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A Combined Strength and Cost Analysis of Concrete by Using Four Different Matrixes of Materials

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ABSTRACT: *Among all construction materials, concrete remains the only choice for most structures, and after water, it is the most widely used substance throughout the world. This article represents the research on four different combinations of concrete mixtures prepared with partially replaced fine aggregate as glass powder and iron powder, partially replaced coarse aggregate using demolished concrete, and uses of GI wire fiber as additional materials with various diameters. The primary investigation was conducted based on the concrete compressive strength with various percentages and sizes of materials. From the experiment, it is found that using glass powder and iron powder as partially replaced fine aggregate has shown an 18% and a 24% increase in compressive strength respectively up to a certain percentage. For demolished concrete, although the strength decreases by percentage, the use of GI wire fiber as additional materials shows remarkable enhancement in the strength of concrete. In this article, cost analysis is also carried out and combined iron powder is found to be the most effective material among four different combinations of concrete mixers for both strength and cost.*

KEYWORDS: Concrete, GI wire, glass powder, iron powder, demolished concrete, recycled concrete

1. Introduction

In the construction industry, a huge quantity of concrete is used which are also considered as highly consumed construction materials of the world. Because of the extensive usage of this material many researchers are investigating the engineering properties of this material and trying to develop the substitute constituents of the concrete mix(Afshinnia & Rangaraju, 2016; Chen, Xu, Chen, & Lui, 2016; Damdelen, 2018; Emon, Manzur, & Sharif, 2017; Hooi & Min, 2017; Mohajerani et al., 2017; Ramdani, Guettala, Benmalek, & Aguiar, 2019; Satyaprakash, Helmand, & Saini, 2019; Verian, Ashraf, & Cao, 2018; Zhou & Chen, 2017). The primary ingredient of concrete is cement, fine aggregate, coarse aggregate, water and admixture (Mindess & Francis, 2008). Among the components, coarse and fine aggregate occupy 70% to 80% of the total volume of concrete (Verian, Ashraf and Cao, 2018) which indicates that the major strength and cost of concrete depend upon the type of aggregate used in construction. Hence, research and practice on sustainability in construction can be supportive to protect the world's ecosystem, preserve natural resources, and improve the environmental conditions of all living creatures on earth. Reusing and recycling of natural waste, demolishing the construction waste, and minimizing industrial waste in the construction industry can be an attempt to achieve the goal. However, for a developing country like Bangladesh, where inert materials like fine and coarse aggregate is very expensive, recycling would be a great achievement to create a sustainable environment. The primary aim of this experiment is to assess the performance of concrete prepared with different types of compositions, such as galvanized iron (GI) wire fiber with mixed concrete, partial replacement of coarse aggregate by demolished concrete, and partial replacement of fine aggregate by glass powder and iron powder. Performance refers to a very broad spectrum, and it is imperative to narrow down the focus on the specific parameters that are intended to be inspected.

2. Experimental Method

In this study, four different types of concretes are prepared. (i) In the first group, concrete is prepared using GI wire fiber with different diameters. (ii) In the second group, coarse aggregate is partially replaced by demolished concrete, which has been collected from different sources in Dhaka.(iii) In the third group, fine aggregate is partially replaced by glass powder. (iv) In the fourth group, fine aggregate is partially replaced by iron powder, which has been collected from different industrial wastes near Gazipur. Three cylinders

Table 1: Matrix of materials

Group	Fine Aggregate (F.A.)	Partially Replaced F.A.	Coarse Aggregate	Partially Replaced C.A.	Additional Materials	No. of Cylinders
1.	Sylhet Sand	-	Brick Chips	-	-	6
2.	Sylhet Sand	-	Brick Chips	-	GI wire fiber	24
3.	Sylhet Sand	Iron Powder	Brick Chips	-	-	24
4.	Sylhet Sand	Glass Powder	Brick Chips	-	-	24
5.	Sylhet Sand	-	Brick Chips	Demolished Concrete	-	24

were prepared for each group, and they were crushed after 7 and 28 days of curing. The matrix is shown in Table 1.

Ordinary Portland cement was used with 19 mm (¾ ") downgraded crushed burnt clay bricks as coarse aggregate and locally available Sylhet sand was used (Fineness Modulus = 2.81) as fine aggregate. Oven-dry rodded unit weight and absorption capacity of brick aggregate was found to be 1040 kg/m^3 and 14.3% respectively. However, in Bangladesh, a major construction work depends on small scale mixing and casting methods, where the concrete mix is proportioned with ratio of 1:1.5:3 for cement, fine aggregate and coarse aggregate with 0.5 water-cement ratios respectively. This mix-design was adopted for the study.

2.1 GI Wire Fiber Mixed Concrete

GI wire of 0.50 mm, 0.70 mm and 1.00 mm diameter and length between 38.5 mm to 45 mm were selected. The amount of fiber was 2% by weight was mixed with concrete to keep the fiber content low enough to maintain workability without admixture. The specification of the GI wire fibers used in this study has shown in Table 2.

Four concrete mixtures were prepared including reference mixture, while the other three mixtures contained GI wire fibers (0.50 mm, 0.70 mm, and 1.00 mm) as 2% by volume of concrete respectively. GI fibers having length between 38.5 mm to 45 mm were used for each of the specimen. Ordinary Portland cement was used with 19 mm (¾ in.) downgraded bricks chips as coarse aggregate with locally available Sylhet (Fineness Modulus = 2.81) as fine aggregate and coarse aggregate respectively.

Table 2: The properties of GI wire fiber

Properties	specifications
Density	7850 kg/m3
Length	38.5 mm - 45 mm
Diameter	0.50 mm
	0.70 mm
	1.00 mm

(a) The diameter of 0.50 mm (b) The diameter of 0.70 mm (c) The diameter of 1.00 mm

Fig 1: GI fiber

Fig 2: Glass powder **Fig 3: Iron powder** **Fig 4: Demolished concrete**

2.2 Glass Powder

In this experiment, a crushed weight washed glass powders was used as a partial replacement for fine aggregate of size 1.18mm, 0.60mm and 0.30mm with FM 3.8. The grading of the glass powder conformed to the requirement of ASTM C33-01.Three types of concrete mixtures were prepared using partially replaced glass powder. The glass powder shown in Fig.2 was 5%, 15% and 25% by volume of fine aggregate.

2.3 Iron Powder

The demolished concrete was collected from different sources of this city. The demolished concrete where brick chips were used as coarse aggregate is shown in Fig.4. A series of four group concrete mixtures were prepared with various percentages (50%, 60%, 70%, and 100%) in respect to the volume of coarse aggregate.

2.4 Recycled Concrete

The demolished concrete was collected from different sources of this city. The demolished concrete where brick chips were used as coarse aggregate is shown in Fig.4. A series of four group concrete mixtures were prepared with various percentages (50%, 60%, 70%, and 100%) in respect to the volume of coarse aggregate.

2.5 Mold Preparation of Concrete Cylinder Specimen

The quantities of gravel and sand were placed in a steel sheet. It was then dry mixed for 1 min. Later, the cement was spread and mixed for 1 min. After that, four types of materials were used separately for different experiments such as GI fibers, recycled concrete as coarse aggregate, glass powder as fine aggregate, and iron powder as fine aggregate. Mixing was continued for 3 minutes to make sure the uniform distribution of fibers and materials throughout the concrete. After that, water was added to the mixtures maintaining the 0.5 w/c ratio. The allowable mixing time was 2-3 minutes to get a uniform mix without segregation. Then the mold (4″

diameter and 8″ height) was filled up by mixed fiber reinforced concrete.

The molds were lightly coated with oil before use, according to ASTM C 192-88, the concrete casting was carried out in a different layer each having a layer of 50 mm. Then each layer was compacted by using a tamping rod for 15 to 30 seconds until no air bubbles emerged from the surface of the concrete, and the concrete was leveled off smoothly to the top of the molds. Finally, the specimens were kept covered in the laboratory for about 24 hours.

2.6 Curing and Testing

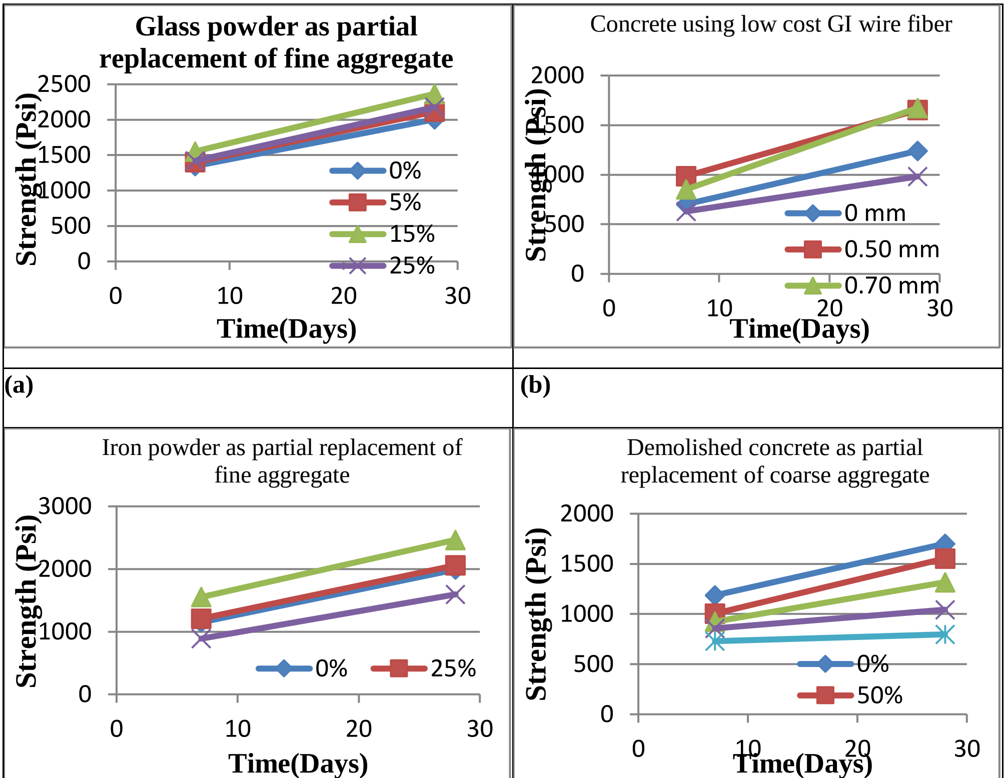
The specimens were remolded carefully and were immersed in water until the age of the test. After curing for 7days and 28days, the specimens were dried for a few hours. However, for testing the specimens the cylinders were placed at the center of the compressive strength test machine at IUBAT civil engineering laboratory and tested under a controlled loading rate. The results of the experiments are shown in Table 3.

Table 3: Matrix of Materials

Type of Materials	Material	Percentage of Materials	Average Compressive Strength (psi)		Cost (BDT) (per cft)
			7 Days	28 Days	
Partially Replaced	Glass Powder	0%	1347.07	2005.77	61.59
	Glass Powder	5%	1401.44	2113.97	61.59
	Glass Powder	15%	1553.63	2366.50	60.14
	Glass Powder	25%	1421.47	2177.45	58.69
Partially Replaced	Iron powder	0%	1150.15	1991.37	65.2
	Iron powder	25%	1208.16	2059.54	73.91
	Iron powder	30%	1551.90	2465.64	75.36
	Iron powder	35%	889.08	1595.42	81.12
Partially Replaced	Demolished concrete	0%	1186	1701.00	60.86
	Demolished concrete	50%	1004	1554	52.17
	Demolished concrete	60%	924	1317	49.27
	Demolished concrete	80%	857	1043	46.34
	Demolished concrete	100%	729	797	43.47
Additional	-	-	701.99	1239.93	65.22
	0.50 mm GI wire	2%	985.36	1653	178.26
	0.70 mm GI Wire	2%	852.27	1673.76	173.9
	1.00 mm GI Wire	2%	630.43	982.14	168.12

3. Result Analysis

Concrete compressive strength of the different combinations of the concrete mix was analyzed, and the cylinders were tested for 7 days and 28 days for glass powder and iron powder as replacement of fine aggregate, low-cost GI wire as additional materials and demolished concrete as partial replacement of coarse aggregate which are shown in Fig 5. Form graphs, it can be portrayed that, the strength increases with time for all the percentages of glass powder, GI wire, iron powder, and recycled aggregate. This indicates that the replaced material does not have any effect on time. But strength increasing rate seems to be very slow in case of 80% and 100% replacement of coarse aggregate in concrete.



(a) **(b)** **(c)** **(d)**

Fig 5: Strength versus time analysis of (a) Glass powder, (b) Low cost GI wire, (c) Iron powder and (d) demolished concrete

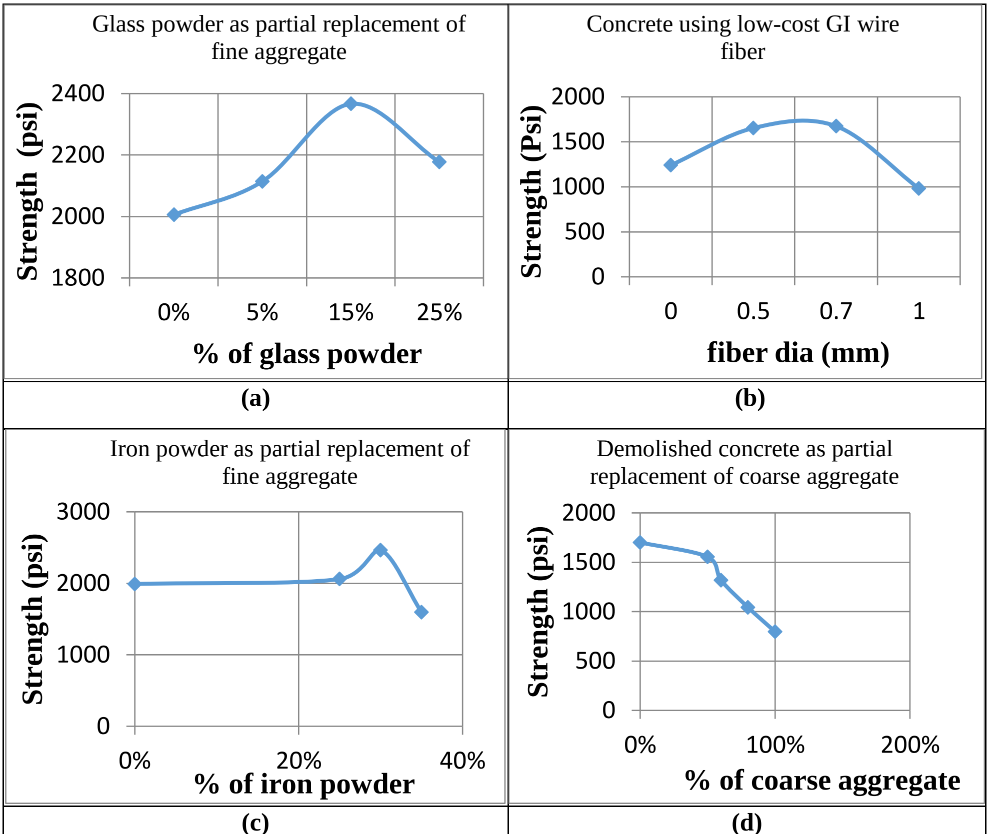
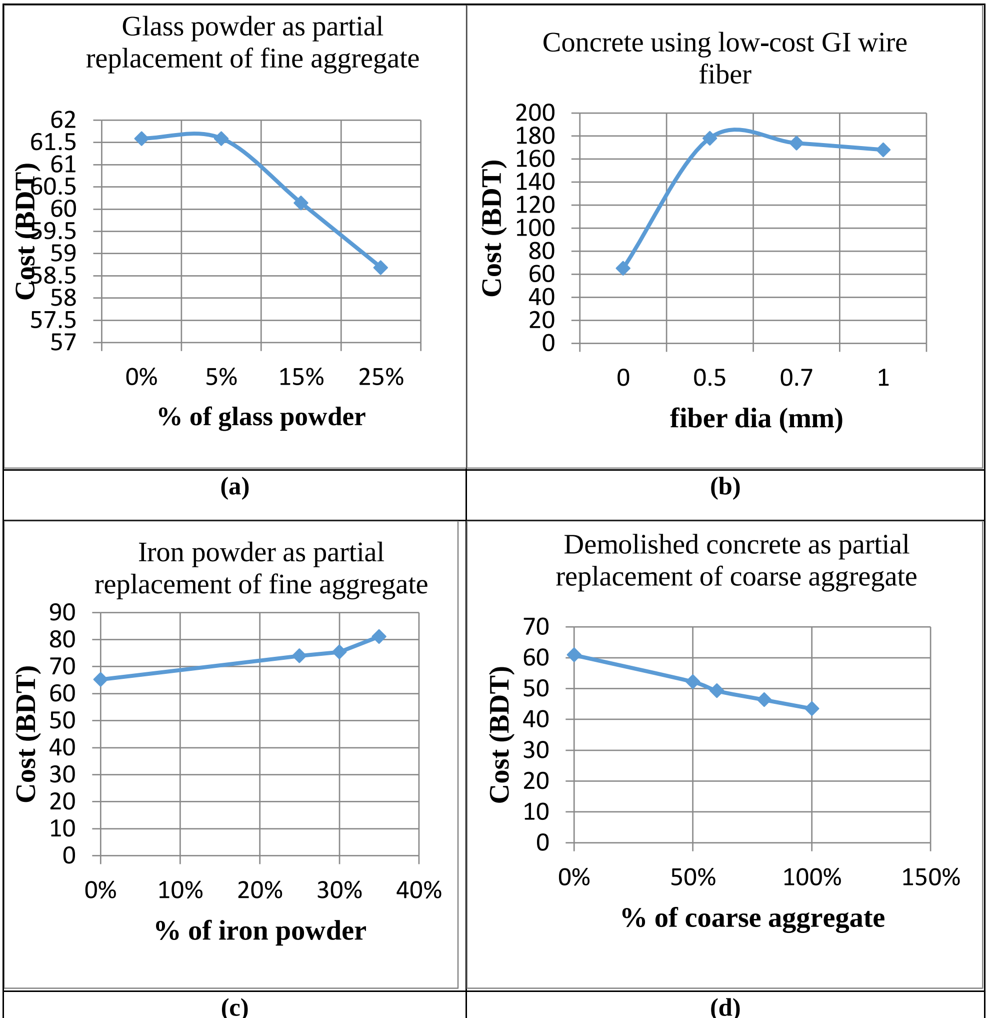


Fig 6: Strength versus material percentage analysis of (a) glass powder, (c) iron powder, (d) demolished concrete and (b) strength versus different diameter of GI wire fiber

Fig. 6 represents the strength of the concrete mix with four different combinations of materials. Data has been taken for various percentages of glass powder, iron powder, coarse aggregate and selected sizes of GI wire fiber. For glass powder, iron powder and GI wire mixed concrete strength increases with the percentage of materials taken, but after a certain percentage the strength of concrete shows a downward trend. For replacement of coarse aggregate, concrete strength decreases with an increasing percentage of demolished concrete.

From figure 7 (a) and (d), it can be observed that the price of partially mixed glass powder concrete and demolished concrete decreases with the increasing percentage of those materials due to the availability of the replaced materials from different sources of debris. On the other hand, the iron powder



(a) **(b)** **(c)** **(d)**

Fig 7: Cost analysis of (a) glass powder, (b) GI wire fiber, (c) iron powder and (d) demolished concrete

and GI wire fiber were purchased from different iron manufacturing industry. That is why, the overall price upsurges with the percentage of iron powder and GI wire fiber used in the concrete as shown in Figure 7 (b) and (c).

Fig. 8 shows the Graph of Cost vs. four various combinations of materials in the primary axis and strength vs. four various combinations of materials in the secondary axis.

Fig 8 (a) shows that using 10% glass powder in concrete, cost and strength intersect where cost is 61 BDT and strength is 2260 psi.

Fig.8 (b) shows that at 0.4 mm fiber diameter, cost and strength intersect where cost is 160 BDT and strength is 1600 psi.

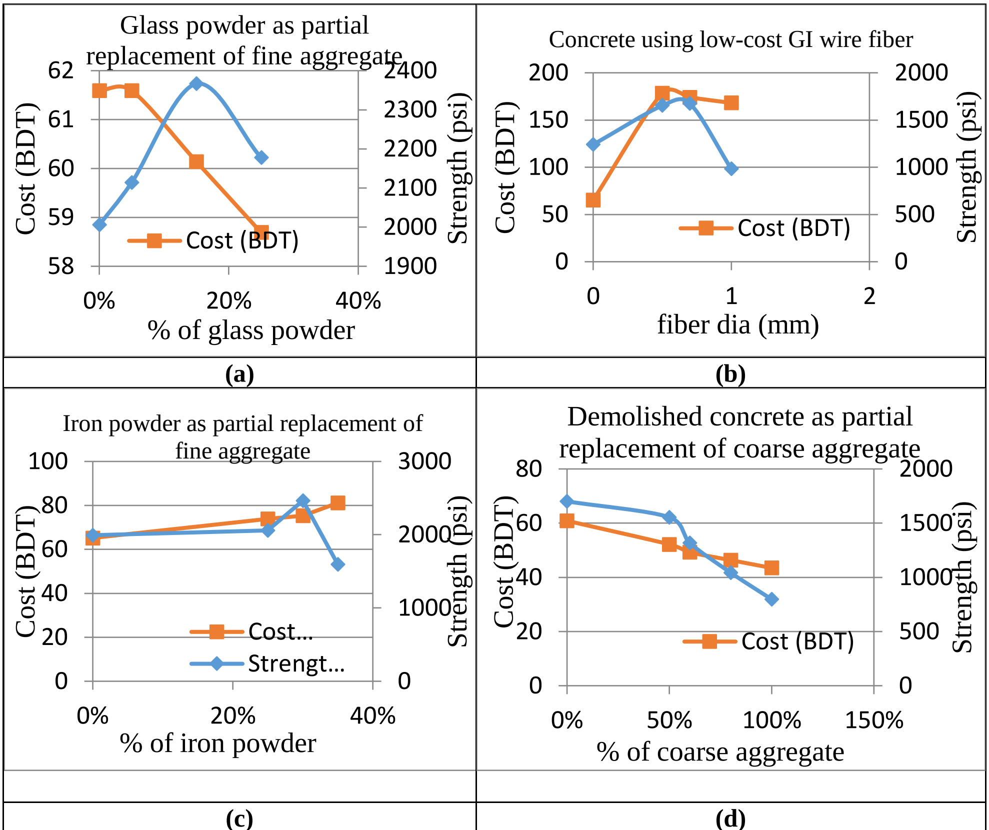


Fig 8: Combined analysis of strength and cost concerning the material percentage of (a) glass powder, (c) iron powder, (d) demolished concrete and (b) different diameter of GI wire fiber

Fig.8(c) shows that at 28% iron powder, cost and strength intersect where cost is 72 BDT and strength is 2700psi.

Fig.8 (d) shows that at 60% coarse aggregate, cost and strength intersect where cost is 48 BDT and strength is 1220psi.

Fig.9 Shows of strength vs. cost for four intersecting points taken from the previous four graph analysis. It can be concluded that using 28% of iron powder provides maximum strength at a reasonable cost compared with other concretes.

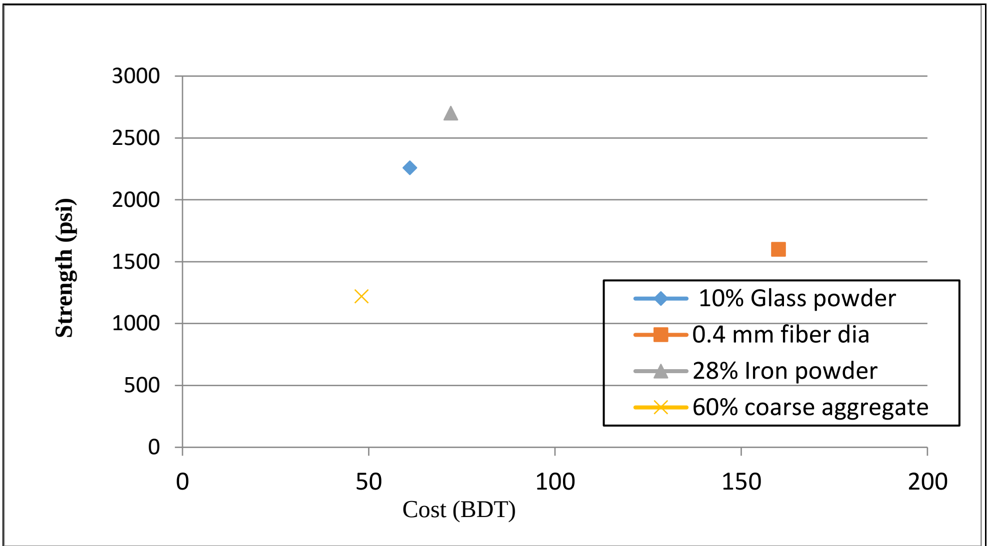


Fig 9: Comparison with four groups of Concrete Mixture

4. Conclusion

In this experiment, total four types of the concrete mixtures were prepared by using four combinations and the overall findings are concluded as below:

1. Using glass powder as partial replacement of fine aggregate can be effectively used in concrete as it has shown an 18% increase in the strength; also, a fair amount of reduction in cost with respect to normal concrete.

2. The iron powder as partial replacement of fine aggregate can be effectively used in concrete as it has shown a 24% increase in the strength although 25% increase in cost at the same time with respect to normal concrete.

3. It is undoubtedly acknowledged that using of GI wire fiber as FRP in concrete has shown rapid development in strength compared to normal concrete. But, at the same time price also increases with the amount of GI fiber when used in concrete.

4. Using recycled concrete as partial replacement of coarse aggregate is very effective with respect to cost. However, on the other hand, strength decreases gradually with an increasing percentage of recycled concrete.

5. Among all these combinations, it can be easily said that iron powder can be most effectively used as partial replacement of fine aggregate considering both cost and strength.

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