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EXPERIMENTAL STUDY ON STRENGTH PARAMETERS OF RECYCLED AGGREGATE CONCRETE USING GGBS AND FLYASH

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Abstract— The rapid growth in the construction and depletion of natural resources requires the technology of recycling and reuse that will be adopted in the field of construction. The use of recycled coarse aggregate (RCA) is one of the approaches to this need and also cement is one of the most energy-intensive construction materials and its production involves very high-temperature processing (1400 ° C to 1500 ° C) and leads to the uncontrolled extraction of natural resources and the emission of CO2 (greenhouse gas). There are many efforts to reduce Portland cement in construction. These efforts include the use of supplementary cementitious materials, as well as the use of alternative materials instead of Portland cement. In the present work, the cement is replaced with GGBS and Flyash at a constant of 40% and 25% and the coarse aggregate is replaced with the recycled coarse aggregate in proportions of 0%, 20%, 40%, 60%, 80% and 100% hardened properties such as compressive strength, split tensile strength and flexural strength are studied for the M30 grade of concrete. It has been observed that as the percentage of coarse aggregate increases the strength decreases.

Keywords— Recycled Coarse Aggregates (RCA), Ground Granulated Blast Furnace Slag (GGBS), Flyash, Ordinary Portland cement (OPC).

I. INTRODUCTION

Concrete is the most widely used building material in the world and Ordinary Portland Cement (OPC) is the main ingredient used in concrete. Cement production releases a large amount of carbon dioxide (CO2) into the atmosphere that contributes significantly to greenhouse gas emissions. It is estimated that one ton of CO_2 is released into the atmosphere for each ton of OPC produced. In view of this, there is a need to develop sustainable alternatives to conventional cement using the cementitious properties of industrial by-products such as fly ash and granulated blast furnace slag. On the other hand, the abundance and availability of fly ash and GGBS around the world create an opportunity to use these byproducts, as a partial replacement and performance enhancer for OPC.

A. Cement

Cement is a binder, a substance used for construction that hardens, and adheres to other materials to join them. Cement is rarely used alone, but to join sand and gravel (aggregates). Cement mixed with fine aggregate produces mortar, or with sand and gravel, produces concrete. Cement is the material most used today and is only behind water as the most consumed resource on the planet.

B. Ground Granulated Blast Furnace Slag (GGBS)

Granulated blast furnace slag (GGBS) is a byproduct of blast furnaces used to make iron or steel. The blast furnaces are fed with a controlled mixture of iron ore, coke, and limestone, and are operated at a temperature of approximately 1500 ° C. When iron ore, coke, and limestone are melted in the blast furnace, two products are produced: molten iron and molten slag. The molten slag is lighter and floats on the cast iron. The molten slag is composed mainly of silicates and alumina from the original iron ore, combined with some limestone oxides. The granulation process of the slag involves cooling the molten slag through high-pressure water jets. This rapidly extinguishes the slag and forms granular particles generally no larger than 5 mm. The rapid cooling prevents the formation of larger crystals and the resulting granular material comprises about 95% non-crystalline calcium aluminosilicates. The granulated slag is further processed by drying and then ground in a vertical roller mill or in a rotating ball mill until a very fine powder is obtained which is GGBS.

Two main uses of GGBS are in the production of slag cement with improved quality, namely Portland Cement Blast Furnace (PBFC) and High Slag Blast Furnace Cement (HSBFC), with a GGBS content typically ranging from 30 and 70%; and in the production of ready-mix or batch-ready durable concrete.

Concrete made with GGBSS sets more slowly than concrete made with OPC, depending on the amount of GGBS in the cementitious material, but also continues to gain strength over a longer period under production conditions. This results in lower heat of hydration and lower temperature increases, and makes it easier to avoid cold joints, but can also affect construction programs where rapid adjustment is required.

The use of GGBS significantly reduces the risk of damage caused by the reaction of alkaline silica (ASR), provides greater resistance to chloride entry, reduces the risk of corrosion by reinforcement and provides greater resistance to sulfate attacks and other chemical products.

C. Flyash

Fly ash is a byproduct of pulverized coal burning in power plants. During combustion, the mineral impurities in the coal (clay, feldspar, quartz, and shale) fuse and float out of the combustion chamber with the exhaust gases. As the molten material rises, it cools and solidifies into spherical glass particles called fly ash. Fly ash is collected from the exhaust gas by electrostatic precipitators or bag filters. The fine powder resembles Portland cement, but it is chemically different. Fly ash chemically reacts with the byproduct calcium hydroxide released by the chemical reaction between cement and water to form additional cementitious products that improve many desirable properties of the concrete. All fly ash exhibits cement properties in varying degrees depending on the physical and chemical properties of fly ash and cement. Compared to cement and water, the chemical reaction between fly ash and calcium hydroxide is usually slower, which causes a delayed hardening of the concrete. ASTM C618 defines two classes of fly ash: Class F fly ash and Class C fly ash. The difference between these classes is the amount of calcium, silica, alumina and iron content in the ash. The chemical properties of fly ash are greatly influenced by the chemical content of the burned carbon.

Class F: The oldest and toughest anthracite burning and the bituminous coal usually produces class F fly ash. Class F fly ash is pozzolanic in nature and contains less than 7% lime (CaO). By possessing pozzolanic properties, the vitreous silica and alumina of Class F fly ash require a cementing agent, such as Portland cement, quick lime or hydrated lime mixed with water to react and produce cementitious compounds. Alternatively, adding a chemical activator such as sodium silicate (glass of water) to a Class F ash.

Class C: Fly ash produced by the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash hardens and becomes stronger over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. The alkali and sulfate (SO4) contents are generally higher in Class C fly ash.

D. *Recycled Coarse Aggregate*

The aggregates of crushed concrete also called Recycled Coarse aggregates are fragments and pieces of concrete buildings that are demolished. This crushed concrete is cleaned of dirt and broken into smaller pieces to make the aggregate that is called recycled aggregate. In addition, the crushed concrete aggregate eliminates the need for disposal by using the readily available concrete as an aggregate source for new concrete or other applications. There are several reasons that encourage the use of crushed concrete, including:

1. It provides a low-cost alternative solution to crush natural raw materials.
2. The aggregate of crushed concrete makes the projects sustainable.
3. Concrete produced with added crushed concrete has a smaller carbon footprint

II. LITERATURE REVIEW

K.V.Pratap, M.Bhaskar, P.S.S.R.Teja (Jan-June 2014)

This paper mainly concentrated on partial replacement of cement with FLY-ASH & GGBS in various proportions with flyash 0%,4%,8%,12%,16% and ggbs as 0%,16%,12%,8%,4% with concrete mix of M60 grade. They concluded that compressive strength, flexural strength, split tensile strength of concrete has improved with the addition of flyash and ggbs. The compressive strength of concrete is increased by a maximum of 11.13 % at 28days with (4+16) % replacement. The flexural strength of concrete is increased by a maximum of 11.74% at 28days with (4+16) % replacement. The split tensile strength of concrete is increased by a maximum of 23.01 %at 28 days with (4+16) % replacement.

B K Varun, Harish B A (Feb 2018)

This paper involves the replacement of cement with fly ash and GGBS of the concrete mix of M30 grade. The main aim is to study the fresh and hardened properties of concrete. To study the fresh properties like slump tests, compaction factor tests and Vee-bee consistometer tests are conducted. To study hard and properties like compression and split tensile strengths are conducted. This study concludes that the incorporation of flyash & ggbs as a partial replacement of cement gives good results in both fresh and hardened state. This study reveals that low volume replacement mix [20%Flyash + 20% GGBS + 60%OPC] is giving good result than high volume mix [40%Flyash + 20% GGBS + 40%OPC].

Syed Asif Ali (July 2014)

This study deals with replacement of cement with 5%,6%,7%,8%,9%,10% by ggbs & 20%,40%,60% by flyash With constant water-cement ratio of 0.45 of mix M25. This study concluded that the optimum percentage of GGBS and fly ash is 9% and

40%. Optimum value of compressive strength for 9% and 40% replacement of the GGBS and fly ash at 7 days curing is found to be 31.59 N\mm2 and for 28 days is found to be 45.47 N\mm^2 Compressive strength increases as partial replacement of fly ash and GGBS increases and tensile strength for 28 days was found to be 12.78 N\mm^2 and flexural strength was found to be 8.81N\mm^2.

Er. Ramanuj Jaldhari & Er. Bharat Nagar (June 2017)
This study deals with the replacement of cement with ggbs and natural coarse aggregate with recycled coarse aggregate. The tests were conducted by replacing the coarse aggregate by 0%, 5%, 10%, 15%, 20%, 25%, 30% of recycled coarse aggregate and 5% of ggbs also used with the recycled aggregate mix for mix M25 with water cement ratio 0.46. The study concluded that by using RCA from demolished concrete, blended with natural aggregate it is possible to achieve desired strength and durability properties. Through the use of supplementary materials with the addition of ggbs it is possible to replace natural coarse aggregate Up to 20% without affecting the strength and durability properties of concrete.

Dr. M.N.Bajad, Nandan Mutha, Hatim Husain, Nikhil Kshirsagar (March-April 2015)
In this study, the natural coarse aggregate is replaced with RCA at a different percentage and the mechanical strength of concrete is tested. In addition, the flyash is introduced as a replacement of cement. The objective of the study is to determine the sustainability of RCA as an alternative material to natural coarse aggregate and to compare the workability and compressive strength result using flyash. The mix design is done for a water-cement ratio of 0.5. Cubes are casted by replacing with 10%, 20%, 30%, and 40% RCA and flyash. The study concluded that the recycled coarse aggregate may be an alternative to conventional concrete. The workability of concrete increased with increase in flyash and decreased with increase in RCA. The specimen's up to 30% replacement of flyash get the strength more than ordinary strength. Optimum strength of concrete was achieved at 20% replacement of cement by flyash. Optimum compressive strength is obtained at the percentage replacement of flyash (30%) and RCA (20%).

Balaraju Yugandhar, Manthena Sri Lakshmi (August 2017)
This study deals with the replacement of cement with flyash, ggbs and broken tiles with percentages of 0%, 10%, 20%, 30%, 40%, and 50% for casting cubes, cylinders, beams and cured for 7,28,56 days for determining compressive strength, split tensile strength, flexural strength.
The study concluded that the compressive strength, split tensile strength, flexural strength was increased up to 0% to 30% and for 40% & 50%, they were decreased. The optimum percentage of replacement was found to be 30%.

Etaveni Madhavi, M.Akhilesh, G.Vishwanath Sharma, K.Venkatesh (April 2016)
In this study the cement was replaced with flyash and ggbs in percentages of 0%, 5%, 7.5%, 710%, 12.5%, and 15%. The cubes were casted to evaluate compressive strength for 7, 14 &28 days. The study concluded that the compressive strength was decreased when compared with conventional concrete.

Prof. Mallesh M., Suresh R. (September 2017)
In this study ggbs and steel slag are used as replacement for cement and fine aggregate and M20 grade of concrete with W/C 0.5 is carried out with five percentage of cement replacement by GGBS i.e., 5%, 10%, 15%, 20%, and 25%, along with the steel slag varied as 0%, 10%, 20%, 30%, and 40%. For all mixes, compressive strength is determined at 7 and 28 days of curing. The study concluded that the optimum strength was obtained at the replacement of 15%ggbs & 30% steel slag.

Prof. Seetharam.Munnur, Siddarth (January 2015)
The study deals with the replacement of cement by ggbs in 10%,20%,30%,40% and 1% steel fibers of a round crimped type having aspect ratio 54 were used and compressive strength, split tensile strength, flexural strength were conducted. The study concluded that with the replacement of ggbs up to 40% and 1% steel fibers compressive and split tensile strength increased about 13% and 18.2% and flexural strength of prism and beams were increased about 15.16% and 15.32%.

Sheikibrahim k, Sathish S, Mohammad Fahad A S, Sathish Sharma A, Karthika H, Shanmuganathan N (April 2018)
This study deals with the replacement of cement completely with ggbs and flyash. GGBS were used in proportion of 0%, 70%, 60%, 50%, and 40% and flyash in proportions of 0%, 30%, 40%, 50%, and 60% with M40 grade of concrete and compressive strength and split tensile strengths were performed.
The experiment concludes that by fully replacing ggbs and flyash with cement for M40 grade of concrete has attained a compressive strength of 32Mpa in 28 days and tensile strength of 205Mpa in 28 days in [60% ggbs + 40% flyash] proportion.

III. Experimental Investigation

A. Cement

In this present work, Birla Gold cement of 53 grade ordinary Portland cement (OPC) is used for casting cubes and cylinders and prisms for all concrete mixes. The cement is of uniform color i.e. Grey and is free from any hard lumps. The various tests conducted on cement are specific gravity, initial and final setting time and fineness. Testing on cement is done as per IS codes. The properties of Portland cement are reported in below table

TABLE I
Properties of Cement

Tests	Results
Standard Consistency	32%
Fineness	6%
Specific Gravity	3.15
Initial Setting Time	150 minutes
Final Setting Time	220 minutes

B. Flyash

In present work, the fly ash is procured from Kakatiya thermal power station and it is located in chelpur village, Bhupalpalle (District), Telangana.

TABLE II
Properties of Flyash

Tests	Results
Specific Gravity	2.25

C. GGBS

In present work, the GGBS is procured from JSW cement Limited (Venkat Sai Enterprises) and it is located at Hunter Road, Warangal Urban (District), Telangana.

TABLE III
Properties of GGBS

Tests	Results
Specific Gravity	2.75

D. Fine Aggregate

The sand used for this project was locally procured and conformed to grading zone II as per IS 383-1970.

TABLE IV
Properties of Fine Aggregate

Tests	Results
Specific Gravity	2.45
Bulk Density	1.5gm/cm^3
Grading Zone	II
Fineness modulus	2.7
% of Voids	35%
Void Ratio	0.53

E. Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20mm is used in the present work.

TABLE V
Properties of Coarse Aggregate

Tests	Results
Specific Gravity	2.77
Bulk Density	1.402gm/cm^3
Void Ratio	0.9
% of Voids	49.8%
Fineness Modulus	7.89

F. Recycled Coarse Aggregate

RCAs used were obtained from laboratory waste and crushed to 20 mm average particle size.

TABLE VI
Properties of Recycled Coarse Aggregate

Tests	Results
Specific Gravity	2.53
Bulk Density	1.371gm/cm^3
% Of Voids	45.71%
Void Ratio	0.84

G. Water

Potable tap water is used for the preparation of specimens and for curing specimens.

H. Mix Design

Mix design is a process of finding the proportions of concrete mix in terms of ratios of cement, fine aggregate, coarse aggregate. The grade designation gives the characteristic strength requirement of concrete. The mix design is done as per IS: 456-2000 and IS: 10262-2009.

TABLE VII
Mix Design of M30 Grade Concrete

Materials	Cement	Fine aggregate	Coarse aggregate	Water (lit.)
Quantity (kg/m^3)	437.77	735.091	1011.285	197
Proportions	1	1.679	2.31	0.45

I. Mix Designation

In the present work total, 7 mix proportions were used. In the 1st mix conventional concrete was casted. From 2ndrd to 7th mix cement was replaced with ggbs and flyash in 40% and 25% along with Coarse aggregate was replaced with Recycled coarse aggregate in ratios of 0%, 20%, 40%, 60%, 80%, 100% respectively.

TABLE VIII
Mix Designation

Mix Designation	Cement	Flyash	GGBS	F.A	NCA	RCA
M-1	35	25	40	100	100	0
M-2	35	25	40	100	100	0
M-3	35	25	40	100	80	20
M-4	35	25	40	100	60	40
M-5	35	25	40	100	40	60
M-6	35	25	40	100	20	80
M-7	35	25	40	100	0	100

IV. RESULTS AND DISCUSSIONS

A. *Compressive Strength:*

TABLE IX
Compressive strength for 7 & 28 days

Mix No.	Compression strength			
	7 days		28 days	
	Load (in KN)	Test value (N/mm^2)	Load (in KN)	Test value (N/mm^2)
M-1	533.3	23.7	800	35.6
M-2	420	18.7	640	28.4
M-3	400	17.8	630	28
M-4	390	17.3	615	27.3
M-5	375	16.7	595	26.4
M-6	370	16.4	590	26.2
M-7	350	15.6	570	25.3

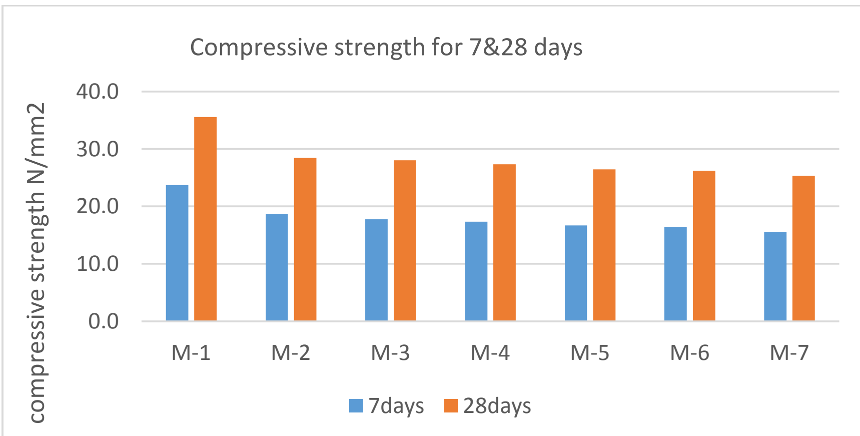

Fig. 1. Compressive strength for 7&28 days

B. *Split Tensile Strength:*

TABLE X
Split Tensile strength for 7 & 28 days

Mix No.	Split tensile strength			
	7 days		28 days	
	Load (in KN)	Test value (N/mm^2)	Load (in KN)	Test value (N/mm^2)
M-1	156.7	2.2	210	3
M-2	100	1.4	160	2.3
M-3	83.3	1.2	140	2
M-4	80	1.1	135	1.9
M-5	73.3	1	125	1.8
M-6	53.3	0.8	120	1.7
M-7	46.7	0.7	100	1.4

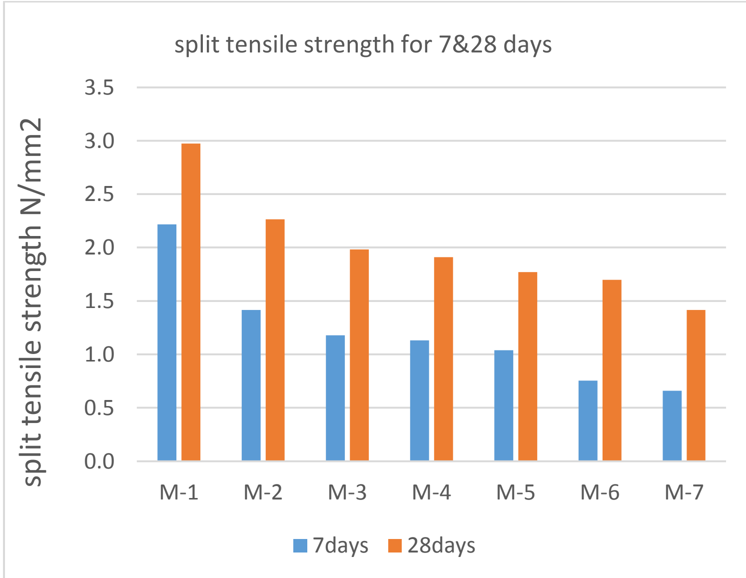

Fig. 2. Split tensile strength for 7&28 days

C. Flexural Strength:

TABLE XI
Flexural strength for 7 & 28 days

Mix No.	**Flexural strength**			
	7 days		**28 days**	
	Load (in KN)	**Test value (N/mm^2)**	**Load (in KN)**	**Test value (N/mm^2)**
M-1	14.5	7.3	16.1	8
M-2	12.2	6.1	14	7
M-3	11	5.5	13.3	6.7
M-4	10.6	5.3	12.6	6.3
M-5	10.2	5.1	11	5.3
M-6	9.6	4.8	10.2	5.1
M-7	9.3	4.7	9.8	4.9

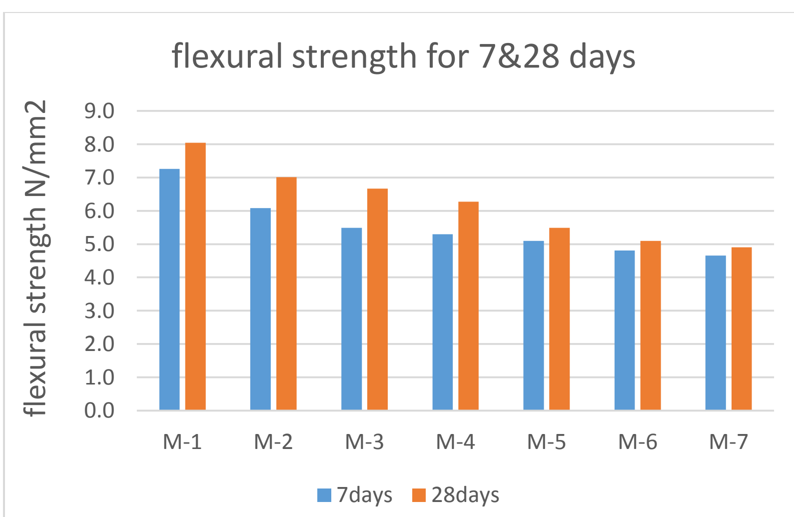

Fig. 3. Flexural strength for 7&28 days

V. CONCLUSIONS

GGBS and Flyash have replaced cement in concrete and natural coarse aggregate has replaced coarse aggregate.

1. The M30 grade of concrete has attained the compressive strength of 18.7 Mpa and 28.4 Mpa for 7 and 28 days respectively.
2. The M30 grade of concrete has attained the Split Tensile strength of 1.4 Mpa and 2.3 Mpa for 7 and 28 days respectively.
3. The M30 grade of concrete has attained the Flexural strength of 6.1Mpa and 7.0 Mpa for 7 and 28 days respectively.

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