"Study and Analysis of Strength of Concrete Containing Recycled Aggregates and Ground Granulated Blast Furnace Slag"

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Abstract- Use of concrete in construction industry is rising every year, resulting into high consumption of natural aggregates and cement. The consumption of such natural resources need to be reduced for sustainability. It is necessary to find suitable option for either full or partial replacement for cement and natural aggregates. Recycled concrete aggregates can serve as a replacement to natural aggregates and Supplementary cementitious materials for cement. Experimental investigation was carried out on five concrete mixes with a target characteristic strength of 35 MPa. Four of which had 0%, 55%, 65%, and 75% replacement of cement with GGBS respectively with 100% replacement of natural aggregates by recycled concrete aggregates and one sample of conventional mix

Keywords -Recycled Concrete Aggregates, Ground Granulated Blast Furnace Slag, Compressive Strength, Economic Analysis.

1. INTRODUCTION

Construction and demolition of structures creates huge amount of waste. The waste generated by construction industry due to construction, renovation, demolition of various buildings, industrial commercial facilities and infrastructure is called construction and demolition(C&D) waste. As the construction industry is growing very rapidly, the waste management has become a necessity. One of the best option till date is to recycle the waste material into recycled usable contents. Normally the C&D waste are used to dump as landfills, which has resulted in shortage of land for dumping in large cities. If these wastes are used for sustainable construction, it can reduce scarcity of dumping place and will also help in conservation of natural aggregates resources.

1.2 Objectives of the study:

(1) The main objective is to study the use of recycled concrete aggregate as a substitute for natural aggregate. It is related to fully replacement of natural coarse aggregate by recycled concrete aggregate.
(2) To evaluate the optimum percentage of GGBS required for getting the maximum benefits through laboratory tests.
(3) To study the use of GGBS as a partial substitute for cement. So it will minimize the consumption of natural material means stone as a natural aggregate and Lime use for making cement. Therefore it helps environment by reducing Co_2 emission by minimizing use of cement.
(4) To carry out analysis for determination cost reduction of concrete made with recycle concrete aggregate, GGBS.

2. REVIEW OF LITERATURE:

2.1 Introduction

The various research programs are carried out for the construction and demolition waste management. Many researches are done for improving properties of recycle aggregate concrete by adding different materials in concrete. Following section reviews literature on the similar studies. In following, reviews are group together for simplicity as use of recycled concrete aggregates and use of GGBS in construction. These are as follows.

2.2 Construction and Demolition Waste Management

Hemalatha B.R (2008) studied the composition of construction and demolition waste. She studied the need the demolition and construction waste for its recycling. Also suggested that recycled aggregate can be used as bulk fill, sub base material in road construction, playground, canal lining and for preparation of new concrete.

2.3Use of Recycled Aggregate as a Replacement of Natural Aggregate and Its effect on Properties

M. Etxeberria (2007) studied recycled coarse aggregates obtained by crushed concrete. He considered four different recycled aggregate concretes which were prepared with 0%, 25%, 50% and 100% of recycled coarse aggregates, respectively. The mix proportions were designed for four concretes in such a way that to achieve the same compressive strengths. Concrete made with 100% of recycled coarse aggregates has 20–25% less compression strength than conventional concrete at 28 days, with the same effective w/c ratio (w/c=0.50) and cement quantity (325 kg of cement/m3). Medium compression strength (30–45 MPa) concrete made with

25% of recycled coarse aggregates achieves the same mechanical properties as that of conventional concrete employing the same quantity of cement and the equal effective w/c ratio.

2.4 Use of Mineral Admixture in Recycled Concrete Aggregate

It is generally known that the use of recycled aggregates in concrete would reduce its compressive strength and render the concrete less durable. Various methods have been attempted to compensate for the lower quality of the recycled aggregates for concrete production C.S. Poon(2012)study the effects of incorporating Class F fly ash in the concrete mix design to mitigate the lower quality of recycled aggregates in concrete is presented. The results show that one of the practical ways to utilize a high percentage of recycled aggregate in concrete is by incorporating 25–35% of fly ash since some of the drawbacks induced byte use of recycled aggregates in concrete could be minimized. It shows the use of fly ash as addition of cement increased the compressive strength. At the same recycled aggregate replacement level, the use of flyash as a partial replacement of cement decreased the compressive strength with the exception of the concrete mixture with25% fly ash at 90 days. However, the use of fly ash as addition of cement increased the compressive strength. The drying shrinkage of concrete increased with an increase in the recycled aggregate content. However, the use of fly ash as a partial replacement or addition of cement was able to reduce the drying shrinkage of the recycled aggregate concrete.

2.5 Use of GGBS in Construction

M.L. Berndt(2009)considered five basic concrete mixes. These were: (1) conventional mix with no material substitutions,(2) 50% replacement of cement with fly ash, (3) 50% replacement of cement with blast furnaceslag, (4) 70% replacement of cement with blast furnace slag and (5) 25% replacement of cement withfly ash and 25% replacement with blast furnace slag. Recycled concrete aggregate was investigated inconventional and slag-modified concretes. Properties investigated included compressive and tensile strengths, elastic modulus, coefficient of permeability and durability in chloride and sulphate solutions.

It was determined that the mixes containing 50% slag gave the best overall performance. Slag was particularlybeneficial for concrete with recycled aggregate and could reduce strength losses. Durability testsindicated slight increases in coefficient of permeability and chloride diffusion coefficient when using recycled concrete aggregate. The combined effects of partial cement replacement and use of recycled concrete aggregate to improve the sustainability of new concrete was investigated. The results indicated that concrete mixes containing 50% replacement of cement with blast furnace slag gave the best results in terms of mechanical properties and durability when either natural or recycled concrete aggregate was used.

3. Experimental setup

3.1 material were use in experiment

3.1.1.Binders

3.1.1.1. Ordinary Portland Cement

The Ordinary Portland cement of 53 Grade (Ultratech) was used for concrete.

3.1.1.2. Ground Granulated Blast Furnace Slag

The Ground Granulated Blast Furnace Slag (Manufactured by Heldberg Cement India) of Grade 120 was used for replacement of cement.

Following are the Chemical composition and physical properties of cement and GGBS

Chemical composition and physical properties of cement and GGBS

Sr. No.	Chemical Composition	Cement	GGBS
1	CaO (Wt%)	63.25	39.84
2	SiO2 (Wt%)	20.80	38.00
3	Al2O3 (Wt%)	4.61	7.52
4	Fe2O3 (Wt%)	2.59	0.31
5	MgO (Wt%)	4.17	10.54
6	Na2O (Wt%)	0.16	0.32
7	K2O (Wt%)	0.50	0.38
8	SO3 (Wt%)	2.70	0.16
9	LOI (Wt%)	0.90	1.42
10	Fineness (m^2/kg)	364	554
11	Specific gravity	3.15	3.00

3.2Tests on material

3.2.1 Bulk density

3.2.2 Specific Gravity & Water Absorption

3.2.3 Sieve Analysis

3.3Mix calculation

(a) volume of concrete = 1 m^3

(b) volume of cement = $\frac{mass\ of\ cement}{specific\ gravity\ of\ cement} \times \frac{1}{1000}$ = $\frac{360}{3.15} \times \frac{1}{1000}$ = 0.114 m^3

(c) volume of water = $\frac{mass\ of\ water}{specific\ gravity\ of\ water} \times \frac{1}{1000}$ = $\frac{144}{1} \times \frac{1}{1000}$ = 0.144 m^3

(d) volume of chemical admixture (superplasticize r@ 2 % by mass cementitious material) = $\frac{mass\ of\ chemical\ admixture}{specific\ gravity\ of\ chemical\ admixture} \times \frac{1}{1000}$ = $\frac{7}{1.11} \times \frac{1}{1000}$ = 0.006 m^3

(e) volume of all in aggregates = [a-(b+c+d)]
(f) mass of coarse aggregate
= e × volume of coarse aggregate × specific gravity of coarse aggregate × 1000
(g) mass of fine aggregate
= e × volume of fine aggregate × specific gravity of fine aggregate × 1000

3.3 Methodology

Considering M35 as target grade five different mix designs were investigated. The first was considered as control mix made of regular ingredients. The second mix contains 100% replacements of natural coarse aggregate with recycled coarse aggregate. The remaining three mixes contain 100% replacements of natural coarse aggregate with recycled coarse aggregate and 55%, 65% and 75% replacements of cement with GGBS. These mixes are named as Mix1, Mix2, Mix3, Mix4 and Mix5 as shown in Table 2. The 7 days and 28 days compressive strength of these mixes were obtained and presented in the present study. A rate analysis was also performed for these mixes to study the level of economy which can be achieved using the recycled material in concrete. Table 2shows the overall percentage of the ingredients used in the respective mixes. To demonstrate the clear idea of ingredients used in sample mixes the bar representation of the proportions are presented in

Details of Mix Combinations

Material	Mix 1 (%)	Mix 2 (%)	Mix 3 (%)	Mix 4 (%)	Mix 5 (%)
Cement	100	100	45	35	25
GGBS	0	0	55	65	75
Natural Aggregate	100	0	0	0	0
Recycled Concrete Coarse Aggregate	0	100	100	100	100
River Sand	100	100	100	100	100

3.3.1 Mixing and casting procedure

The mix design was carried out for M35 grade concrete and considering Superplastisizer as 0.5 % by weight of cement, using IS10262:2009 Procedure. Further the same mix proportions are used for other mixes replacing the natural coursed aggregates with recycled coursed aggregates and partial replacement of binder as shown in Table 1 and Figure 1. The proportions so obtained are presented in Table 3.The concrete was mixed using a laboratory concrete pan mixer in three steps. Firstly, the fine and coarse aggregates were dry blended for one minute, followed by addition of cement and GGBS as per respective proportions and dry blending for next one minute in pan. Then two thirds of the super plasticizer and water mix was added continuing the mixing for next one minute. The remaining water and super plasticizer mix were then added and the total mixing time was 6 min. Concrete was poured in mould and compacted using a vibrating table. All concrete sp was poured in mould and compacted using a vibrating table. All concrete specimens were demolded after 24 hours and cured in water at normal room temperature.

Table No. 3: Mix Proportions for the Mixes Considered in Study

Material		**Mix Proportions per m^3**				
		Mi x 1	**Mi x 2**	**Mi x 3**	**Mi x 4**	**Mi x 5**
Cement (Kg)		360	360	162	126	90
GGBS (Kg)		0	0	198	234	270
Water (Kg)		144	144	144	144	144
Sand (Kg)		735	735	735	735	735
Natural Coarse Aggregate (Kg)	20mm	729	0	0	0	0
	10mm	486	0	0	0	0
RecycledCoarse Aggregate(Kg)	20mm	0	729	729	729	729
	10mm	0	486	486	486	486
Super plasticizer (liters)		6	6	6	6	6

3.4 Properties of Concrete

3.4.1 Workability

The workability of concrete was checked by **Slump Cone test**. In Slump Cone test, the concrete was fill in the open cone of dimension (Bottom Diameter: 20cm, Top Diameter: 10cm and Height: 30cm) in three layers and tamped well. Then cone was lift up slowly and difference between cone height and deformed shape cone height was slump which was measured by scale.

3.4.2 Compressive Strength

The cubes of size 15 x15 x 15 cm were prepared. The Crushing Strength for 7 days,28 days was measured in Compression Testing Machine by breaking Cubes. The 5.2 KN /second loading rate is applied up for breaking cubes. The strength is calculated in N/mm^2 by formula = (Load in N/ Area of cube face mm^2).

4. Result & Discussion

4.1 Workability

The results achieved from slump cone test are given in Figure 2, it was observed that the mix with 100 % replacement of natural coarse aggregates shows less workability as compared to that of control mix. Whereas the other mixes are found to be more workable as compare to the control mix. It was observed that the workability increases with increase in percentage of GGBS.

Results of Slump Cone Test

Concrete Mix	Slump Value (mm)
Mix 1	78
Mix 2	73
Mix 3	83
Mix 4	87
Mix 5	92

4.2 Compressive strength

Six cubes of each mix design were prepared 3 of which were tested after 7 days of curing and 3 after 28 days of curing. The mean value of each set of three cubes obtained from compression test are shown in Figure 3 and Figure 4. The average compressive strength of each mix at 7 days and 28 days are shown in Figure 3 and Figure 4 respectively. It was observed that the mixes with RCA and GGBS achieves less strength as compared to that of conventional mix at 7 days of curing, but at 28 days these mixes succeeds to achieve a strength nearly equal to the target strength. It was observed that the mix 3 exhibits the strength fairly equal to that of conventional mix *i.e.* mix 1.

Results of Compression Test

Concrete Mix	Compressive Strength (MPa)	
	7 Days	28 Days
Mix 1	28.50	38.40
Mix 2	26.40	34.20
Mix 3	26.70	38.25
Mix 4	25.30	36.42
Mix 5	25.20	35.53

CONCLUSION

Experimental investigation was carried out on five concrete mixes with a target characteristic strength of 35 MPa. Four of which had 0%, 55%, 65%, and 75% replacement of cement with GGBS respectively with 100% replacement of natural aggregates by recycled concrete aggregates and one sample of conventional mix

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