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Use of Recycled Glass Powder and Mill Scale as Partial Replacement of Cement and Fine Aggregate for Sustainable Concrete Practice

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Abstract

Concrete is an extensively used construction material in a developing country like Bangladesh. Almost every high-rise building, bridge, culvert, dam and rigid pavement construction etc. works is followed by the wide use of concrete, which requires using a high range of natural fine aggregates and cement. Thus, sources of natural fine aggregates and cements are decreasing and the demand for partial substitutes of these has become a buzzword for upcoming sustainable construction. Mill scale is defined in our country as a flaky hazardous fine solid waste of the steel industry that forms on the steel surface during the steel manufacturing process. Another solid, indecomposable waste is glass, which is disposed in landfills. This study aims at checking the suitability of making sustainable concrete by using milled glass powder and Mill Scale as partial replacements of cement and natural sand, respectively. Milled glass powder bonds cementitiously in concrete, whereas mill scale has fine aggregate-like properties. In this study, to investigate the actual effects of Mill scale on the compressive strength of concrete, varying proportions of Mill scale were used in the presence of a certain proportion of glass powder. The compressive strength of the partially replaced concrete is recorded as 7th, 14th and 28th days curing. The obtained results reveal that partially replaced Mill Scale and glass powder increased the concrete strength gradually.

Keywords: *Mill Scale; Milled glass powder; Cementitiously; Sustainable concrete.*

1 Introduction

Wastes produced by steelmaking plants include scales and sludge from oily mills. They're produced at the rolling mill facility when hot steel is being cooled and rolled. A by-product of the rolling mill used in the steel hot rolling process is called mill scale. The annual production of mill scales is estimated to be 13.5 million tons worldwide(Gaballah et al., 2013). Some metalworking and steelmaking waste has found widespread application in the construction industry, such as the use of granulated slag from the production of pig iron as concrete aggregates. About 500 kg/ton of solid wastes of various types are produced during various iron and steel-making processes; one such waste is mill scale, which accounts for 2% of the steel produced(Gaballah et al., 2013) .Steel mill scale was used after grinding it in Los Angeles machine and maximum tensile strength was observed at 60% replacement of standard sand while 40% replacement of sand provided the maximum compressive strength of M35 grade concrete(Singhal, Bhunia, & Pandel, 2015) . Up to 25% replacement of sand by billet scale was used and it was found out that the concrete up to 15% replacement level of billet scale showed an increase in performance than the control mixture(Note, Naganathan, Musazay, & Nasional, 2014). Every year, millions of tons of waste glass are produced worldwide. Glass is disposed of in landfills after it becomes waste, which is unsustainable because glass does not disintegrate in the environment. Target compressive strength of 35 MPa at 28 days was achieved for all samples up to 0–20% glass addition while that for 25% addition was slightly lower(Islam, Rahman, & Kazi, 2017). With further progression of reaction at the age of 90 days, recycled glass concretes with 10, 15 and 20% glass addition provided mean compressive strengths exceeding the control concrete and 10% cement replacement gave the highest value among them(Islam et al., 2017). Numerous tests were conducted to study the effect of 5%, 10% and 15% replacement of cement by glass powder on compressive strength and durability(Ibrahim, 2017). The effects of particle size were evaluated by using glass powder of size

600µm - 100µm(Ibrahim, 2017). The results showed that the maximum increase in strength of concrete occurred when 10% replacement was done with glass powder(Ibrahim, 2017). This research examined the potential of mill scale and glass powder to produce sustainable concrete.

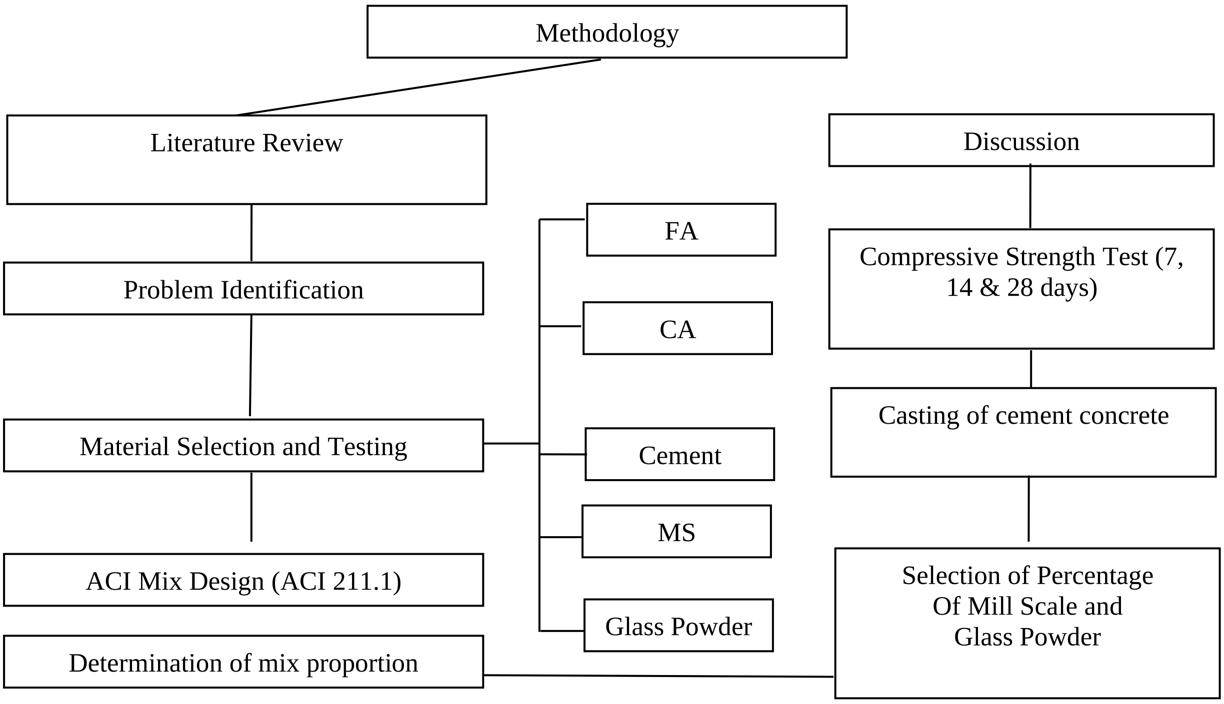
2. Materials and Methods

2.1 Material Collection:

This includes collection of steel mill scale from Bangladesh Steel Re-rolling Mills Limited and glass powder from local recycled glass breaking, Sylhet sand and OPC cement. Mill scale contains 73.90% total iron (FeT), 0.90% SiO_2, moisture 4.20%.

2.2 Methodology:

First, a thorough analysis of the existing literature on the use of mill scale and glass powder for producing sustainable concrete is conducted. Analyzing the findings revealed the potential benefits of combining mill scale and glass powder. Determining the mix fraction is done in accordance with ACI Mix Design (ACI 211.1) and the literature research. The samples are cast in front of the university lab, water-cured in drums for 7, 14, and 28 days, and tested in accordance with ASTM standards. The roadmap of study is given below:



2.3 Mixing Ratio:

Using ACI mix selection method a concrete mix design ratio was calculated for the target strength of 21 MPa. The water to binder ratio (W/B) of each mixture therefore considered as 0.45. Mix trail sample numbers are listed as S1 through S6 for easier comprehension. The requirement of cement, sand, coarse aggregate, Glass powder, Mill scale and water to per m^3 sample are shown in the table:

Table 1. Different Batching Proportion of Raw Material

Sample No	Percentage of Cement replaced by Glass Powder	Percentage of Cement	Percentage of sand replaced by Mill Scale	Percentage of Sand
S1	0	100	0	100
S2	10	90	0	100
S3	10	90	10	90
S4	10	90	15	85

S5	10	90	20	80
S6	10	90	25	75

2.4 Process flow diagram:

Figure 1. Concrete Dry mixing

Figure 2. Concrete wet mixing

Figure 3. Slump test

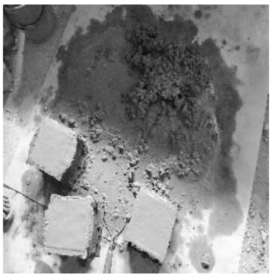


Figure 4. Concrete Cube

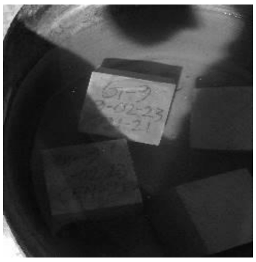


Figure 5. Curing

Figure 6. Dried specimen

Figure 7. specimen testing by UTM

Figure 8. Reading taken

3. Results and Discussion

3.1 Results of Material Properties Tests:

The properties such as specific gravity, absorption capacity, moisture content were tested in the lab and the result of tests is shown in the following table.

Table 2. Properties of Materials

Properties	Fine Aggregate	Coarse Aggregate	Ordinary Portland Cement	Glass Powder	Mill Scale
Specific Gravity	2.65	2.93	3.15	3.08	5.9
Absorption Capacity (%)	1.76	1.5%	1510	-	0.44
Moisture Content	1.21	0,89	-	-	4.2
Unit Weight (kg/m^3)	1590	1560	-	-	5550
FM	2.57	-	-	-	2.51

3.2 Slump test

Slump test was performed as per ASTM for percentages of replacement sand with Mill Scale and Cement with various percentages of glass powder present in the concrete (Table-1). The height of the cone after removing the mold is measured using the standard tamping rod and the values of the height of the cone are shown in the (Figure. 9) from which it is found that slump value decreases gradually with increasing percentage of Mill Scale.

For the sample containing the highest proportion of Mill Scale (S6) it is noted that slump value decreases about 19% while comparing with the control mix. The decreased slump value may occur due to the irregular and flaky surface texture of the particles in Mill Scale.

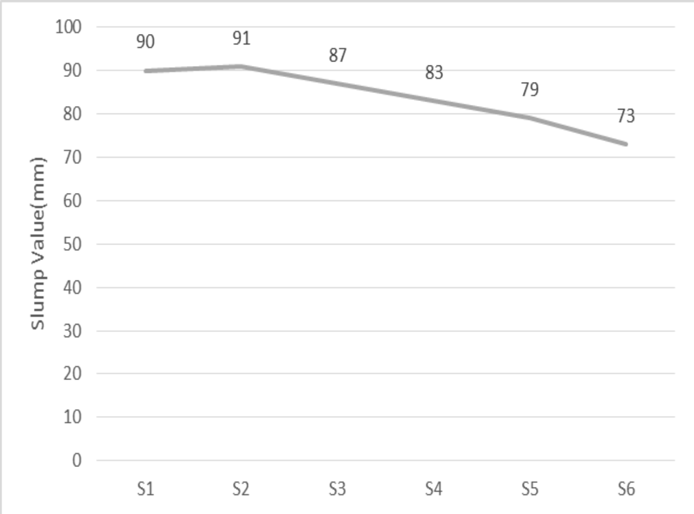


Figure 9. Slump Value of different concrete with variation in Glass Powder and Mill scale

3.3 Compressive strength test

Compression testing machine was used to conduct this test. Compressive Strength increases up to 20% (S3 to S5) increase in Mill Scale. After 25 %(S6) mill scale increase the compressive strength decrease gradually. From 6 trial mix maximum compressive strength attained from S5 (Table-1).

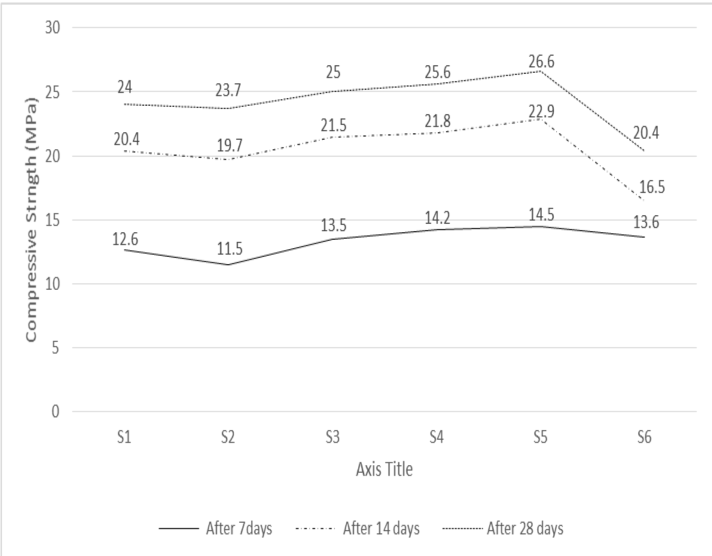


Figure 10. Compressive Strength of different concrete with variation in Glass Powder and Mill Scale

3.4 Single Block Weight:

The weight of the sample block (Table-1) is determined at the university lab using a weight machine. Concrete block weight increases with the increase of mill scale. As mill scale unit weight is higher comparing to fine aggregate it helps to increase the block weight.

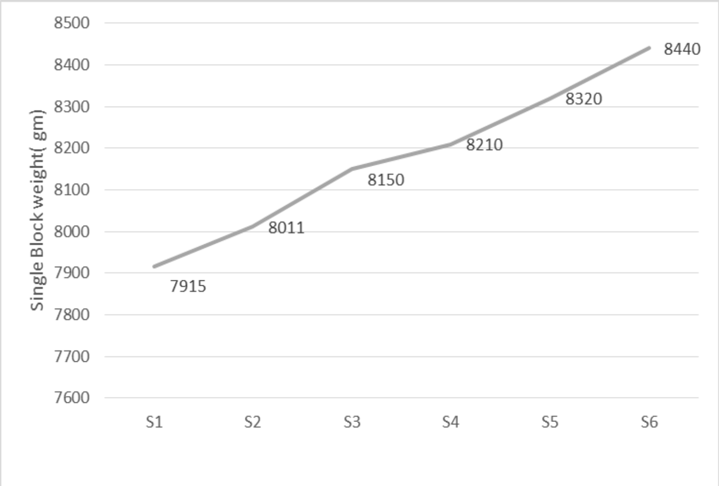


Figure 11. Single Block Weight of different concrete with variation in Glass Powder and Mill Scale

3.5 Water Absorption

This test is conducted to check the durability of concrete block and determine the percentage of water absorbed by concrete block. The test results from figure indicates that water absorption of concrete block decreases with the increase amount of mill scale. As glass powder and mill scale is finer in particle size, pore spaces of the block percentage decreases with the increase of finer elements

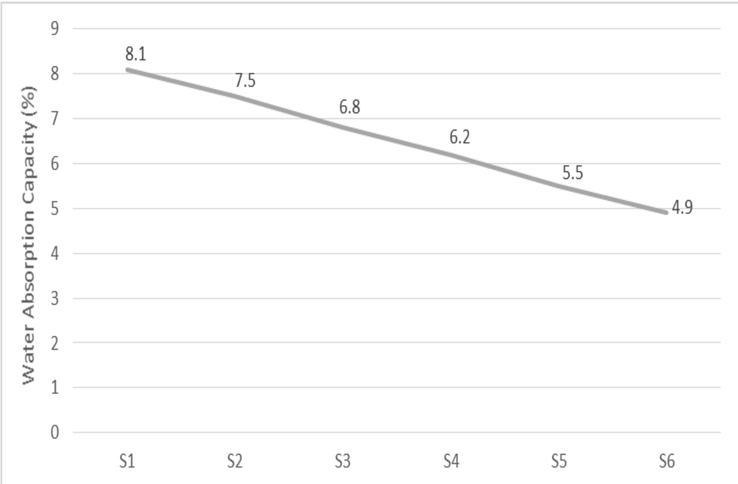


Figure 12. Water Absorption of different concrete with variation in Glass Powder and Mill Scale

4. Conclusion and Recommendation

Based on the present study, following conclusion and recommendation can be obtained:

1. The compressive strength value is increasing up to 20% replacement by mill scale as a result of the partial replacement of glass powder and mill scale. Compressive strength reduces after 20% substitution by Mill Scale (Figure 10). The study's 28 Days S5 Mix Trial with 20% Replaced Mill Scale yielded a highest compressive strength of 26.6 MPa, which is higher than From S1 and S2 Mix Trail (Table 1), where there is no replacement carried out using mill scale. That suggests that Mill Scale improves the compressive strength of concrete.
2. Mill scale unit (5550 kg/m^3) weight is higher than unit weight of Fine Aggregate (1590 kg/m^3). The weight of the concrete specimen increases with increased amount of partial replacement of glass powder and mill scale.
3. Long time performance evaluation is highly recommended.

References

Gaballah, N. M., Zikry, A. F., Khalifa, M. G., Farag, A. B., El-Hussiny, N. A., & Shalabi, M. E. H. (2013). Production of Iron from Mill Scale Industrial Waste via Hydrogen. Open Journal of Inorganic Non-Metallic Materials, 03(03), 23–28. https://doi.org/10.4236/ojinm.2013.33005.

Ibrahim, K. I. M. (2017). The Effect of Using Waste Glass [WG] as Partial Replacement of sand on Concrete. IOSR Journal of Mechanical and Civil Engineering, 14(2), 41–45. https://doi.org/10.9790/1684-1402024145.

Islam, G. M. S., Rahman, M. H., & Kazi, N. (2017). Waste glass powder as partial replacement of cement for sustainable concrete practice. International Journal of Sustainable Built Environment, 6(1), 37–44. https://doi.org/10.1016/j.ijsbe.2016.10.005.

Note, T., Naganathan, S., Musazay, J. A., & Nasional, U. T. (2014). c r v i h o e f c f. 15(4), 635–649.

Singhal, A., Bhunia, D., & Pandel, B. (2015). Effect of Sand Replacement By Mill Scale on the Properties of Concrete. International Journal of Engineering Technology Science and Research, 2, 60–67. Retrieved from http://www.ijetsr.com/images/short_pdf/1425491811_60-67_JNU286_ijetsr.