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Mechanical Properties of Concrete Incorporating GGBS, Waste Foundry Sand and Waste Ceramic Tiles

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Abstract:
From the last few years various researches had done work in concreting and invent various techniques and methods to produce concrete which has the desired properties. Concrete is one of the most vital and common materials used in the construction field. The current area of research in the concrete was introducing Ground Granulated Blast Furnace Slag (GGBS), waste foundry sand (WFS) and waste ceramic tiles in the ordinary concrete. The present paper is an effort to quantify the strength of ground granulated blast furnace slag (GGBS) at various replacement levels and evaluate its efficiencies in concrete. Cement with GGBS replacement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement savings, energy savings, cost savings, environmental and socio-economic benefits, Waste foundry sand is the by product of metal casting industries, which causes environmental problems because of its improper disposal. Construction industries requires huge amount of ceramic tiles and other ceramic for architectural appearance, the productions of which are drastically increased, due to this waste is also produce during handling and usage of ceramic tiles. Thus, its usage in building material, construction and in other fields is essential for reduction of environmental problems. This research was carried out to produce an eco –friendly concrete . This paper recommends the effective use GGBS and waste foundry sand as a partial replacement for cement and fine aggregate and waste ceramic tiles as a partial replacement for course aggregate in concrete. Ingredients for concrete are cement, GGBS, course aggregate, waste ceramic tiles, fine aggregate and waste foundry sand (WFS) in an experimental investigation was carried out on concrete containing GGBS in the range of 0%,10%,20%,30% and 40%, waste foundry sand (WFS) in the range of 0%,10%,20%,30% and 40% and waste ceramic tiles (WCT) in the range of 0%,10%,20%,30%and 40% by weight for M-25 grade concrete. Concrete was produced, tested and compared with conventional concrete for workability, compressed strength, split tensile strength and flexural strength. These tests were carried out on standard cube for 7and 28 days and cylinder and beam for 28 days to determine the properties of concrete. The aim of this research was to know the behaviour and mechanical properties of concrete for its eco-friendly and economical use.

Keywords: Industrial waste, Ground Granulated Blast Furnace Slag (GGBS), Waste Foundry Sand (WFS), Waste Ceramic Tiles (WCT), OPC, Eco-friendly, Compressive strength, Split tensile strength, Flexural strength, Workability.

1. INTRODUCTION

1.1 General

Concrete is a standout amongst the most broadly used development materials on the planet, with around two billion tons put generally speaking each year. It is widely utilized as a part of light of the way that it offers noteworthy quality and quality at a sensible cost. Cement can be by and large fabricated by locally available materials, can be thrown into an extensive variety of basic plans and need less support amid its administration life. In its age and use, no dangerous substances are emanated. The principle environmental disadvantage of cement is the releases of carbon-di-oxide (CO_2) gas in the midst of produce of bond clinker, have made a need to reduce the concrete use through the use of supplementary materials.

The word concrete starts from the Latin word "cements" which implies thick. Concrete as a development material has a broad potential wherever all through the world and next just to the usage of water. Concrete is a composite material made out of water, totals (coarse and fine) set in a hard system of material (the bond or folio) that fills the voids among the totals and glues them together. Concrete is for the most part used for making compositional structures, foundations, square and pavements. Concrete is used in enormous sum all inclusive for foundation by humanity. The measure of cement used all around the globe is twofold that of steel, plastics, wood, aluminum and so on. It is surveyed that present use of cement all around is 14billion tons for each year. To meet this essential broad measures of characteristic assets are required and these regular assets are getting depleted each day.

1.2 Objectives

Following are the main objectives of the project:

- To illustrate the behavior of partial replacement of GGBS (0%, 10%, 20%, 30% and 40%) in concrete for various curing periods.
- To study the behavior of concrete when sand and coarse aggregate is replaced by waste foundry sand and waste ceramic tiles (0%, 10%, 20%, 30%, and 40%).
- To evaluate the strength properties such as compressive strength, split tensile strength and flexural strength.
- To reduce the use of cement and to use the waste abundantlyavailable material GGBS so as to make it eco friendly.

1.3 Scope for further Study

From ancient time the ordinary Portland cement has been replaced with other materials having almost similar properties as that of cement. The searching of any replacement material in concrete has become an interesting research has much scope in future also. The binding materials which are used as replacement materials for cement should consume less energy and should be economical. The construction becomes innovative when there is any advanced development in the materials used. In this work, cement is replaced partially by GGBS and waste foundry sand and waste ceramic tiles is replaced by sand and coarse aggregates optimum level of replacements are found. Inorder to achieve the objectives, the experimental investigation is highlighted.Behavior of concrete is studied under the addition waste foundry sand and waste ceramic tiles by conducting compression, split tensile and flexural tests. According to Indian Standard codes all the tests are carried.

2 METHODOLOGY

2.1 Introduction

It is important to completely characterize the material to analyze its nature and performance before it is utilized for experimental study. In this view, this chapter concentrates on characterization of all the raw materials utilized is examined to analyze its physical and mineralogical properties. The materials utilized for the manufacture of concrete in this study are as follows

1. Ordinary Portland Cement (OPC)
2. Coarse aggregate
3. Fine aggregate
4. Water
5. Ground Granulated Blast Furnace slag (GGBS)
6. Waste foundry sand (WFS)
7. Waste ceramic tiles (WCT)

2.1.1 Ordinary Portland cement (OPC)

In the present studyOPC-53 grade was used throughout the investigation. To determine its various physical properties, testing has been done according to IS conforming to (12269-1989). Experimental results are listed in table 2.1.

Table 2.1 Physical Properties of cement

Sl. No.	Particulars	Tests Conducted on	Requirement as per IS:8112-1989	Test Results found
1	Specific gravity	Sp.gr. bottle	3.18	3.1
2	Fineness of Cement	90micron sieve	<10	4%
3	Normal consistency %	Vicat apparatus	35>	31%
4	Initial setting time (min)	Vicat apparatus	Minimum of 30min	55min.
5	Final setting time (min)	Vicat apparatus	<600min	355min

2.1.2 Coarse aggregate

The aggregates which are retained on BIS test sieve 4.75mm is called as coarse aggregates. The crushed stone is for the most part utilized as coarse aggregates. The type of work determines. The maximum size of the coarse aggregates is 20mm. Specific gravity of this 20mm down size aggregateis found. The sieve analysis data of coarse aggregate used are shown in table 2.2.

Table 2.2 Physical properties of coarse aggregate

Sl. No	Description	Test Results
1	Nominal size used	20mm
2	Fineness modulus	5.31
3	Specific gravity	2.67
4	Water absorption	0.6%

2.1.3 Fine Aggregates

River sand confirming zone II of IS 383-1970 is used for the present work. FA usually passes through 4.75mm IS sieve. Hence river sand is used as fine aggregate here. Sieve analysis results and properties of fine aggregate is shown below.

Table 2.2 Physical properties of Fine aggregate

Sl. No	Description	Test Results
1	Sand zone	20mm
2	Fineness modulus	2.59
3	Specific gravity	2.63
4	Water absorption	1.0%

2.1.4 Water

Water is the most basic and effectively accessible part of concrete as it effectively includes in compound response with bond. A little measure of water get utilized as a part of the hydration of bond, shaping restricting grid and remaining water goes about as a grease in the middle of fine and coarse total and does the solid functional. Ordinarily the bond requires around 3/10 of its weight of water for procedure of hydration. Subsequently least water concrete proportion essential is 0.2. Be that as it may, overabundance water is important to grease up the solid blend which does the solid serviceable. The water prerequisite is kept least alongside utilization of synthetic plasticizer which is particularly fundamental for high review solid, so the water-folio proportion of 0.2 to 0.35 is reasonable for high review concrete. In the present work, consumable faucet water available at utilized for blending and relieving the solid and it ought to have pH esteem is 7 utilized.

2.1.5 Ground Granulated Blast Furnace Slag

Ground Granulated impact heater slag (GGBS) is a side-effect from the impact heater used to make press. These work at a temperature of around 1500 degrees centigrade and are nourished with a painstakingly controlled blend of iron metal, coke and lime stone. The iron metal is decreased to press and the rest of the materials from a slag that buoys on top the iron. This slag is occasionally finished off as a liquid fluid and on the off chance that it is to be utilized for the make of GGBS it must be quickly quenclud in substantial volumes of water. The quencling improves the cementations' properties and delivered granular like coarse sand. This granulated slag is then dried and ground to a fine powder.

Albeit regularly assigned as GGBS in the United kingdom. It can likewise be alluded as GGBS or Slag bond concrete is essentially a blend of fine totals, coarse totals and bond. The primary issue is unique traditional materials are draining and utilize are in chase for exchange building materials which stacks as here on the motivation behind GGBS. Being a result and waste utilizing it viably up to some degree benefit as venture for a greener domain and in the meantime remembering that the quality of the solid does not debase by the utilization GGBS.

Fig:2.1 Ground Granulated Blast furnace slag

2.1.6 Waste Foundry Sand (WFS)

Foundry sand is amazing silica sand with uniform physical attributes. Metal foundries utilize a lot of the metal throwing process. Foundries effectively reuse and reuse the sand ordinarily in a foundry and the rest of the sand that is named as foundry sand is expelled from foundry. This examination shows the data about the structural designing utilizations of foundry sand, which is actually stable and is earth safe. Utilization of foundry sand in different designing applications can take care of the issue of transfer of foundry sand and different purposes.

Foundry sand comprises basically of silica sand, covered with a thin film of consumed carbon, remaining fastener (bentonite, ocean coal, gums) and residue. Foundry sand can be utilized as a part of cement to enhance its quality and other toughness factors. Foundry sand can be utilized as a fractional substitution of fine totals or aggregate substitution of fine total and as supplementary expansion to accomplish diverse properties of cement.

Fig:3.5 Waste foundry sand

2.1.7 Waste Ceramic tiles (WCT)

Broken tiles were gathered from the strong misuse of fired assembling unit and from obliterated building. The waste tiles were smashed into little pieces by physically and by utilizing crusher. The required size of pulverized tile total was isolated to utilize them as incomplete substitution to the common coarse total. The tile squander which is lesser than 4.75mm size was ignored. The pounded tile total going through 16.0mm strainer and held on 12.5mm sifter are utilized. Smashed tiles were in part supplanted instead of coarse total by the rates 0%, 10%, 20%, 30% and 40%.

Fig: 3.6 Waste ceramic tiles

3. CONCRETE MIX DESIGN

Mix design is the procedure of selecting suitable components of concrete and finding out their relative proportion for producing concrete of certain minimum strength as cost effective as possible for the present work concrete grade of M25 proposed to be utilized in any RCC members is adopted. Mix design is done according to strength of concrete of code IS: 10262-2009[13]. Test on trial mixes have been done. At least a mix proportion that gives required 28 days cube compressive strength with least amount of cement content and necessary workability 50 to 75mm is chosen.

3.1 MIX DESIGN FOR M25 GRADE CONCRETE:

Table 3.1 Final Mix Proportion

Water	Cement	Fine aggregates	Coarse aggregates
208.01	175 kg/m3	676.8 kg/m3	1174.01 kg/m3
208.01	1	2.307	3.98

Table 3.2Details of Mix variation for M25 Grade of concrete

Sl. No	% replacement	Mix proportion						W/c ratio
		C	GGBS	FA	WFS	CA	WCT	
1	CC	1182	0	2375	0	4106	0	0.46
2	10	1063.8	118.2	2137.5	237.5	3695.4	410.6	0.46
3	20	945.6	236.4	1900	475.0	3284.8	821.2	0.46
4	30	827.4	354.6	1662.5	712.5	2874.2	1231.8	0.46
5	40	709.2	472.8	1425	950	2463.6	1642.4	0.46

4. RESULTS AND DISCUSSION

4.1 Slump Test

Slump test done for cc and variations with GGBS as partial replacement at 0%,10%,20%,30% and 40% for cement and waste ceramic tiles as coarse aggregate replacement at 0%,10%,20%,30% and 40% and waste foundry sand as fine aggregate replacement at 0%,10%,20%,30% and 40% respectively. The results are tabulated in Table 4.1.

Table 4.1 Workability of concrete at conventional and replaced stages

Sl.No	% replacement of GGBS, WFS&WCT	Water added	W/C ratio	Slump	Degree of work ability
1	CC	160ml	0.46	12	Low
2	10	160ml	0.46	44	Low
3	20	160ml	0.46	55	Medium
4	30	160ml	0.46	68	Medium
5	40	160ml	0.46	74	Medium

4.2 Compressive strength Test

Compressive strength of concrete made with waste ceramic tiles and waste foundry sand as replacement of natural aggregates and replacement of cement with GGBS at varying percentage of 0%,10%,20%,30% and 40% replacement level for all variation was determined at 7days and 28days. The test results are shown in Table 4.2 and 4.3 and figure 4.1.

Table 4.2 Compressive strength results of GGBS,WFS and WCT mixed concrete for 7days in N/mm²

Mix proportion			Mix designation	Ultimate load (KN)			Compressive Strength N/mm² 7 days
GGBS (%)	WFS (%)	WCT (%)		Trial 1	Trail 2	Average	
0	0	0	M1	390	420	405	18.00
	0	0	M2	410	420	415	18.44
	10	10	M3	500	480	490	21.77
10	20	20	M4	490	520	505	22.44
	30	30	M5	510	520	515	22.58
	40	40	M6	480	490	485	21.55
	0	0	M7	390	400	395	17.55
	10	10	M8	380	410	395	17.55
20	20	20	M9	480	420	450	20.00
	30	30	M10	470	490	480	21.33
	40	40	M11	380	460	420	18.66
	0	0	M12	380	400	390	17.33
	10	10	M13	390	430	410	18.22
30	20	20	M14	450	480	465	20.66
	30	30	M15	520	490	505	22.44
	40	40	M16	530	510	520	23.11
	0	0	M17	420	440	430	19.11
	10	10	M18	390	430	410	18.22
40	20	20	M19	400	360	380	16.88
	30	30	M20	380	360	370	16.00
	40	40	M21	360	370	365	16.44

Table 4.3 Compressive strength results of GGBS,WFS and WCT mixed concrete for 28days in N/mm²

Mix proportion			Mix designation	Ultimate load (KN)			Compressive Strength N/mm² 28 days
GGBS (%)	WFS (%)	WCT (%)		Trial 1	Trail 2	Average	
0	0	0	M1	540	550	545	24.22
	0	0	M2	590	610	600	26.67
	10	10	M3	620	640	630	28.00
10	20	20	M4	690	710	700	31.11
	30	30	M5	780	760	770	34.22
	40	40	M6	780	800	790	35.11
	0	0	M7	590	510	550	24.44
	10	10	M8	770	810	790	35.11
20	20	20	M9	800	820	810	36.00
	30	30	M10	870	890	880	39.11
	40	40	M11	910	930	920	40.88
	0	0	M12	490	510	500	22.22
	10	10	M13	840	800	820	36.44
30	20	20	M14	910	910	910	40.44
	30	30	M15	980	960	970	43.11
	40	40	M16	940	960	950	42.20
	0	0	M17	550	530	540	24.00
	10	10	M18	680	640	660	29.33
40	20	20	M19	700	660	680	30.22
	30	30	M20	690	660	675	30.00
	40	40	M21	670	630	650	28.89

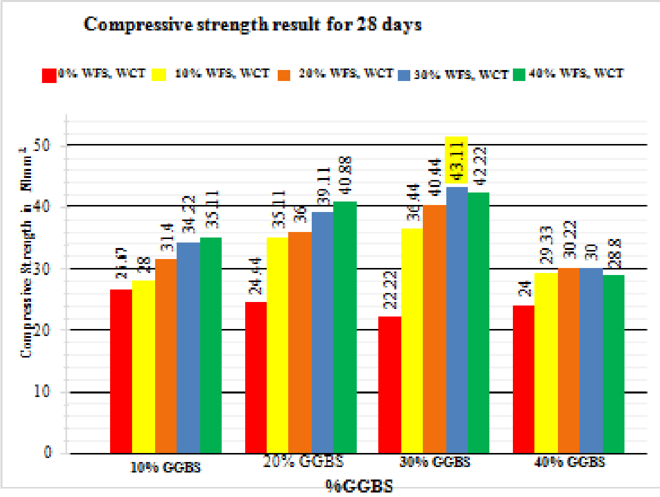

Fig: 4.1. Effect of GGBS and WFS, WCT percentages on 28thdays compressive strength

4.3 Split Tensile Strength Test

The test results of split tensile strength of M25 grade concrete with waste ceramic tiles and waste foundry sand as replacement of natural aggregates and replacement of cement with GGBS at varying percentage 0%,10%,20%,30% and 40% replacement level for all variations obtained. The strength values for using periods28 days are given in Table 4.4 and figures 4.2 and there values are compared with the normal concrete.

Table 4.4 Split tensile strength results of GGBS, WFS and WCT mixed concrete for 28days in N/mm²

Mix proportion			Mix designation	Ultimate load (KN)			Split tensile Strength N/mm² 28 days
GGBS (%)	WFS (%)	WCT (%)		Trial 1	Trail 2	Average	
0	0	0	M1	250	230	240	2.97
	0	0	M2	190	200	195	2.75
	10	10	M3	180	220	200	2.83
10	20	20	M4	230	210	220	3.11
	30	30	M5	240	210	230	3.25
	40	40	M6	250	270	260	3.67
	0	0	M7	190	230	210	2.97
	10	10	M8	210	230	220	3.11
20	20	20	M9	230	230	230	3.25
	30	30	M10	240	250	245	3.46
	40	40	M11	260	240	250	3.53
	0	0	M12	200	260	230	3.25
	10	10	M13	250	220	235	3.32
30	20	20	M14	260	260	260	3.67
	30	30	M15	280	260	270	3.81
	40	40	M16	260	240	250	3.53
	0	0	M17	210	220	210	2.97
	10	10	M18	220	220	220	3.12
40	20	20	M19	240	220	230	3.25
	30	30	M20	230	230	230	3.20
	40	40	M21	210	230	220	3.12

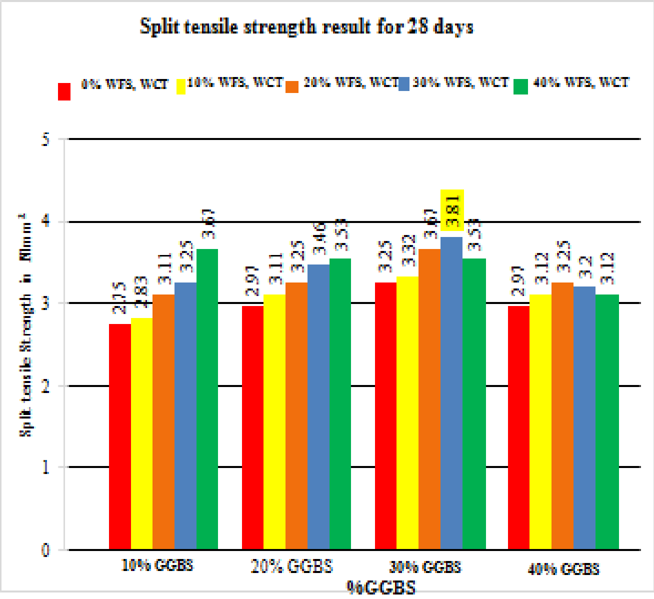

Fig: 4.2. Effect of GGBS and WFS, WCT percentages on 28th days split tensile strength

4.4 Flexural Strength Test

The test results of flexural strength of M25 grade concrete with standard 100mm X 100mm X 500mm beams at 28days age. Obtained are tabulated in the Table 5.5 and the results are graphically show in the fig with waste ceramic tiles and waste foundry sand as replacement of natural aggregates and replacement of cement with GGBS at varying percentage 0%,10%,20%,30% and 40% replacement level for all variations obtained.

Table 4.5 Flexural strength results of GGBS, WFS and WCT mixed concrete for 28days in N/mm^2

Mix proportion			Mix designation	Ultimate load (KN)			Flexural Strength N/mm^2 28 days
GGBS (%)	WFS (%)	WCT (%)		Trial 1	Trail 2	Average	
0	0	0	M1	17	16	16.5	8.25
	0	0	M2	14	16	15	7.50
	10	10	M3	16	16	16	8.00
10	20	20	M4	18	16	17	8.50
	30	30	M5	18	18	18	9.00
	40	40	M6	18	18	18	9.00
	0	0	M7	16	16	16	8.00
	10	10	M8	18	18	18	9.00
20	20	20	M9	19	19	19	9.50
	30	30	M10	20	20	20	10.00
	40	40	M11	21	21	21	10.50
	0	0	M12	16	16	16	8.00
	10	10	M13	19	19	19	9.50
30	20	20	M14	20	20	20	10.00
	30	30	M15	22	22	22	11.00
	40	40	M16	21	21	21	10.50
	0	0	M17	15	15	15	7.50
	10	10	M18	16	16	15	8.00
40	20	20	M19	16	16	15	7.50
	30	30	M20	14	14	14	7.00
	40	40	M21	14	14	12	6.00

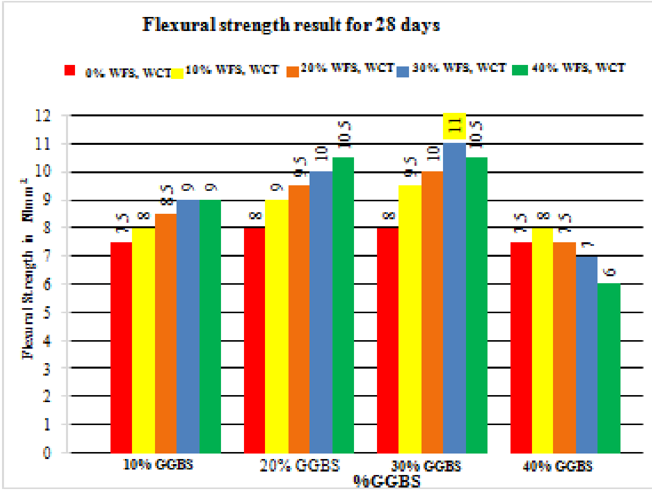

Fig: 4.3Effect of GGBS and WFS,WCT percentages on 28thdays flexural strength

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6. CONCLUSION

In this project an attempt is made to study the mechanical properties of concrete incorporating GGBS, waste foundry sand and waste ceramic tiles. The 0%,10%,20%,30% and 40% of the GGBS is used in this project and the sand and coarse aggregate replacement with waste foundry sand and waste ceramic tiles is varied from 0%,10%,20%,30% and 40%. The mix design is done as per the IS 10262-2009. The specimen are prepared and cured as per the standard and tested for the properties. The conclusions of the study are:

1. The compressive strength of the specimen containing 30% GGBS, 30% waste foundry sand and 30% waste ceramic Tiles a replacement for cement, fine aggregate and coarse aggregate gives 28th days strength results a reduction in strength of 43.11 N/mm^2 and it is lesser compared to conventional concrete strength of 24.22 N/mm^2, and thus it confirms the use of GGBS as binding material along with cement.

2. The split tensile strength of the specimen containing 30% GGBS, 30% waste foundry sand and 30% waste ceramic tile as a replacement for cement, fine aggregate and coarse aggregate gives values of 28 days strength results a reduction in strength of 11 N/mm^2 and it is lesser compared to conventional concrete strength of 8.25 N/mm^2 with mixed concrete.

3. Flexural strength of 30% GGBS, 30% waste foundry sand and 30% waste ceramic tile mixed concrete shows a strength of 11 N/mm^2 which is more than the conventional concrete strength and the concrete with combination of GGBS, waste foundry sand and waste ceramic tiles also gives the considerable improvement in strength.

4. Workability of concrete mix increases with increase in percentage of GGBS, waste foundry sand and waste ceramic tile as compare to regular concrete.

5. The results showed that the strength properties of concrete were acceptable it was worth in utilizing GGBS, waste foundry sand and waste ceramic tile in concrete as a partial replacement for cement, fine aggregate and coarse aggregate and also it proves as a good technique for solving an environmental issue caused by its disposal.

6. As GGBS is waste from industries, waste foundry sand is waste from metal industries and waste ceramic tiles is waste from construction industries therefore waste can be effectively use in concrete mix hence an eco-friendly construction mater.

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