

Influence of Mix Proportion of Sylhet and Local River Sand on the Compressive Strength of Concrete

Ali Ahmed

Department of Civil Engineering, Stamford University Bangladesh, Dhaka, Bangladesh.

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ABSTRACT

This study is aimed to observe the effect of mix proportion of Sylhet and locally available river sand on the compressive strengths of concrete. A series of laboratory tests is carried out for six different mix proportions 5:0, 4:1, 3:2, 2:3, 1:4 and 0:5 of Sylhet sand and local river sand, respectively. For all of the mix ratios, compressive strengths are determined at 28 days. The compressive strengths increase by designing the appropriate gradation of sand mix, which is determined by fineness modulus of both types of sand and their mixes. The results indicate that the best of the corresponding six mix proportions of Sylhet and local sand is 3:2.

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Introduction

Concrete mixes are proportioned on the basis of achieving the desired compressive strength at the specified age, which often play a vital role in concrete making. The proper selection of the concrete ingredients and their relative proportions in concrete mix are the key parameters of making concrete of desired strength [1]. Different methods are available to produce a normal concrete mix of desired strength [2]. Among the various methods in use, the method adopted in the commentary of American Concrete Institute Committee 363 [3] is widely implemented by the both research community and design offices. However, some recent experiences and subsequent studies made at Bangladesh University of Engineering and Technology have revealed that the ACI method of mix design is unable to predict the relative ratio of fine and coarse aggregates for few cases. In such cases, the designed mixes could not attain desired strength [4, 5].

In the process of attaining strength, concrete chemically bonds the aggregates from which fine aggregate acts as filler with the help of binding material. There are two types of aggregates used in making concrete mass; they are fine and coarse aggregates. As the voids containing in the coarse aggregate are filled up with fine aggregate and the voids in the fine aggregate are filled up with the binding material, the finest grading of concrete mass which contributes to obtain maximum strengths of concrete [6,7] is processed to produce.

An experimental study has been carried out in Concrete Material and Strength of Materials laboratories of Stamford University Bangladesh to observe the effects of fineness modulus of fine aggregates on the strength of concrete. In this present study, the isolated influence of sand mix proportions on the compressive strength of concrete has also been aimed to investigate. To determine the isolated contribution of the mixing ratios of Sylhet sand and local river sand on the properties of concrete, the effect of other concrete mix design variables are kept constant. Based on the experimental results of stress-strain relationships and 28-day compressive strengths

of concrete cylinders, the best option among six mix proportions of Sylhet and local river sand is identified.

Experimental Program

Constituent Materials of Concrete

The constituent materials used in the preparation of concrete cylinders are tested to identify their essential properties in order to assure their uniformity of supply in concrete mass. Ordinary Portland of Scan brand cement is used in this experimental study. The specific gravity of the cement material is 3.148 defined according to ASTM C128-84 [8]. Fineness modulus of Sylhet sand and local river sand are determined by conducting sieve analysis [9] in the Concrete Material Laboratory and they are 3.19 and 1.58, respectively. The respective values of specific gravities of Sylhet sand and local river sand are obtained 2.71 and 2.74 following ASTM C128-84 [8]. Crushed, angular and graded coarse aggregates of nominal maximum sizes of $\frac{3}{4}$ " and $\frac{1}{2}$ " are used in proportion of 3:1 in the investigation. The combined specific gravity of the coarse aggregates is 2.87 determined in accordance with ASTM C127-84 [10]. Normal supply water is used to make the fresh concrete with water/cement ratio of 0.5.

Experimental Procedure

The batching of concrete is done by weighing the constituent materials based on the adopted mix ratio of 1:1.5:3 [11]; the quantities with other properties of constituent materials of concrete are shown in Table 1. The fine aggregate portion defined in ASTM C778-13 Standard Specification for Standard Sand Format [12] is achieved by combining Sylhet sand and local river sand of different ratios taken as the parameter studied in this investigation. Based on total quantity of fine aggregate, the weights of Sylhet sand and local river sand shown in Table 1 are obtained for six different mix combinations, while the quantities of cement, coarse aggregate and water remained constant as stated before. The materials such as cement, sand and crashed stones of ratio 1:1.5:3 in weight are then manually mixed thoroughly before adding

Tele:

E-mail address: aliahmed@stamforduniversity.edu.bd

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water following as standard procedure ASTM Standard C 470-87 [13]. Afterward prescribed quantity of water is added gradually and mixing is continued persistently until a workable mixture is obtained. Then, the workability that is the quantity of water content of fresh concrete is checked using slump test following the ASTM C143-78 slump test standards [14]; slump of fresh concrete is found 1.27". Casting in a prepared steel container is made by filling each mould with freshly mixed concrete in three layers. Each layer is compacted manually using a ¾" diameter steel tamping rod applying 25 strokes on a layer. Casted test cylinders and curing process of prepared cylinders are shown in Figure 1.

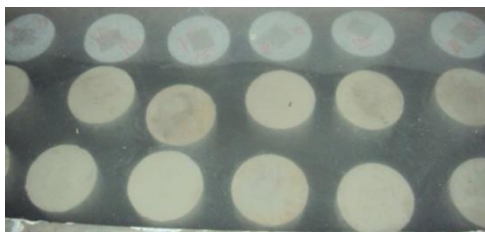
Table 1. Materials used to prepare three test cylinders

Material	Weight lb	Quantity concrete lb/ft ³	Specific gravity	Fineness Modulus
Ordinary Portland cement	13.79	23.41	3.148	–
Combined sand	Sylhet	20.69	35.12	2.71
	Local river		2.74	1.58
Crashed stone	¾" size	31.03	70.23	2.87
	½" size			
Water	6.90	11.71	1.00	–

The test setup for compressive strength tests of cylinders is shown in Figure 2. A manually driven universal testing machine is used for conducting the experiments compliant with ASTM C39-86, Standard Test Method to determine Compressive Strength of Cylindrical Concrete Specimens [15] to produce relative deformation to the applied load. Standard cylinders measuring 6" diameter and 12" length are moulded and stored in water for 28 days as recommended by ASTM C31-88 Standard Practice for Making and Curing Concrete Test Specimens in the Field [16] before the compressive strength tests. Three similar specimens are prepared for each test option. Compressive strength tests of cylinders are conducted in the Strength of Materials Laboratory of Stamford University Bangladesh.



a) 18 casted test cylinders before curing



b) 28-day curing of test cylinders

Figure 1. Casted test specimens and their curing

Description of Cylinder Test Specimens

Six set of test cylinders are prepared conforming to ASTM C31-88 standard [16] with the concrete mixing proportion 1:1.5:3 of cement, sand and crashed stone, respectively. Admixture is not considered in the experimental study. Each set of experiment contains three similar cylinder tests. In order to investigate the effect of Sylhet sand and local river sand (hereinafter denotes as local sand) mix proportion

on the compressive strength of concrete, sand used as fine aggregate in the concrete mixture is composed of Sylhet sand and local sand and the variation of both sand mix proportion is taken as a parameter investigated in this phase of study. Six types of test cylinder specimens are prepared based on varied ratios of those two types of sand mixes for the experimental observation. The test options are

Cylinder Test Option 1

The test cylinder is identified by S5LS0 which describes about the content of sand while other components of concrete mixture remain constant among all cylinders. In this option, each cylinder is prepared with the fine aggregates, a mixture of Sylhet sand and local sand of ratio 5:0 that is the mix retaining 100% of Sylhet sand with no local sand, in making fresh concrete mixture to prepare the first set of three cylinders.

Cylinder Test Option 2

The test cylinder is identified by S4LS1 which is similar to cylinder test option 1 except the mix proportion of fine aggregates (i.e. sand types). The mixture of sand types is composed of Sylhet sand and local sand of ratio 4:1 that is the mix retaining 80% of Sylhet sand and 20% of local sand to prepare the second set of three cylinders.

Cylinder Test Option 3

The test cylinder is identified by S3LS2 which is similar to the above two cylinder test options except the mix proportion of sand types. The mixture of fine aggregates (i.e. sand types) is composed of Sylhet sand and local sand of ratio 3:2 that is the mix retaining 60% of Sylhet sand and 40% of local sand to prepare the third set of three cylinders.

Cylinder Test Option 4

The test cylinder is identified by S2LS3 which is similar to the above three cylinder test options except the mix proportion of fine aggregates (i.e. sand types). The mixture of fine aggregates is composed of Sylhet sand and local sand of ratio 2:3 that is the mix retaining 40% of Sylhet sand and 60% of local sand to prepare the fourth set of three cylinders.

Cylinder Test Option 5

The test cylinder is identified by S1LS4 which is similar to the above four cylinder test options except the mix proportion of fine aggregates. The mixture of fine aggregates is composed of Sylhet sand and local sand of ratio 1:4 that is the mix retaining 20% of Sylhet sand and 80% of local sand to prepare the fifth set of three cylinders.

Cylinder Test Option 6

The test cylinder is identified by S0LS5 which is similar to the above five cylinder test options except the mix proportion of fine aggregates. The mixture of fine aggregates is composed of Sylhet sand and local sand of ratio 0:5 that is the mix retaining 100% of local sand with no Sylhet sand to prepare the sixth set of three cylinders.

Experimental Results and Discussion

Figure 2 shows the load cell dial on the right picture interpreting applied loads on the testing cylinder and deformation reading dial gage on the left picture measuring

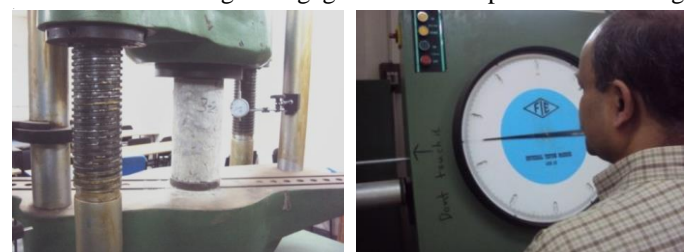


Figure 2. Test setup of a cylinder with load cell on the right

relative length change of the testing cylinder. The readings received from the dial gage are converted into deformation in millimeters dividing them by 100 and then strain is produced from the deformation dividing by the length of the cylinder in millimeters. On the other hand, stresses are the product of ratios of applied loads taken from the load cell dial and the cross sectional area of the cylinder. The stress-strain diagrams of all six options of cylinder tests are shown in Figure 3. Each of Figures 3a to f represents the results of three similar test cylinders of options S5LS0, S4LS1, S3LS2, S2LS3, S1LS4 and S0LS5, respectively.

The median curve from the three stress-strain curves of similar cylinders for each test option is derived and the stress-strain curves of median values are compared in Figure 4a. From the comparison, it is observed that test option S3LS2 containing the mixture of fine aggregates of 60% of Sylhet sand and 40% local sand demonstrates higher compressive stresses comparing with the other test options for any respective strain up to the ultimate state of concrete cylinders while the first test option S5LS0 used 100% of Sylhet sand without local sand in preparation of concrete mixture shows worse condition of strength gain. In addition, Figure 4b shows the ultimate strength capacities for all test options. This Figure also demonstrates that the test option S3LS2 is showing the highest compressive strength of 4.104 ksi (28.297 MPa) and the lowest strength of 3.143 ksi (21.673 MPa) is demonstrated for option S0LS5. The strength readings are in between of these two options for the remaining test options. Sieve analysis is performed for the six options of Sylhet sand and local sand mixes (as described in the cylinder test options) in Concrete Material Laboratory of Stamford University Bangladesh to obtain fineness modulus (FM) values according to ASTM C136-84a standard [9]. Obtained results of relationship of concrete compressive strength and fineness modulus of fine aggregates, which are

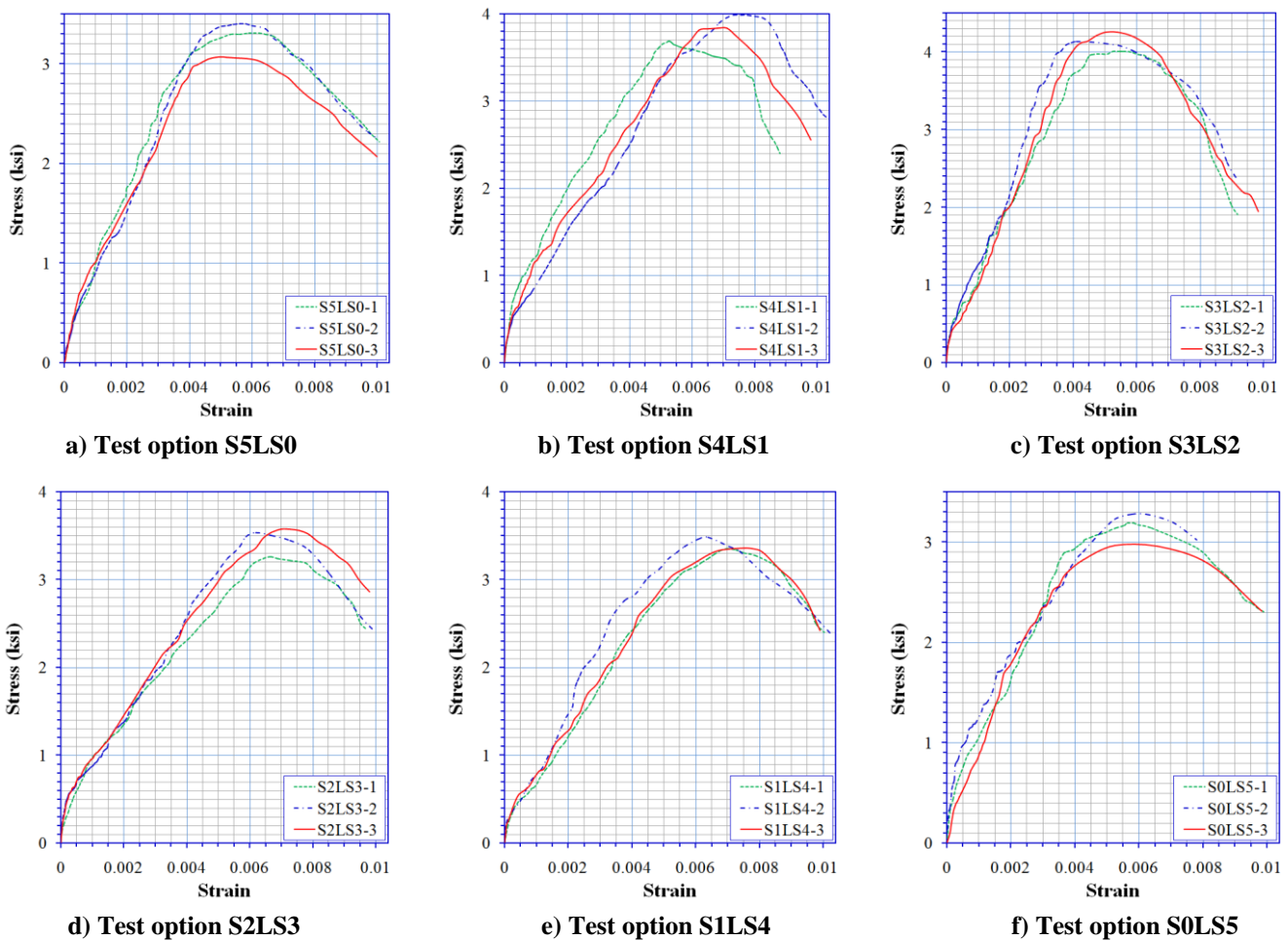


Figure 3. Stress-strain relationship driven from the compressive strength test of cylinders

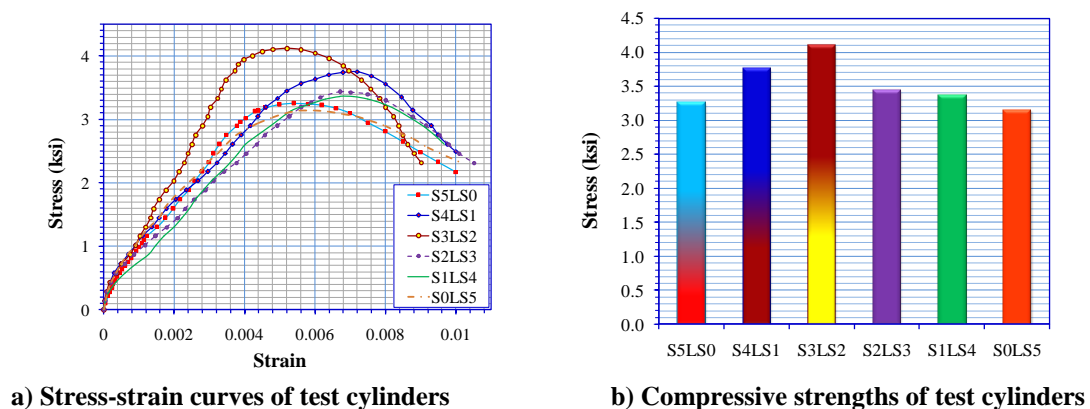


Figure 4. Comparison among the results of test cylinders of six options

the mixture of Sylhet sand and local sand, are shown in Figure 5. It is obvious from the figure that at the beginning, concrete strength increases as FM value (red solid line) goes up to the 2.47; then, strength starts reducing with farther increase of FM values. Thus, the biggest FM value of fine aggregate is not the perfect solution of receiving the highest strength of concrete rather finest grading of aggregates' mixture can offer highest strength of concrete cylinder; it was also observed by Haque et al. [17] in their experimental study. A trend line of the relationship of concrete compressive strength and fineness modulus of the mix of Sylhet sand and local sand shown with green breaking line is derived using a third order polynomial equation shown in Eq. 1. Maximum compressive strength of concrete can be achieved using this equation implying values of variable parameter FM of mixed fine aggregates (i.e. Sylhet sand and local sand) for this case of study and the highest compressive strength of concrete f'_c is calculated 4.051 ksi (27.93 MPa) for FM value $\eta = 2.67$.

$$f'_c = -0.855\eta^3 + 5.155\eta^2 - 9.26\eta + 8.3 \quad [1]$$

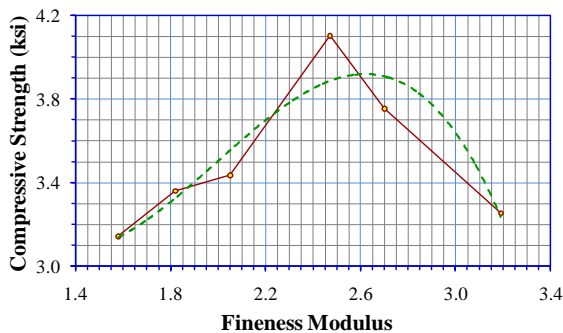


Figure 5. Correlation of concrete compressive strength to the FM of fine aggregate

Conclusions

Extensive cylinder tests are carried out to investigate the isolated effect of mix proportion of Sylhet sand and local sand on the compressive strength of concrete while the other components of concrete mixture remain constant. Six types of Sylhet sand and local sand mix proportions are used to prepare the concrete cylinders to construct stress-strain relationships by conducting the compressive strength tests of cylinders. This study reveals that

1. S3LS2 test cylinders which contain 60% of Sylhet sand and 40% of local sand showed the highest compressive strength of 4.104 ksi (28.297 MPa). On the other hand, cylinders prepared with 100% of Sylhet sand or 100% of local sand demonstrated worse performances; compressive strength of these two options are 3.254 ksi (22.44 MPa) and 3.143ksi (21.67 MPa), respectively.

2. Not only higher FM values of sand cause of getting higher compressive strength of concrete but also the finest grading of fine aggregates in concrete mixture can facilitate to achieve the better performance in concrete compressive strength behavior.

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