USE OF SLAG AS COARSE AGGREGATE AND ITS EFFECT ON MECHANICAL PROPERTIES OF CONCRETE

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ABSTRACT
Traditional coarse aggregates are very costly and its reserve will be gradually finished, possessing a great threat. Slag is considered as third class hazardous waste that requires a large place for dumping. To transform the slag into an environment-friendly resource and to save the environment from the pollution, the possibility of the use of slag as coarse aggregate cannot be overlooked. The main objective of the study is to investigate the strength properties of slag incorporated as coarse aggregate in concrete. The proportion of slag and stone chips used as coarse aggregate was varied from 0 to 100%. A total of 500 specimens of 4 inches cube were cast using plain water in normal temperature for the curing periods of 7, 14, 28,90 and 180 days. W/C ratios were varied as 0.60, 0.50 and 0.42 for making 20, 30 and 40 MPa concrete respectively and compressive as well as tensile strengths were evaluated. Concrete made by replacing coarse aggregate with BFS is observed to increase upto a replacement level of 40%.

Keywords: Coarse aggregate; compressive strength; concrete, slag tensile strength

INTRODUCTION
Slag is a byproduct of steel production left over after a desired metal has been separated (i.e., smelted) from its raw ore and it is usually a mixture of metal oxides and silicon dioxide. Low iron slag is considered as third class hazardous waste which may require a large place for dumping. Traditional coarse aggregates like stone chips, brick chips are very costly and huge amount of stones are withdrawn from Sylhet every day and as a result one day the reserve of stones will be finished which will possess a great threat to us. As per the survey conducted by En Safe, Inc. (2002) a single ferroalloys industry produces 220,000 tons of low carbon slag per year. Also survey report of European Slag Association EUROSLAG conducted among its member (European steelworks and processing companies) since 2000, it is known that in 2008, 45.6 million tons of ferrous slag was produced and more than 400 million tons of iron and steel slag is produced each year in the world. Scarcity of coarse aggregate in future and problem of dumping place for slag can be minimized if slag can be used as the partial replacement of coarse aggregate, fine aggregate or cement. The objective of the study is to minimize the cost of construction by using slag as a replacement of coarse aggregate in making environmental friendly concrete and solving the dumping problem of slag. The compressive as well as tensile strength of concrete due to the use of slag as a replacement of coarse aggregates in various proportions and at different curing period are evaluated so as to observe the effectiveness of slag as coarse aggregate in concrete.

Reviews of literature survey are presented as below-
Chen Meizhu, Zhou Mingkai, Wu Shaopeng (2007) worked on mortar made up of ground granulated blast furnace, gypsum, clinker and steel slag sand. The experimental results show the application of steel slag sand may reduce the dosage of cement clinker and increase the content of industrial waste product using steel slag sand.
Isa Yuksel, Omer Ozkan, Turhan Bilir (2006) experimented use of non ground granulated blast furnace slag as fine aggregate in concrete. The study concluded that the ratio of GGBs/sand is governing criteria

for the effects on the strength and durability characteristics.
Li Yun-feng, Yao Yan, Wang Liang (2009) investigated effects of steel slag powder on the workability and mechanical properties of concrete. Experimental results show that mechanical properties can be improved further due to the synergistic effect and mutual activation when compound mineral admixtures with steel slag powder and blast furnace slag powder mixed in concrete.
Saud Al-Otaibi (2008) studied use of recycling steel mill as fine aggregate in cement mortars. The replacement of 40% steel mill scale with that of fine aggregate increased compressive strength by 40%, drying shrinkage was lower when using steel mill scale.
Tarun R Naik, Shiw S Singh, Mathew P Tharaniyil, Robert B Wendfort (1996) investigated application of foundry by-product materials in manufacture of concrete and masonry products. Compressive strength of concrete decreased slightly due to the replacement of regular coarse aggregate with foundry slag however strengths were appropriate for structural concrete.

METHODOLOGY

In this study, concrete strength of 20, 30 and 40MPa are considered with a W/C ratio of 0.60, 0.50 and 0.42 respectively for the replacement level of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%.of natural coarse aggregate by slag and studied for compressive as well as tensile strengths for the curing periods of 7days, 14days, 28days, 90days, 180days. For each percent replacement and curing period 6 samples are prepared, 3 samples for compressive strength and 3 samples for tensile strength test.

Mix Proportions

The concrete mix proportions (design) were obtained for a control mix of slump 4 ± 1 in. (100 ± 25 mm) for 20, 30 and 40 MPa of concrete with a W/C ratio of 0.60, 0.50 & 0.42 respectively.

Materials

ASTM Type I Ordinary Portland Cement (OPC) conforming to ASTM C-150 was used as binding material. Locally available natural sand passing through 4.75 mm sieve and retained on 0.015 mm sieve and stone chips passing through 20 mm sieve was used. Slag from the steel plant was consumed throughout the experimental investigations. Table 1 shows the properties of ingredient materials used in this experimental investigation. Table 2 shows the physical properties of OPC.

TEST CONDUCTED

(a) Compressive Strength tests

Compressive strength of concrete specimens was tested at the ages of 7, 14, 28, 90 and 180 days in accordance with the BS EN 12390-3:2009. Reported strength is taken as the average of three tests results.

(b) Tensile Strength tests

Tensile strength of concrete specimens was tested at the ages of 7, 14, 28, 90 and 180 days in accordance with the BS EN 12390-3:2006. Reported strength is taken as the average of three tests results.

RESULTS AND DISCUSSIONS

The test results of the study are shown below through the graphical presentation (Ref. Fig.1 to Fig.6).

Compressive strength and tensile strength:

For making compressive & tensile tests specimens, compaction is done by a temping rod in place of vibrator machine. The specimens are cured in open air water tank in tap water in room temperature. The specimens were dried up before the tests. However, in the rainy season it is very difficult to dry which might cause the variation of test results. In normal consistency test, initial & final setting time test is affected by the temperature & the humidity of the surrounding medium. In this investigation, tests are

Table 1: Physical Properties of Ingredient Materials

Properties	Fine Aggregate	Coarse Aggregate	Slag
Fineness Modulus	2.40	6.55	--
Specific Gravity	2.58	2.67	2.57
Unit Weight (kg/m^3)	1600	1700	1350
Absorption capacity (%)	2.05	1.63	1.55
Moisture content (%)	0.908	0.30	--
Bulk Specific Gravity	--	--	2.62

Table 1: Physical Properties of Cement

Properties	OPC
Fineness (cm^2/gm)	98.5
Normal consistency	27%
Soundness	2.7 mm
Initial Setting	180 min
Final Setting	270 min

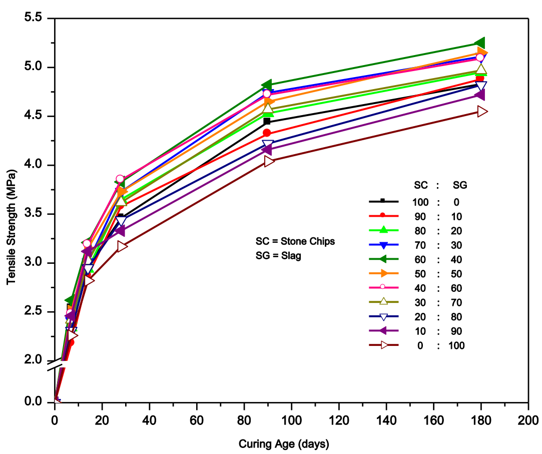

Fig.2: Tensile Strength - Curing Age for 20 MPa Concrete

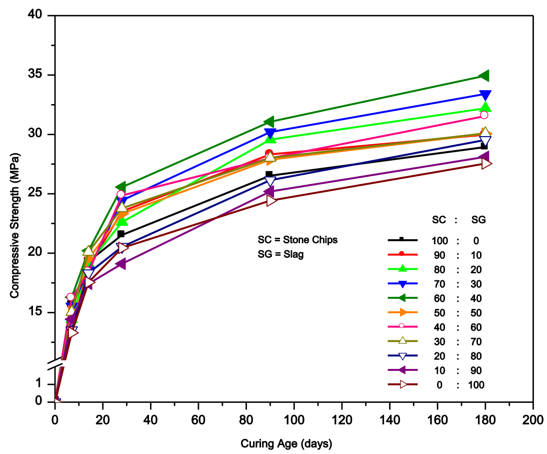

Fig.1: Compressive Strength - Curing Age for 20 MPa Concrete

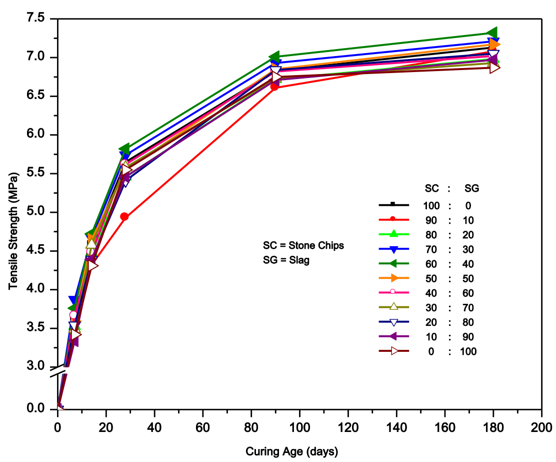

Fig.4: Tensile Strength - Curing Age for 30 MPa Concrete

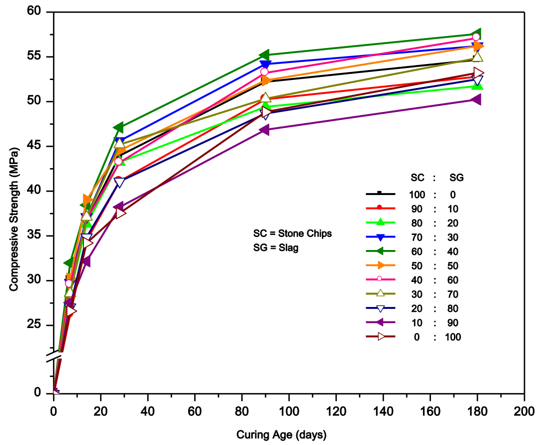

Fig.5: Compressive Strength - Curing Age for 40 MPa Concrete

carried out in room temperature and humidity condition.

The test result shows that 40% slag replacement shows good result. Also replacement levels of 50% and 60% shows reasonable improvement of concrete strengths at different ages. Table 3 shows the summary of the test results.

CONCLUSION

The following conclusions can be drawn from the study:

(1) Compressive strength of concrete made by replacing coarse aggregate by slag is higher than normal conventional concrete (concrete with stones chips).

(2) Compressive strength as well as tensile strength for concrete made by replacing coarse aggregate by slag is observed to increase upto replacement level of 40%.

(3) Concrete made by using 40% partial replacement of Slag shows the strength improvements that vary from around 6 to 20%.

Finally, it can be concluded that, Slag from Bangladesh Steel Re-Rolling Mills (BSRM) can be used as coarse aggregate at a proportion of 40% of total coarse aggregate which may offer more compressive and tensile strength and also considering the environmental issue.