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"Replacing cement with GGBS and Enhancing performance by Adding Tio2 and alkali activaters"

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ABSTRACT

Ordinary Portland cement (OPC) is used as binding material in Conventional concrete. OPC production is producing 7% of Carbon dioxide (C02) gas emission globally. So, to form an environment friendly concrete we can replace OPC with other materials Such as GGBS, fyash, metacolin etc, with the help of which we can reduce the pollution in environment, such a concrete is called as Geopolymer Concrete. In these papers Geopolymer Concrete considered to be the alternative of Conventional Concrete.

Geopolymer Concrete is also referred as Green Concrete. This paper present's the behaviour of Geopolymer Concrete when the OPC is replaced by 50% and 80% of GGBS and Titanium dioxide (Tio2) 1%,1.5% and 2% with alkali activators are added by 1% Alkali activators used in this experiment are Sodium hydroxide (NaOH), sodium silicate (Na2sio3). The Specimens were used for Compressive strength, Flexural strength & Split tensile strength test & were tested at 7,28 and 56, days of curing. For replacement of 50% GGBS,1.5% titanium dioxide & 1% Alkali activator, results obtained are increase in 4.3% compressive strength,16.98% flexural strength,16.35% split tensile strength. For replacement of 80% GGBS,1.5% of Titanium dioxide,1% of Alkali activators, we got higher flexural strength and split tensile strength as compared to conventional concrete, but this percentage does not satisfy characteristic compressive strength for 28 days.but for 56 days comprssive strength shows good results. Geopolymer concrete offers a cost-effective alternative to traditional concrete. It's low production cost and long-term durability make it an alternative solution for infrastructure development while addressing environmental concerns.

Keywords; GGBS, TIO2, Geopolymer concrete, sodium silicate (Na2sio3), sodium hydroxide (NAOH)

1.INTRODUCTION

Cement is Essential in construction, second only to water, but making Ordinary Portland Cement (OPC) harms the environment by using lots of natural resources and releasing a huge amount of CO2, about 2.7 billion tons each year. So, finding a greener option is crucial. One promising alternative is geopolymer technology, which was highlighted by Davidovits in 1998. Geopolymers have been around since the 1940s but aren't widely used. They are made from minerals rich in silicon and aluminum and react with strong alkali solutions to form a solid binder through a process called geopolymerization. Geopolymer concrete is becoming popular in ready-mixed and precast industries because it's eco- friendly. It uses industrial by-products like fly ash and blast furnace slag, cutting CO2 emissions by up to 80%. This makes it a great alternative to OPC, especially for large cement producers like India. Overall, geopolymer concrete offers a sustainable way to reduce CO2 emissions in construction while recycling industrial waste. Ground Granulated Blast Furnace Slag (GGBS) is a by-product of iron making in blast furnaces. It forms when iron ore, coke, and lime are heated, and the leftover slag, which floats on the iron, is cooled quickly in water to make granules. These are dried and ground into a fine powder called GGBS or slag cement. GGBS can replace some cement in concrete, which is important as traditional materials become scarce. It helps the environment by using waste but must not weaken the concrete. GGBS mainly contains glassy materials that react well when finely ground and mixed with water. Adding titanium dioxide (TiO_2) and alkali activators like sodium silicate and sodium hydroxide to GGBS enhances concrete's strength and durability. TiO_2 also helps keep surfaces clean and reduces pollution, making the concrete stronger and more environmentally friendly.

NEED OF THE STUDY

The study is necessary to explore the potential of Ground Granulated Blast Furnace Slag (GGBS) as a sustainable alternative in construction. GGBS can significantly reduce carbon emissions and energy consumption compared to traditional cement. Additionally, understanding its properties and performance will help in optimizing its use, improving the durability and strength of concrete structures, and promoting eco-friendly construction practices. This research could lead to more sustainable building materials and methods, benefiting the environment and the construction industry.

Objectives

1. To study the effect of GGBS by partial replacement of cement for high strength concrete.

2. To study the improvement in workability of high strength concrete by partial replacement of cement by GGBS.

3. Reproduce green concrete by using GGBS with alkali activators using Titanium dioxide **[TiO_2]**

4. Performance Enhancement: Evaluate how GGBS affects concrete mechanical properties and long-term durability, including resistance to ASR, sulfate attack, and chloride ingress.

5. Sustainability and Environmental Benefits: Assess the environmental advantages of GGBS concrete, including reduced greenhouse gas emissions and resource depletion.

6. Economic Viability: Analyse the cost-effectiveness of GGBS in concrete production, considering lifecycle costs and construction economics.

7. Workability Improvement: Study GGBS's impact on fresh concrete workability and develop optimized mix designs.

8. Compatibility with Admixtures and Supplementary Materials: Evaluate GGBS compatibility with other concrete additives and materials for synergies and adverse effects.

2. RELATED WORK

The approach of replacing cement with other materials started in mid-20th century and was more widely adopted in the construction industry by researchers and engineers due to its potential benefits in improving concrete properties. In this project, we are more centred on research about concrete manufacture using GGBS, Titanium dioxide, sodium silicate, sodium hydroxide.

P.Hemalatha, K. Ramujee ,et, al . [1] Our research focuses on reducing the carbon footprint of concrete by eliminating cement and creating geo-polymer concrete (GPC). Using binders like fly ash, wollastonite, and GGBS, along with alkali activators and titanium oxide, we developed self- compacting GPC. Testing at 7, 14, and 28 days showed that adding 4% titanium oxide, with or without wollastonite, significantly improved strength by 18-20%. This eco-friendly concrete offersenhanced performance and sustainability.

T.R.Praveenkumar, M.S. Meddah, et, al . [2] Our study explores using 10% rice husk ash (RHA) and up to 5% titanium dioxide (TiO2) nanoparticles to replace Portland cement. The mix with 10% RHA and 3% TiO2 showed the best strength and durability, analyzed using SEM and XRD. Higher TiO2 levels decreased these properties, making 3% TiO2 the optimal replacement. This approach aims to improve sustainability and reduce CO2 emissions in construction.

Vinod Kumar, et, al. [3] This experiment explores replacing cement with GGBS in M40 concrete to create green concrete and reduce carbon footprints. By testing different GGBS proportions (10%, 20%, 30%, 40%), they found that 30% GGBS provides optimal strength and improved workability, making it a cost-effective alternative to conventional concrete. Mechanical tests on the specimens confirmed that partial GGBS substitution maintains strength while reducing overall costs by 15%.

Nancy hammad,Amr El-Nemr, et, al. [4] Rapid construction in Egypt and other developing countries drives high cement and concrete production, harming the environment. This study tested alkali-activated slag concrete (AAC) with polypropylene and steel fibers to reduce Ordinary Portland Cement (OPC) use. Results showed AAC achieved 85% of its 28-day compressive strength in just 1 day, with fiber addition boosting strength and tensile properties. The findings suggest that AAC with fibers is a strong, eco-friendly alternative to traditional concrete, supportedby detailed microstructural analysis conventional concrete.

V.Gokul, D.Anolin Steffi, R.Kaviya,C.V.Harni, et, al. [5] Building on expansive soils, such as clay, poses risks due to high compressibility, low shear strength, and uneven settlement. An experimental study improved the stability of clayey soil using Ground Granulated Blast Furnace Slag (GGBS) and 12 M Sodium Hydroxide (NaOH) with Alkali to Binder ratios of 0.40 and 0.60. GGBS was added at 6%, 12%, 18%, and 24%, and the Unconfined Compressive Strength Test showed strength improvements at 28 days, reaching up to 4062 KPa with an A/B ratio of 0.60.

3. RESEARCH METHODOLOGY

In this experimental study, the optimum percentage of a combination of GGBS and Titanium dioxide (Tio_2) along with the ratio of, sodium silicate, sodium hydroxide partially replacing cement is found by comparing test results of different proportions of mixes with M60 concrete. From previous research papers analysis cement replacement is about 10 to 60 % is beneficial, sodium silicate and sodium hydroxide be used about 1%. Taking into consideration these previous studies various trial mixes will be taken to get the optimum amount of cement replacement to a combination of GGBS and titanium dioxide with the addition of NAOH and Na_2sio_3 content. cement replacementto a combination of GGBS and Titanium dioxide.

Firstly, 50% and 80% cement were replaced by GGBS and Titanium dioxide in various percentages as 1%, 1.5% and 2 % addition to NAOH and Na_2sio_3 used in 1% of concrete and optimum amount of fibre content giving maximum strength are found out and noted

Then the test results are compared for, compressive strength and flexural strength and splite tensile strength for varying percentages of polypropylene.

Variables

The main variables in this study are:

- Titanium dioxide (Tio_2) in 1%, 1.5% and 2%
- The proportion of GGBS for 50% cement replacement and 80% cement replacement

3.1 Experimental performance:

3.1.1 Materials

We use locally available materials to produce the geopolymer concrete. OPC 53 gread cement were used of Jsw cement.20mm & 10mm size coarse aggregate used in 60% and 40% respectively. As fine aggregate crush sand was used in this research. sugarcane bagasse ash, ground granulated blast furnace slag and titanium dioxide was used as supplementary cementitious material. Potable water is used for mixing of materials and for curing also. PCE based MasterPolyheed 8350 was used as admixture. the primary test for cement, SCBA, GGBS, coarse aggregate, fine aggregate was conducted. From primarytests properties of materials mentioned below.

Cement:

Cement is a binding material used in construction to bind other material tightly together. It is a finest powder made of limestone, clay and other material that are heated to a high temperature and then ground into a fine powder. In these, research Ordinary Portland cement is used of JSW Cement of grade 53.

Table no 01: Physical Properties of Cement

PHYSICAL PROPERTIES	OBTAINED VALUES
Specific Gravity	3.15
Fineness	7%
Colour	Grey
Standard Consistency	32
Initial Setting Time	29 min
Final Setting Time	360 min
Bulk Density	1420 kg/m^3

Grund granulated blast furnace slag (GGBS):

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of iron industry. It is obtained by method during rapid cooling take place when transformation of molten iron slag from furnace in water or steam which produce the glassy granular product after that its dried and ground in fine powder i.e. GGBS. GGBS is a strength enhancing compound which improves the durability of concrete. Its main advantage is slow heat of hydration. 10% replacement of cement by GGBS in this research carriedout.

Table no 02: Physical Properties of GGBS

PHYSICAL PROPERTIES	OBTAINED VALUES
Specific Gravity	2.9
Fineness(m^2/kg)	386
Colour	Grey
Bulk Density	1230 kg/m^3

Fine Aggregate:

Fine aggregates that were crushed sand used which is locally available material. This crushed sand is washed due to which it has negligible amount of dust particles. This sand does not contain particles passing from 75 µ.

Table no 04: Physical Properties of fine aggregate

PHYSICAL PROPERTIES	OBTAINED VALUES
Specific Gravity	2.625
Fineness Modulus	3.23 (zone I)
Type	Crushed
Water Absorption	1 %
Bulk density	1612 kg/m^3

Coarse aggregate:

The coarse aggregates (CA) used which are locally available. The Coarse aggregate formed by the basalt rock at the stone crusher, it can have various sizes. But, for This Experimental work maximum nominal size of aggregates used was 20 mm and 10mm aggregates are the major ingredients of concrete.

Table no 05: Physical Properties of coarse aggregate

PHYSICAL PROPERTIES	OBTAINED VALUES
Specific Gravity	2.75
NMSA	20 mm
Fineness Modulus	7.33
Bulk Density	1575 kg/m^3
Water Absorption	1.5%
Type	Angular
Crushing value	10%
Impact value	7.57%
Abrasion value	12%
Elongation and flakiness index	15% & 13%

Titanium dioxide:

TiO_2 pigments help to maintain the quality of products for longer. TiO_2 enhances their opacity and supports durability through a resistance to heat, light and weathering. TiO_2 is used widely in the built environment and can help to make construction products and buildings more sustainable.

Alkaline activators:

Alkaline activators are primarily used as a solution prepared by the soluble alkali elements in the form of hydroxide or silicate or a combination of both. The most popular type of Alkaline activators are sodium/potassium silicate and sodium/potassium hydroxide (NaOH, KOH) Alkali substances are present in cements used as a binder in concrete only in a minimum content.in this research we used sodium silicate and sodium hydroxide as alkali activators.

Admixture:

We used MasterPolyheed 8350 Mid-Range Water Reducer is an admixture that provide medium water reduction and longer slump retention without affecting setting time. It facilitates production of high- quality concrete with improved durability. It has been developed for use in Structural concrete, Mass concrete, Pumpable concrete, RMC plant, Site batching plant.

Water:

Water used in the casting was drinking water maintaining the pH level of water between 6.5 to 7.5.

3.2 Mix design:

Mix Designation	Cement replacement %	Titanium dioxide (Tio_2)%	Alkali activater %
MIX CC	0	0	0
Mix 1	50	1	1
Mix 2		1.5	
Mix 3		2	
Mix 4	80	1	1
Mix 5		1.5	
Mix 6		2	

concrete mix design given below is designed with using IS-10262(2019) and IS-456(2000)

Table 1: Designations of mixed proportions

Mix ID	Cement	GGBS	$NaoH+Na_2sio_3$	Tio_2	Aggregate		Super-plasticizer
					Crushsand	Coarse aggregate	
Mix CC	628.32	0	0	0	1024.6	1024.6	6.16
Mix 1	308	308	6.16	6.992	1024.6	1024.6	6.16
Mix 2				13.984			
Mix 3				20.976			
Mix 4	132	492.8	6.16	6.992			
Mix 5				13.984			
Mix 6				20.976			

Table 2: Mix proportions (Kg/m3)

Following are the different mix notations of concrete used for experimental work:

i. CK= Ordinary Portland Cement Concrete

ii. S1= 50%GGBS and 1%TiO_2 replacement in cement.

iii. S2= 50%GGBS and 1.5%TiO_2 replacement in cement.

iv. S3=50%GGBS and 2%TiO_2 replacement in cement.

v. S4= 80%GGBS and 1%TiO_2 replacement in cement.

vi. S5= 80%GGBS and 1.5%TiO_2 replacement in cement.

vii. S6= 80%GGBS and 2%TiO_2 replacement in cement.

3.3 sample preparation:

one conventional mix and nine designed mixes by mixing proper quantities of water, cement, SCBA, GGBS, Titanium dioxide fine aggregate and coarse aggregate. After preparation of concrete mix, it should be poured in the moulds for respective tests. For the compressive test, the two-point flexural test specimen is cubical in shape, it shall be 150mm X 150mm X 150mm, 100mm X 100mm X 500mm respectively. For splitting tensile strength test, specified the specimens shall be cylinder 150mm in diameter and 300mm long. A total of 60 cube specimens, 30 cylindrical specimens, 30 prism/beam specimens were prepared to conduct the test. The mixing was done by machine mixing.

3.4 Testing methods:

Compressive Strength:

According to IS 516:2021, the compressive strength test was conducted on cube specimens having size of 150 mm x150 mm x150 mm. The average compressive strength of three cube specimens wasnoted at 7 and 28 days.

Flexural strength:

According to 516:2021, the flexural strength test was conducted on prism specimens having size of 100 mm x 100 mm x 500 mm.

Split Tensile Strength:

According to 516:2021, the split tensile strength test was conducted after 28 days of curing on cylindrical specimen having size of 150 mm diameter and 300 mm height.

4. RESULTS AND DISCUSSION

In this Paper, we are dealing with the results obtained by the various tests. Workability of concrete, compressive strength test, flexural strength test and splitting tensile test were conducted on the conventional concrete and geopolymer Concrete. Results are shown by the values achieved and their graph. Comparative results using graphs are also discussed. Experimental work was aimed to study the effect of geopolymer concrete, on Mechanical properties of concrete and its feasibility in the actual field of construction, especially compressive strength, Flexural strength and split tensile strength.

4.1. Compressive strength of concrete: For Mix 1 to Mix 6, the compressive strength of concrete increases with an increase in 50% of GGBS and 1% of Titanium dioxide (Tio_2), as shown in Fig (a) and Fig (b).. S2 (50%GGBS and 1.5%TiO2) shows good result i.e. having maximum compressive strength, S3(50%GGBS and 2%TiO2),S1(50%GGBS and 1%TiO2), S6(80%GGBS and 2%TiO2) shows very low strength compare with ordinary Portland cementconcrete.(CC)

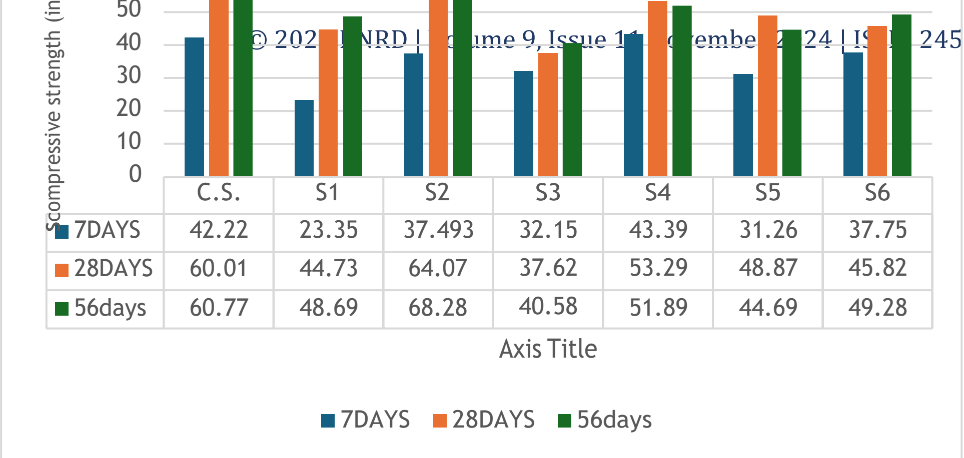

Fig 1: Compressive strength

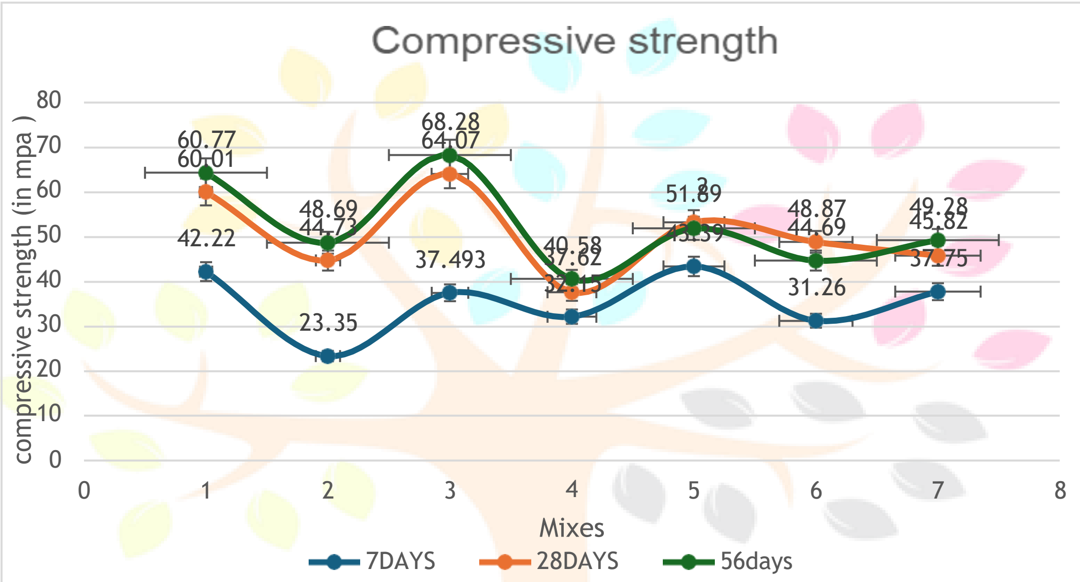

Fig 2: Compressive strength

4.2. Flexural strength of concrete: The flexural strength of normal M60 grade concrete is 3.13 N/mm2 (0.7 Fck) according to IS456:2000 : Results show that S2 having proportion (50%GGBS and 1.5%TiO2) and S5 (80%GGBS and 1.5%TiO2) shows better result, S4(50%GGBS and 1%TiO2), S5(80%GGBS and 1.5%TiO2) shows poor result as compared with ordinary Portland cement concrete.(CC) Graph show that S2 having proportion (50%GGBS and 1.5%TiO2), S5(80%GGBS and 1.5%TiO2) and S6 (80%GGBS and 2%TiO2) shows better result, S3(50%GGBS and 2%TiO2), S4(80%GGBS and 1%TiO2), shows poor result as compared with ordinary Portland cement concrete (CC)

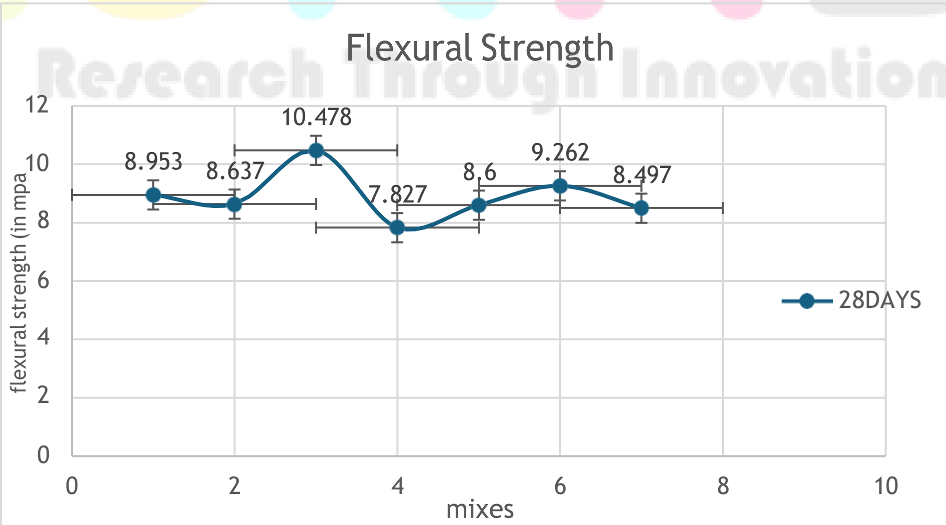

Fig 3: Flexural strength

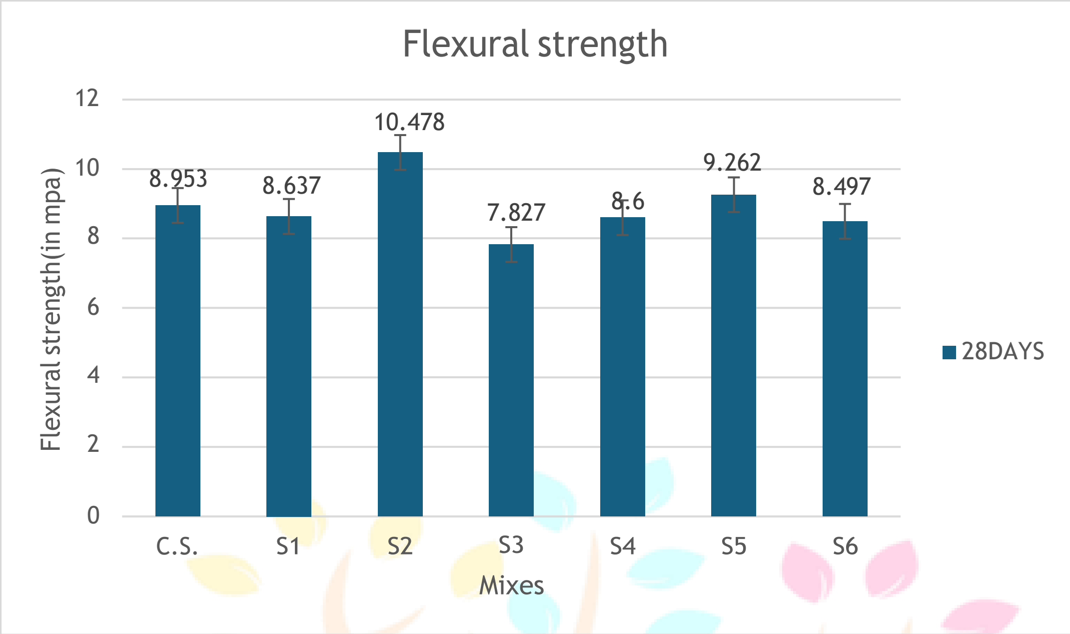

Fig 4: Flexural strength

4.3. split tensile strength: According to 516:2021, the split tensile strength test was conducted after 28 days of curing on cylindrical specimen having size of 150 mm diameter and 300 mm height. Splitting Tensile Strength results show that mix S2(50%GGBS and 1.5%TiO2), S1(50%GGBS and 1%TiO2) and S6(80%GGBS and 2%TiO2) achieve greater strength and S3(50%GGBS and 2%TiO), S4(80%GGBS and 1%TiO2), got poor strength as compare with the ordinary Portland cement concrete(CC)

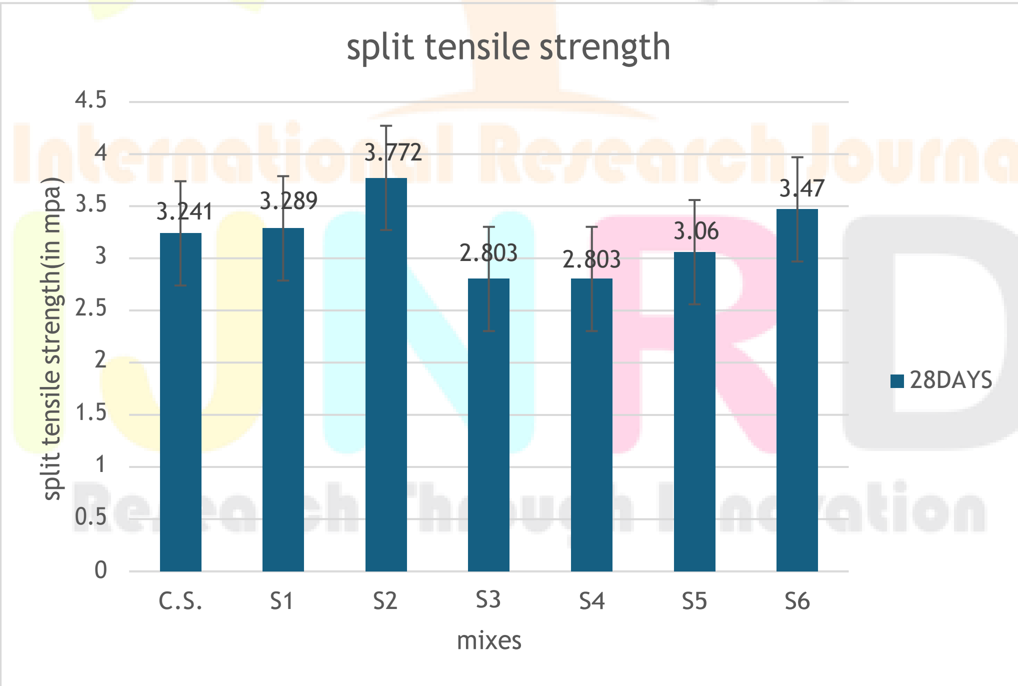

Fig 5 split tensile strength.

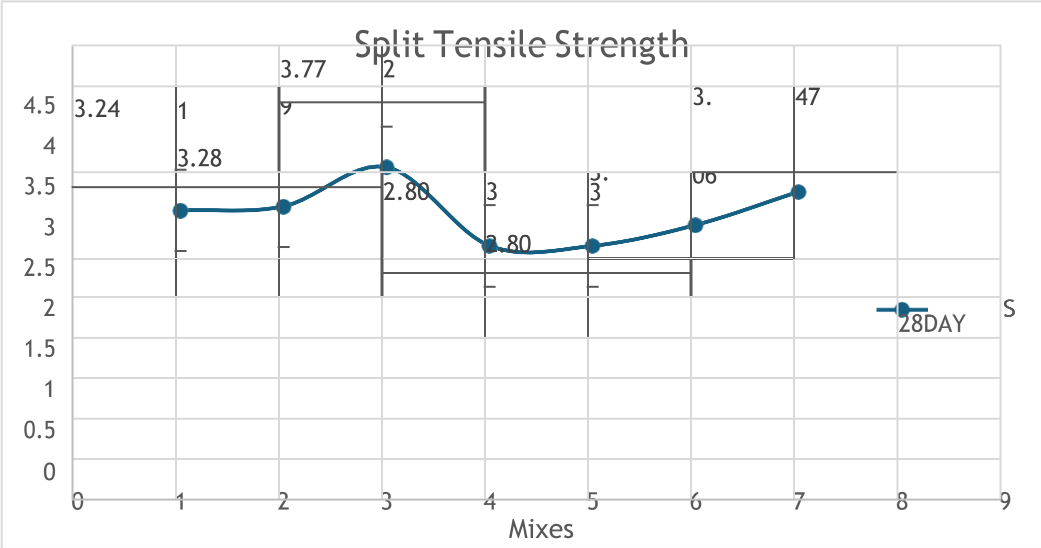

Fig 6 split tensile strength.

V. CONCLUSION:

1. 50% GGBS and 80% GGBS overall showed increase in flexural strength and split tensile strength when compared to 0% GGBS.

2. Test results of 50% GGBS showed maximum increase in compressive strength, flexural strength and split tensile strength by 6%,17% and 18% respectively when comparedwith 0% GGBS.

3. Durability of 50% GGBS achieved maximum compressive strength, flexural strength and split tensile strength by 12.35%, 16.98% and 16.38% respectively after 56 days of curing when compared to 0% GGBS. Therefore, it can be concluded that durability of 30% GGBS is optimum concrete mix as compared to all mixes.

4. Flexural test results when compared to 0% GGBS showed increase in strength by 16.38% and 3.45% for 50% GGBS and 80% GGBS respectively.

5. Splitting tensile test results when compared to 0% GGBS showed increase in strength by 16.38% and 7.09% for 50% GGBS and 80% GGBS respectively.

Future scope of the study:

- The future scope of studying GGBS and TiO2 with alkali activators lies in developing high-performance, sustainable, and multifunctional concrete with enhanced durability, self- cleaning properties, and reduced environmental impact.
- Improved Strength and Durability: Developing concrete that is stronger and lasts longer.
- Environmental Benefits: Reducing carbon footprint and using industrial by-products.
- Self-Cleaning Properties: Creating concrete surfaces that can clean themselves and purify theair.
- Improved Strength and Durability: Developing concrete that is stronger and lasts longer.

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