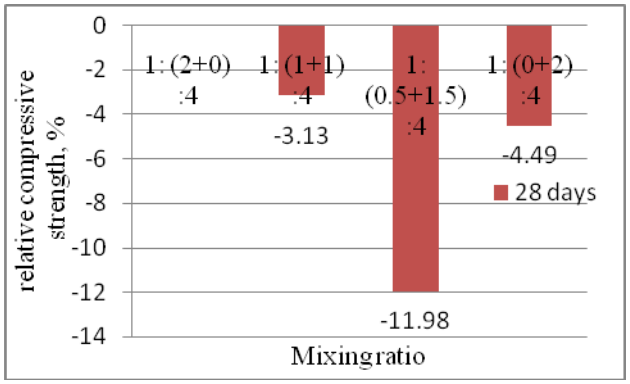

Fig 6: Relative strength for different ratio of sand and powder under 1:2:4

Figure 6 represents the relative strength for the different ratio under 1:2:4. It can be seen that the minimum value is obtained for 1: (0.5+1.5) :4 and is decreased by 11.98% from the maximum value which is obtained for 1: 2+0 :4.

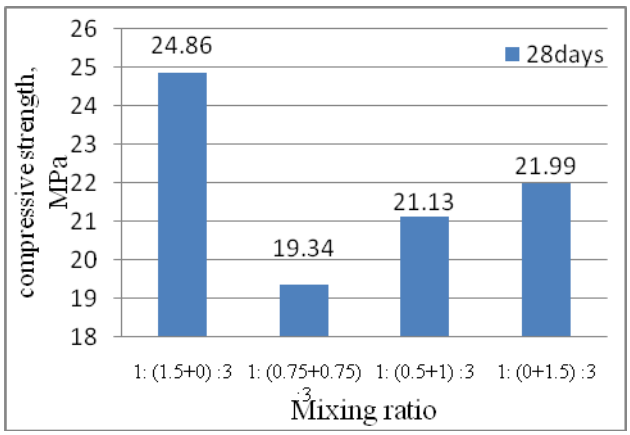

Fig 7: Compressive Strength of concrete cylinder of 1:1.5:3 at 28 days

Fig 7 shows that the changes in compressive strength of the concrete cylinder for the various proportions of sand and powder sand at 28 days. The strength decreased from 24.86 MPa to 19.34 MPa for the ratio of 1: 1.5+0 :3 and 1: 0.75+0.75 :3 respectively and then increased to 21.99 MPa for 1:0:1.5:3.

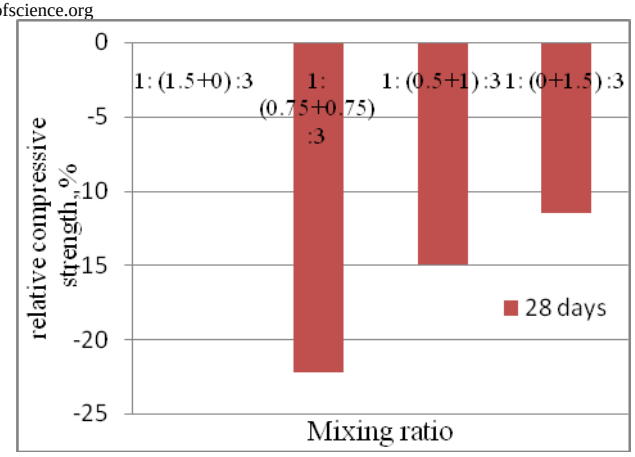

Fig 8: Relative strength for different ratio of sand and powder under 1:1.5:3.

Figure 8 shows the relative strength of concrete cylinder for the ratio of 1:1.5:3. The strength is decreased by 22.2% for 1: 0.75+0.75:3 from 1: 2+0 :4 and it is much less for 1: 0+1.5 :3 is 11.54%.

From these graphs it can be seen that the compressive strength for the concrete from sand and stone showed a value of 24.86 MPa and that for powder sand and stone was 21.99 MPa which is only 11.5% less than that for sand. From the laboratory experiment, minimum compressive strength of concrete is obtained 19.34 MPa for the ratio of 1: 0.75: 0.75:3.

From the sieve analysis it is found that the fineness modulus of sand is 2.84 and that for powder is 2.09. With coarser particle concrete obtain higher strength. With a lower fineness modulus powder showed encouraging performance.

In this experiment concrete with powder sand showed equivalent strength than sand. With a mixture of powder and sand concrete obtained lesser strength. This is due to lower value of fineness modulus of powder sand. If grading of powder sand is conducted it will show a higher strength.

So for the structure required high strength this mixture can be used under careful observation. The grading of powder sand should be done carefully to obtain a better result.

Powder sand has generally no economical value and is treated as waste. It also has a bad impact on public health and environment. So if it is used in preparing mortar and concrete the cost will be minimized as well as the waste will be reduced. Again if enough powder sand is not available, sand and powder sand can be mixed together which will also give a satisfactory result.

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4. CONCLUSION

From the study it can be concluded that powder sand can be used for mortar as an alternative of sand. For mortar, mixture of sand and powder sand can be used as well as it showed better performance. For concrete mixture of powder sand with sand showed a little poor performance. So mixture of powder sand and sand can be used for medium grade concrete. If better quality of powder sand can be used it may give better result in terms of strength. Proper gradation of sand and powder sand can give a better result. Moreover, the economic value of powder sand is almost zero and generally is treated as waste. If it is used in making of mortar and concrete cost will be minimized as well as waste will be reduced.

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