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Study of Properties of High Strength Concrete Prepared by Replacement of Fine Aggregate with Weathered Crystalline Rock Sand & Partial Replacement of Cement with GGBS

Roshan Sasidharan
M.Tech Student
ICET
Muvattupuzha,India

Ranjan Abraham
Asst Professor
ICET
Muvattupuzha

***Abstract*— Concrete is a composite construction material composed of cement, fine aggregate, coarse aggregate and water. Aggregate occupy 70-75% of the total volume of concrete. Concrete is designated as "high strength concrete" on the basis of its compressive strength measured at a given age. Concrete mix that show 40MPa or more compressive strength at 28-days are designated as high-strength concrete. Now a days, 60-100 MPa concrete mixes are commercially developed. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas a major contributor for green house effect and global warming. Hence it is inevitable to search either for a substitute to cement or partially replace it by some other material. Mineral admixtures such as blast furnace slag powder can be used as partial replacement to cement by 5 to 30%. From earlier days onwards river sand is used as fine aggregate. Nowadays, M-sand, pit sand etc. are also used. Since pit sand is available only at certain regions and due to the scarcity of river sand and M-sand, it has become necessary to find an alternative material, as fine aggregate. The alternative material selected here is fine aggregate from Weathered Crystalline Rock. This type of rock is abundantly available at low cost in tropical areas. This paper discusses the fresh state & mechanical properties of high strength concrete using weathered crystalline rock sand as fine aggregate.**

Keywords*— *High strength concrete, Weathered crystalline rock sand, M-Sand.

I. INTRODUCTION

Concrete is a widely used construction material around the world, and its properties have been undergoing changes through technological advances. So far, numerous types of Concrete have been developed. Concrete is designated as "high-strengthconcrete" on the basis of its compressive strength measured at a given age. Any concrete mixtures that showed 40 MPa or more compressive strength at 28-days are designed as high-strength concrete. Now a days 60-100MPa concrete mixtures are commercially developed and used in the construction of high-rise buildings and long-span bridges in many parts of the world. With natural aggregates, it is possible to make concretes up to 120MPa compressive strength by improving the strength of the cement paste, which is controlled through the choice of cement ratio and type and dosage of admixtures. These developments have led to increased applications of high-strength concrete (HSC) all around the globe. HSC offers many advantages over conventional concrete. The high compressive strength can be advantageously used in compression members like columns and piles. Higher compressive strength of concrete results reduction in column size and increases available floor space. HSC can also be effectively used in structures such as domes, folded plates, shells and arches where large in-plane compressive stresses exist. The inherent techniques of producing HSC generate a dense microstructure making ingress of deleterious chemicals from the environment into the concrete core difficult, thus enhancing the long-term durability and performance of the structure. Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas a major contributor for green house effect and global warming into the atmosphere. Hence it is inevitable to search either for another material or partially replace it by some other material. The search for any such material which can be used as an alternative for cement, should lead to global sustainable development and lowest possible environmental impact. Mineral admixtures such as blast furnace slag powder can be used as partial replacement of cement by 5 to 30%. Compressive strength of blast furnace slag concrete with different dosage of slag was studied as a partial replacement of cement. From the experimental investigations, it has been observed that, the optimum replacement of Ground Granulated Blast Furnace Slag Powder to cement without much change in compressive strength is 15%.

In the present scenario, scarcity of river sand and increasing cost of M- sand are the major issues in the construction field. Hence an alternative construction material which can fully or partially replace the fine aggregate without affecting the property of High strength concrete would be advantageous. Nowadays, M-sand, & pit sand. are also used as fine aggregate. Since pit sand is available only at certain regions and due to the scarcity of river sand and M-sand, it has become necessary to find an alternative material, as fine aggregate. The alternative material selected here is sand from Weathered Crystalline Rock. And this type of rock is abundantly available at low cost in tropical areas. This paper discusses the use of Weathered Crystalline Sand as fine

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aggregate in concrete. Comparison of properties like fineness, specific gravity, bulking of sand, bulk density, compressive strength of mortar cubes and compressive strength of concrete cubes using different fine aggregates is also conducted.

A. High Strength Concrete

Concrete, a composite consisting of aggregates enclosed in a matrix of cement paste including possible pozzolans, has two major components – cement paste and aggregates. The strength of concrete depends upon the strength of these components, their deformation properties, and the adhesion between the paste and aggregate surface (Berntsson et al., 1990). With most natural aggregates, it is possible to make concretes up to 120 MPa compressive strength by improving the strength of the cement paste, which can be controlled through the choice of water-content ratio and type and dosage of admixtures (Mehta and Aitcin, 1990). However, with the recent advancement in concrete technology and the availability of various types of mineral and chemical admixtures, and special superplasticizer, concrete with a compressive strength of up to 100 MPa can now be produced commercially with an acceptable level of variability using ordinary When the general performance of concrete is substantially higher than that of normal type concrete, such concrete is regarded as high performance concrete (HPC). Three of the key attributes to HPC are discussed. They are: strength, ductility and durability. In order to know the intrinsic differences between normal type concrete and high performance concrete, micro-structure and composition of HPC are studied. Stress strain behavior of HPC under biaxial and triaxial loading are described. Finally, the application of HPC in tall building construction is discussed. A general overview of the development of HPC, covering the topic from the laboratory testing to the industrial application.

B. Granulated Blast Furnace Slag

Blast furnace slag is a solid waste discharged in large quantities by the iron and steel industry in India. The re-cycling of these slag's will become an important measure for the environmental protection. Iron and steel are basic materials that underpin modern civilization, and due to many years of research the slag that is generated as a by-product in iron and steel production is now in use as a material in its own right in various sectors. Slag enjoys stable quality and properties that are difficult to obtain from natural materials and in the 21st century is gaining increasing attention as an environmentally friendly material from the perspectives of resource saving, energy conservation and CO2 reduction. The primary constituents of slag are lime (CaO) and silica (SiO2). Portland cement also contains these constituents. The primary constituent of slag is soluble in water and exhibits an alkalinity like that of cement or concrete. And as it is removed at high temperatures of 1,200°C and greater, it contains no organic matter whatsoever. Ground Granulated Blast furnace slag (GGBS) is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is produced which is instantaneously tapped and quenched by water. This rapid quenching of molten slag facilitates formation of "Granulated slag". Ground Granulated Blast furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material. However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material. Though the use of GGBS in the form of Portland slag cement is not uncommon in India, experience of using GGBS as partial replacement of cement in concrete in India is scanty. GGBS essentially consists of silicates and alumina silicates of calcium and other bases that are developed in a molten condition simultaneously with iron in a blast furnace. The chemical composition of oxides in GGBS is similar to that of Portland cement but the proportion varies. This paper deals with the use of the blast furnace slag powder as a partial replacement of OPC and its effect on strength of cement concrete mix

Fig.1 Granulated blast furnace slag

C. Weathered Crystalline Rock

Weathered Crystalline Rocks are metamorphic rocks seen in the tropical areas like Kerala. They are formed by the weathering action on the rocks. Weathered crystalline rock is the outer layer of the underlying hard rock. Hence excessive mining is not required to obtain these types of rocks. In Kerala, weathered crystalline rock is used for the construction of small compound walls instead of random rubble and Laterite bricks. Generally, weathered crystalline rock sand is used for plastering works. Chemical combination of the weathered crystalline rock is almost similar to the chemical combination of naturally occurring rocks. Silica is the major constituent in natural sand and weathered crystalline rock. Other constituents like oxides of Manganese, Magnesium, Iron, Aluminium etc. are in the safe limits. Other trace elements are in the range of ppm those are not at all affects the chemical activity of fine aggregate. From earlier days onwards river sand is used as fine aggregate. Nowadays, M-sand, pit sand etc. are also used. Since pit sand is available only at certain regions and due to the scarcity of river sand and M-sand, it has become necessary to find an alternative material, as fine aggregate. The alternative material selected here is sand from Weathered Crystalline Rock. And this type of rock is abundantly available at low cost in tropical areas. This paper discusses the use of Weathered Crystalline Sand as fine aggregate in concrete. A comparison of properties like fineness, specific gravity, bulking of sand, bulk density, compressive strength of mortar cubes and compressive strength of concrete cubes using different fine aggregates is also conducted.

Fig.2 Weathered Crystalline Rock Sand

II. METHODOLOGY

The methodology adopted for the present experimental investigation is as follows:

A. Literature Review

B. Selection Of Materials

- Cement(Ordinary Portland Cement), Blast Furnace Slag, Coarse Aggregate, Weathered crystalline Rock Sand as fine aggregate, Super Plasticizer.

C. Determination of Material Properties

- Cement:-Specific gravity, initial setting time, final setting time, standard consistency
- Blast furnace slag:- Physical and chemical properties, specific gravity
- Fine aggregate:- Specific Gravity, water absorption, sieve analysis, bulk density and percentage of voids
- Coarse Aggregate:-Specific gravity, water absorption, sieve analysis, aggregate crushing value
- Water
- Super Plasticizer

D. Preparation Of Specimen

- Preparation of M40 Mix
- Preparation of mix with coarse aggregate and fine aggregate as weathered crystalline rock sand and find the optimum percentage of coarse and fine aggregate for M40 mix.
- Preparation of concrete with optimum percentage of coarse and fine aggregate with partial replacement of cement with blast furnace slag(40%,50%,60%)
- Cube of size 150×150×150mm, Beam of size100×100×500mm, and cylinder of size300×150mm are casted to conduct test for compressive strength, flexural strength, splitting tensile strength of mixes. Age for compressive strength is 3,7,and 28 days and for flexural and splitting tensile strength 7 and 28 days

E. Laboratory Tests

- Study on fresh state properties by conducting slump and compaction factor test.
- Study of hardened state properties by conducting tests for Compressive strength, splitting tensile strength, flexure strength, water absorption.

III. MATERIAL CHARACTERIZATION

A. Cement

OPC 53 grade concrete was used in this study

TABLE.1 PROPERTIES OF CEMENT

Test	Values
Standard Consistency	35%
Initial Setting Time	240 min
Specific Gravity	3.125
Fineness	5%

B. Fine Aggregate

M-Sand was used for the study

TABLE.2 PROPERTIES OF FINE AGGREGATE

Test Conducted	Values Obtained
Specific Gravity	2.69
Fineness	2.59%
Water Absorption	1.5%
Bulk Density	1.13 kg/l
Percentage voids	54.44%
Water Content	2.2%

C. Coarse Aggregate

Coarse aggregate conforms to table 2 of IS 383-1970

TABLE.3 PROPERTIES OF FINE AGGREGATE

Test	Values
Specific Gravity	2.67
Fineness	7.45%
Water Absorption	0.8%
Bulk Density	1.25 kg/l
Percentage Voids	50.41%
Aggregate Crushing Value	28.66%

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D. WEATHERED CRYSTALLINE ROCK SAND

TABLE.4 PROPERTIES OF WEATHERED CRYSTALLINE ROCK SAND

Test	Values
Specific Gravity	2.65
Fineness	2.75%
Water Absorption	3%

E. GROUND GRANULATED BLAST FURNACE SLAG

TABLE.5 PROPERTIES OF GROUND GRANULATED BLAST FURNACE SLAG

Propety	Value
Specific gravity	2.93
Fineness	3.89%
Particle size	97.10 microns

F. SUPER PLASTICIZER

TABLE.6 PROPERTIES OF SUPER PLASTICIZER

Property	Value
Aspect	Light brown liquid
Relative Density	1.08 ± 0.01 at 25°C
pH	> 6
Chloride ion content	< 0.2%

IV. MIX DESIGN

A. CONTROL MIX

TABLE.7 CONTROL MIX

Mix Proportion	
Cement	414.74 kg/m³
Water	157.60 kg/m³
Super Plasticizer	1.24 kg/m³
Fine Aggregate	801.23 kg/m³
Coarse Aggregate	1096.50 kg/m³

V. TEST FOR FRESH STATE PROPERTIES

TABLE.8 FRESH PROPERTIES OF CONCRETE

Test	Control Mix	Wcrs Mix	GGBS Mix		
			40%	50%	60%
Slump	100mm	120mm	110mm	110mm	110mm
Compaction Factor	0.91	0.89	0.90	0.90	0.90

VI. TEST FOR HARDENED STATE PROPERTIES

A. CONTROL MIX

TABLE.9 CONTROL MIX

Test	3 Days (N/mm2)	7 Days (N/mm2)	28 Days (N/mm2)
Compressive Strength	28.89	40.00	50.37
Splitting Tensile Strength	--	2.26	2.74
Flexural Strength	--	7.29	9.56

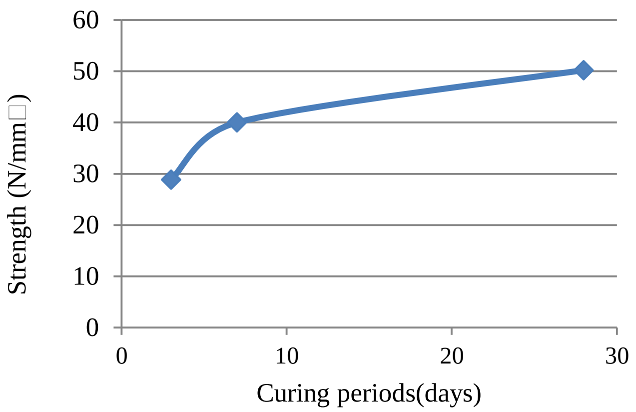

Fig. 3 Compressive Strength

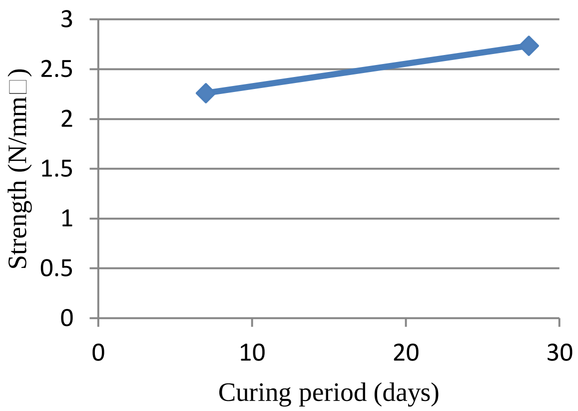

Fig.4 Splitting Tensile Strength

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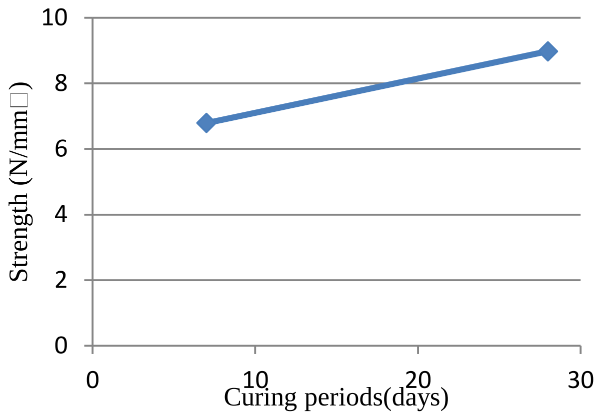

Fig.5 Flexural Strength

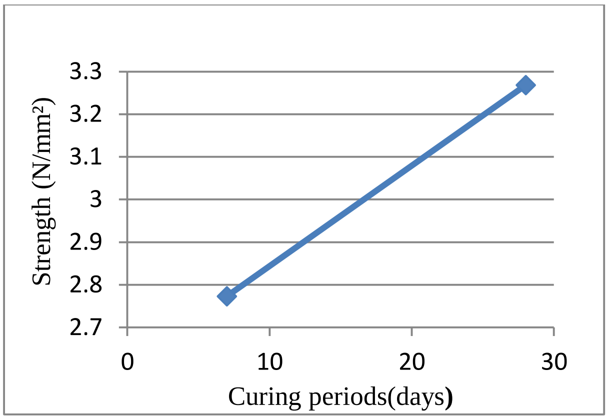

Fig. 7 Splitting Strength

B. WCRS MIX

TABLE.10 RESULTS

Test	3 Days (N/mm²)	7 Days (N/mm²)	28 Days (N/mm²)
Compressive Strength	32.44	35.85	53.33
Splitting Tensile Strength	---	2.773	3.268
Flexural Strength	---	7.456	9.677

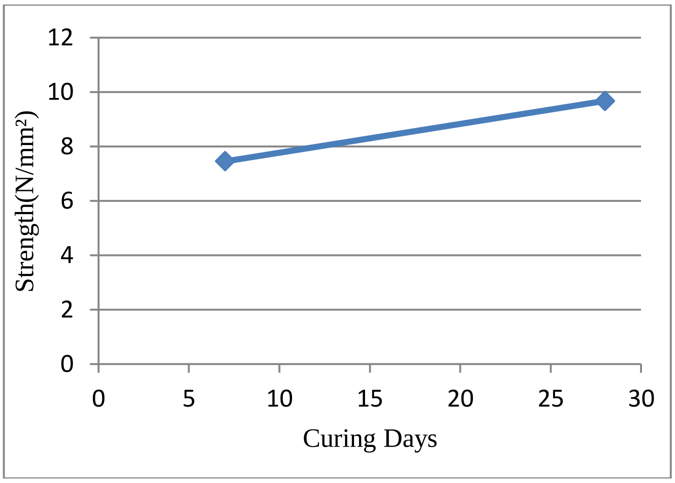

Fig.8 Flexural Strength

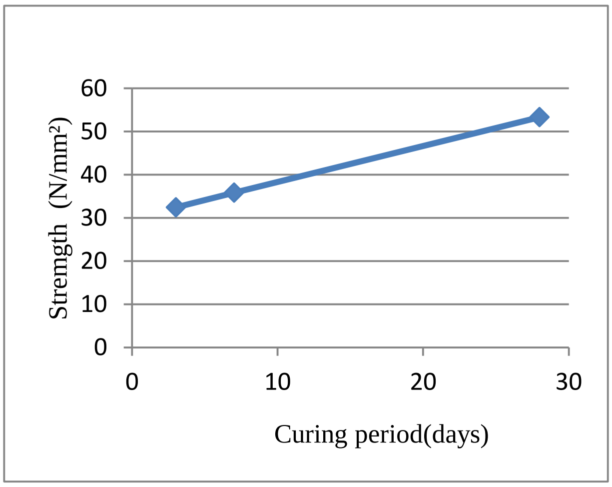

Fig. 6 Compressive Strength

C. COMPARISON OF CONTROL MIX & WCRS MIX

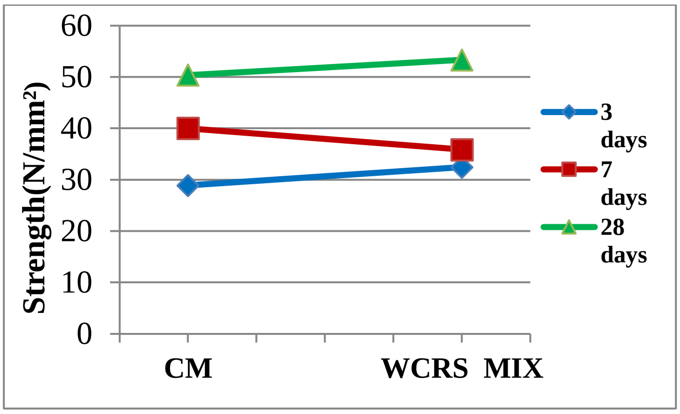

Fig. 9 Compressive Strength

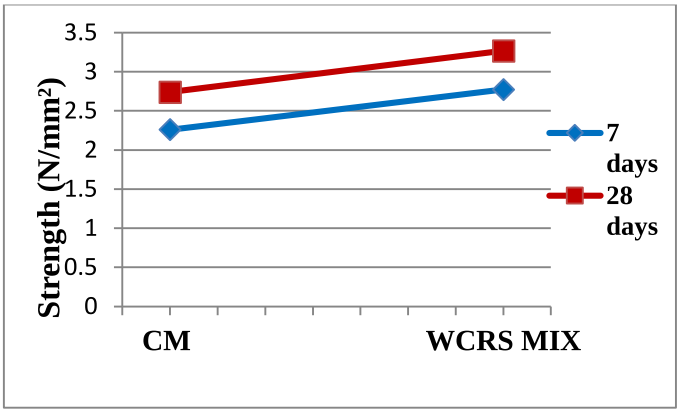

Fig. 10 Splitting Strength

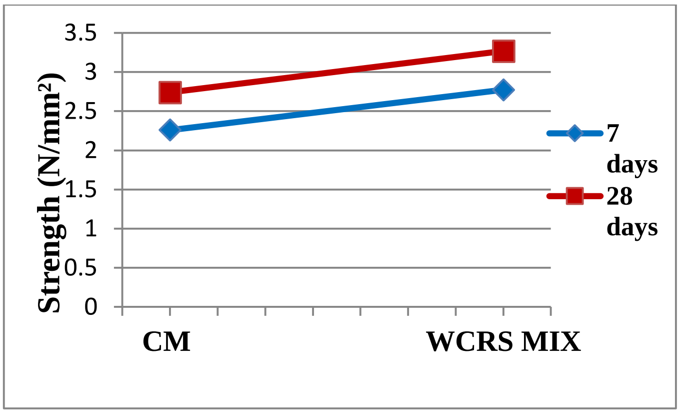

Fig.11 Flexural Strength

D. WCRS mix with cement partially replaced with GGBS

TABLE.11 RESULTS

Test	Curing Period	GGBS Added In Percentage		
		40%	50%	60%
COMPRESSIVE STRENGTH	3 days	10.67N/mm2	11.65N/mm2	10.88N/mm2
	7 days	27N/mm2	29.25N/mm2	27.29N/mm2
	28 days	42N/mm2	48.60N/mm2	40.29N/mm2
SPLITTING TENSILE STRENGTH	7 days	1.88N/mm2	2.44N/mm2	1.60N/mm2
	28 days	2.85N/mm2	3.28N/mm2	3.01N/mm2
FLEXURAL STRENGTH	7 days	4.08N/mm2	5.33N/mm2	4.69N/mm2
	28 days	4.55N/mm2	6.83N/mm2	5.38N/mm2

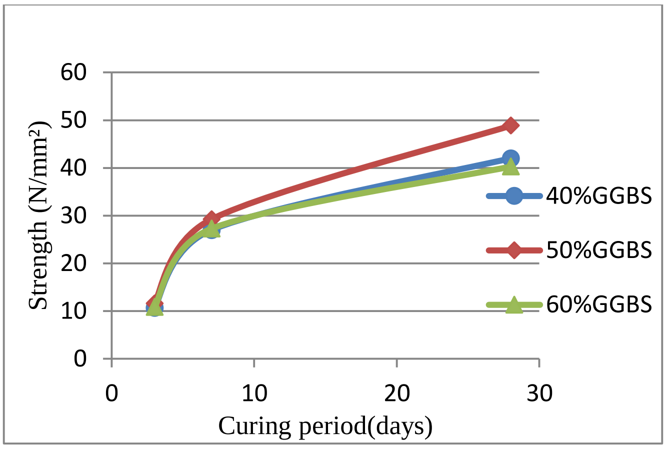

Fig. 12 Compressive Strength

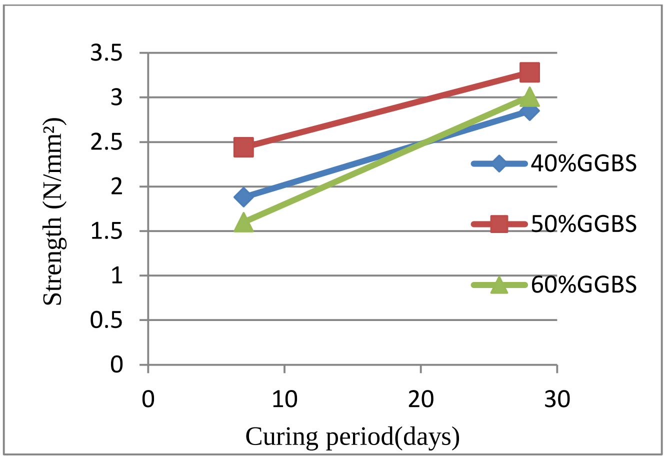

Fig. 13 Splitting Strength

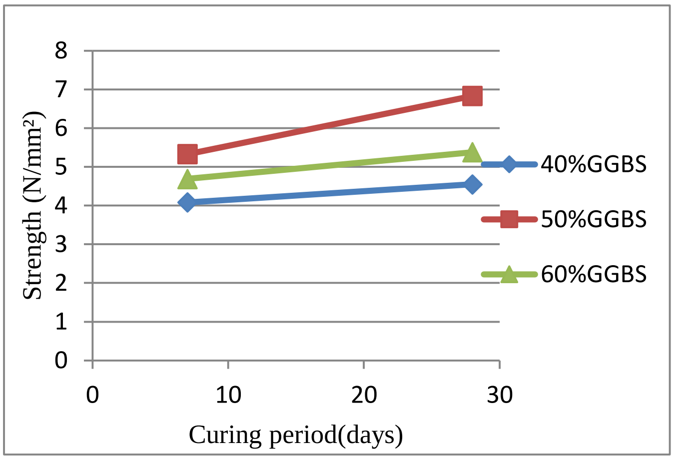

Fig.14 Flexural Strength

E. Control mix with cement partially replaced with GGBS

TABLE.12 MIX PROPORTION

Test	Curing Period	GGBS Added In Percentage		
		40%	50%	60%
COMPRESSIVE STRENGTH	3 days	15.05N/mm^2	16.09N/mm^2	15.38N/mm^2
	7 days	37.81N/mm^2	40.00N/mm^2	37.85N/mm^2
	28 days	50.21N/mm^2	53.33N/mm^2	51.40N/mm^2
SPLITTING TENSILE STRENGTH	7 days	2.42N/mm^2	2.85N/mm^2	2.66N/mm^2
	28 days	3.19N/mm^2	3.90N/mm^2	3.57N/mm^2
FLEXURAL STRENGTH	7 days	5.02N/mm^2	5.85N/mm^2	5.33N/mm^2
	28 days	6.83N/mm^2	7.75N/mm^2	7.00N/mm^2

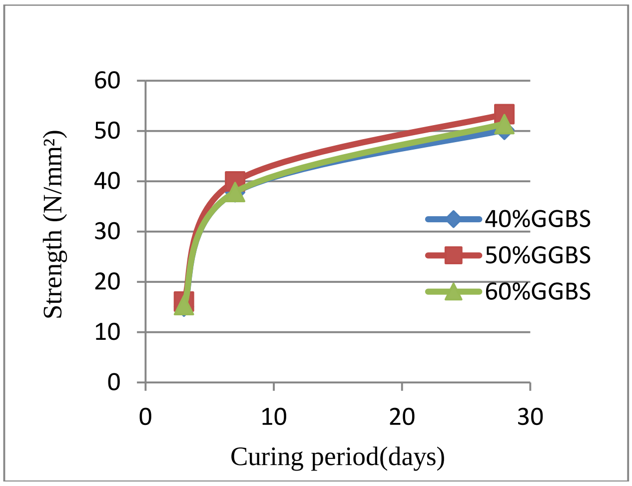

Fig. 15 Compressive Strength

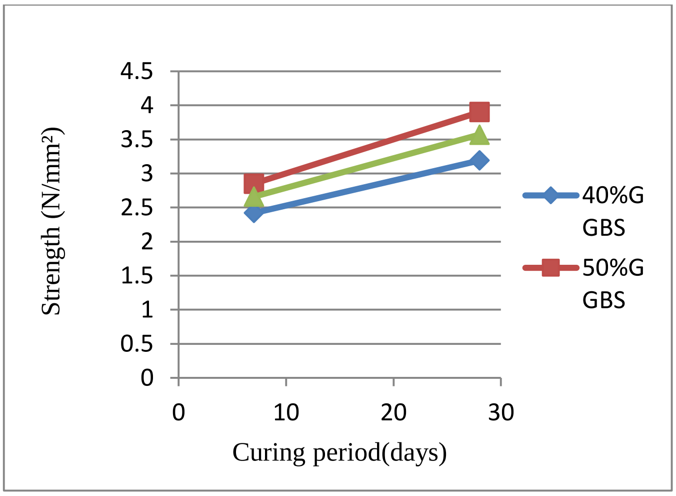

Fig. 16 Splitting Strength

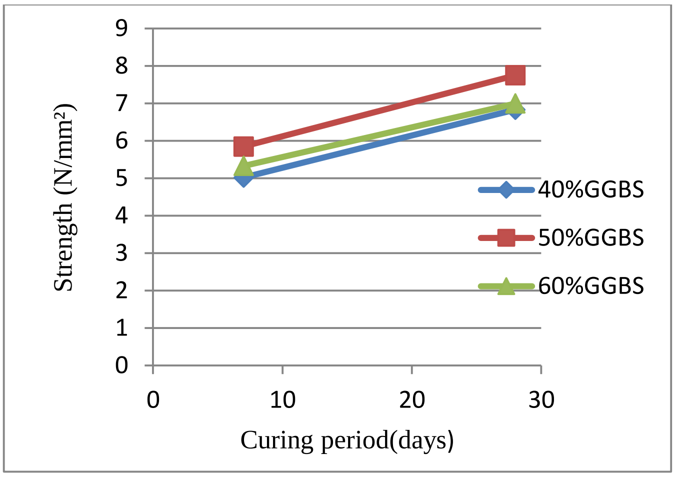

Fig.17 Flexural Strength

F. COMPARISON OF TWO MIXES WCRS MIX AND MSAND MIX WITH CEMENT REPLACED WITH GGBS

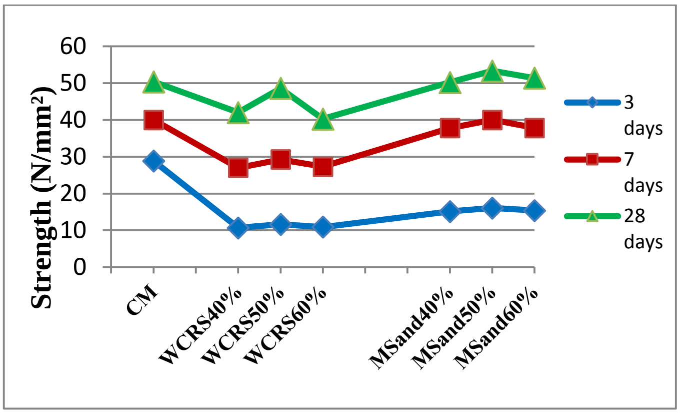

Fig. 18 Compressive Strength

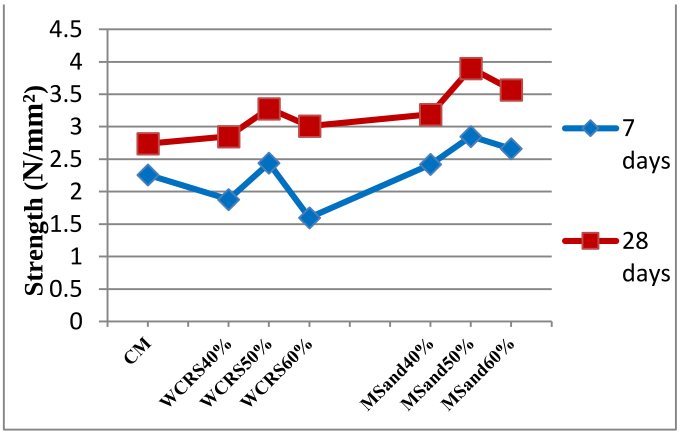

Fig. 19 Splitting Strength

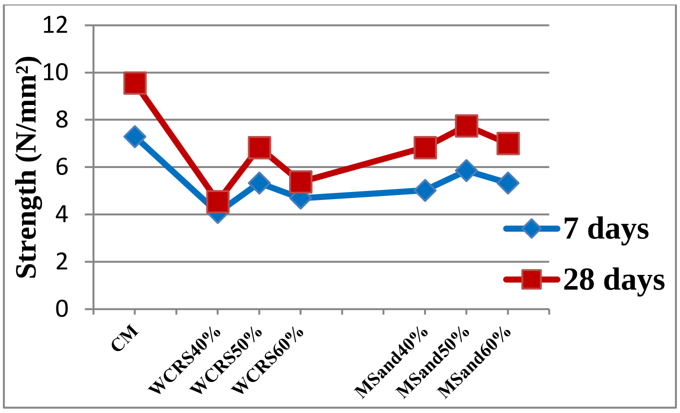

Fig.20 Flexural Strength

VII. CONCLUSIONS

- On comparison of control mix with WCRS mix, WCRS mix showed much higher strength than the target strength of control mix by about 10.53%.
- On comparing the two mix, those replaced with fine aggregate as Msand and 50%GGBS attained higher target strength of control mix by about 10.52%.
- Mix with cement partially replaced with 50% GGBS and WCRS as fine aggregate to an extent attained higher target strength of control mix by about 0.73%.
- Use of M40 mix in which cement is replaced with 50% GGBS can reduce the consumption, thus reducing production of cement and emission of carbon dioxide to atmosphere.
- WCRS can be used as an alternative to fine aggregate, thus reducing the consumption of river sand and Msand.

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