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Analysis of a New Type of Concrete that Partially Replaces Cement with GGBS and Glass Powder

G Madhava Swamy[1], P Sucharitha[2]
[1]PG Scholar, [2]Assistant Professor, Department of Civil Engineering, Dr. KVSRIT, KURNOOL

***Abstract:** With the exponential growth of industrialization, industrial by-products are also increasing day by day. One of the by-products of the steel industry is ground granulated blast furnace slag (GGBS). In addition, GGBS is a good cement mortar due to its durability and strength, and glass waste is a waste material that can replace cement. After 28 days, the pozzolanic reaction between cement hydration and glass powder showed that cement replacement did not affect the compressive strength of concrete. The use of GGBS and waste glass powder (WGP) is the focus of this article. In this experiment, slag (GGBS) and mineral additive (WGP) were used instead of cement by weight. To examine the differences in concrete properties, the differences between glass powder and GGBS were added to the cement. The results regarding air entrainment were compared with partial replacement of glass powder and GGBS. We examined the strength of concrete with the addition of WGP (5%, 10%, 15%, 20%& 25%) to the M40 mixture. Additional cement can be replaced with additional materials such as 40 with GGBS (5%, 10%, 15%and 20% weight cement) at the desired WGP percentage change. Splitting tensile strength, flexural strength and compressive strength tests were conducted. The tests showed that the combination with one sample had better effect than the combination model.*
***Keywords:** compressive strength, flexural strength, splitting tensile strength, waste glass powder, ground granulated blast furnace slag.*

I. INTRODUCTION

Concrete is a composite material, usually composed of cement, coarse and fine aggregates, and water. and industrial wastes such as WGP to replace it. If the embodied energy of concrete can be reduced in a way that does not affect performance or increase cost. About %. Many studies have shown that GGBS concrete protects the steel reinforcement more systematically, thus preventing the reinforcement from corrosion and protecting the entire structure. Reduces corrosion. In addition, GGBS can make the structure more stable without changing the value. GGBS formed in thermal power plants generally does not need to be poured into the concrete in advance. strength. In this project, the suitability of glass powder as an additional mineral and its effect on concrete were investigated. The main purpose of this experiment was to evaluate the effect of concrete properties by testing concrete in which WGP and GGBS partially replaced cement.

A. Glass powder

The first glassmaker was found in this region in 3000 BC. The first glass was made in Egypt in 1500 BC. At that time, the glass industry was slow and demand was high due to low heat, poor pottery and insufficient air to melt the raw materials. The invention of the flute in 30 BC, which made glass more abundant and cheap, made glass available to human beings for the first time in history. Colorless glass first appeared in the 1st century AD with the introduction of metal products. In 1688, France developed a technology for assembling panels. This development makes it easier to assemble the right equipment. Glass can also be made from a combination of oxides (silica), soda, dolomite ($CaMg(CO3)2$) and stone ($CaCO3$) at temperatures up to 1600°C. It does not crystallize. Special additives are added to the glass to ensure colour development. Additional materials used include quartz, alkali metal silicates, soda-lime glass (vessels, floats, sheets, light and tempered glass), salt glass (seals for chemicals and pharmaceuticals), lead glass. As of 2015, wine containers alone accounted for 44% of waste; packaging is expected to contribute 116,000 tons of waste to landfills.

B. GGBS

GGBS is obtained by quenching molten metal with water in a blast furnace to obtain a glass granular material, which is dried and ground into a fine powder. GGBS is a waste material of the metal industry, and its use and production have increased many times.

In the past few years, it has been used as a different material and filler for Portland cement (OPC) and sand in concrete, respectively, in experimental studies. GGBS is usually mixed with OPC to form durable concrete. GGBS is mainly used in Europe, and its use is increasingly in the United States and Asia (especially Japan and Singapore) due to its strong performance, which can extend the life of the building from 50 years to 100 years. The two main uses of GGBS are in the production of higher quality products, primarily Portland blast furnace cement (PBFC) and high slag blast furnace cement (HSBFC). Permanent concrete construction, mixed or blended on site. GGBS cement is considered to be listed in concrete as it is safe from sulphate attack and chloride attack. GGBS is currently successfully replacing sulphate resistant silicate cement (SRPC) in the market due to its sulphate resistance and high quality properties as well as its lower cost compared to OPC. 50% GGBS replacement is used in concrete to prevent chloride attack. Chloride attack occurs in reinforced concrete in marine areas and on large bridges where the concrete is affected by road de-icing. Concrete containing GGBS MAAs has the highest strength compared to concrete made from Portland cement. It has a higher proportion of energy enhancing metals. The strength of concrete made with GGBS increases over time, with 28-day strength doubling in 10 to 12 years. Since the product does not contain lime, its permeability is reduced. This is why GGBS is so effective in stopping efflorescence when used with a 50 to 60 percent change**.**

II. OBJECTIVE

Glass powder can be used instead of cement to remove weak concrete. The proportion of glass powder is 5%, 10%, 15%, 20%, 25%. Ordinary stone also contains additional minerals such as GGB in the proportion of 0%, 5%, 10%, 15% and 20%. Glass powder partially replaces cement.

III. MATERIALS

Grouting is done by mixing cement or adhesive into the material or materials used to fill the joint gaps and assembly. The aim of this experiment is to determine how the combination of GGBS and glass powder (GGBS-GP) affects the mechanical properties and durability of M40 concrete samples. The durability of concretes containing glass powder at 5%, 10%, 15%, 20% and 25% was investigated. While the glass powder conversion remains the same, the cement content can be increased with mineral additives such as GGBS (5%, 10%, 15% and 20%). The main components used in this study are water, fine and coarse aggregate, GGBS glass powder and cement. IS: 383-2016 Quality materials as per specification, Water [Portable], Coarse Aggregate, GGBS-glass powder.
Class 53 Common Portland Cement, adhering to IS: 269-2015
Fine Aggregate, adhering to IS: 383-2016
Coarse Aggregate, according to IS: 383-2016
Water [Portable]
Glass powder & GGBS
Super plastisizer Conplast wl xtra

IV. EXPERIMENTAL INVESTIGATION

Normal Consistency of Cement	32%
Setting Time of Standard Cement	Intial -40 min Final - 535 min
Specific Gravity Of Cement	3.10
Fineness Test of Cement by Sieve Analysis	96%
Soundness of Cement	4 mm
Fineness Modulus of Fine Aggregate	4.07
Fineness Modulus of Coarse Aggregate	3.9
Specific Gravity of Fine aggregate	2.56
Water Absorption Test on Fine Aggregate	1.59%
Bulking of Fine Aggregate	32.45%

Specific Gravity & Water Absorption of Coarse aggregate	2.68 & 1.68%
Specific Gravity of Glass powder & GGBS	2.60 & 2.85
Size(µm) of Glass powder & GGBS	< 150 & < 10 to 100
Colour of Glass powder & GGBS	Greyish-white & Off-white

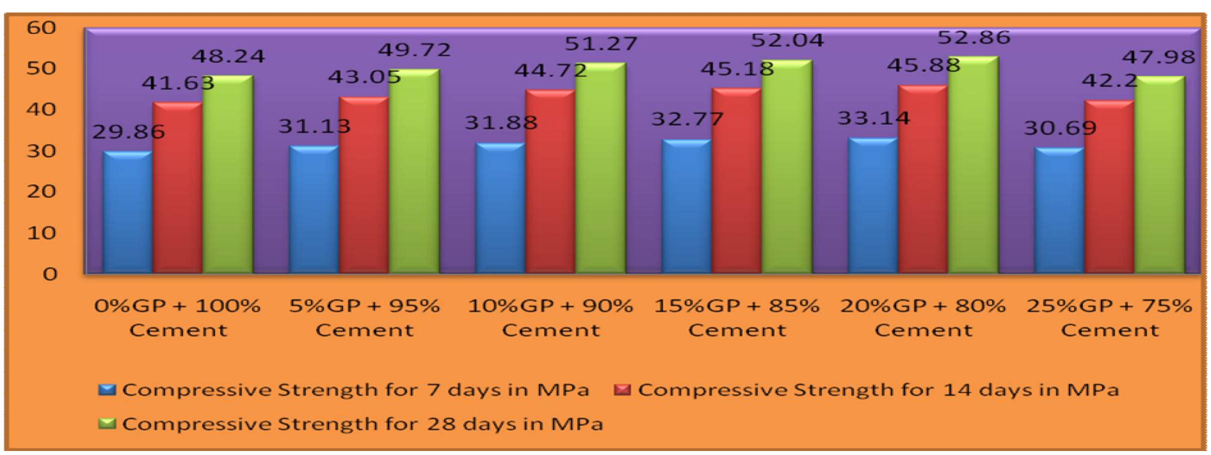
V. MIX DESIGN

Grade	M40
Proportion	M40
W/C ratio	1 : 1.70: 3.01
Cement	0.36
Fine Aggregate	403 Kg/m^3
Coarse Aggregate	687 Kg/m^3
Water	1215 Kg/m^3
Chemical admixture	145 Kg/m^3

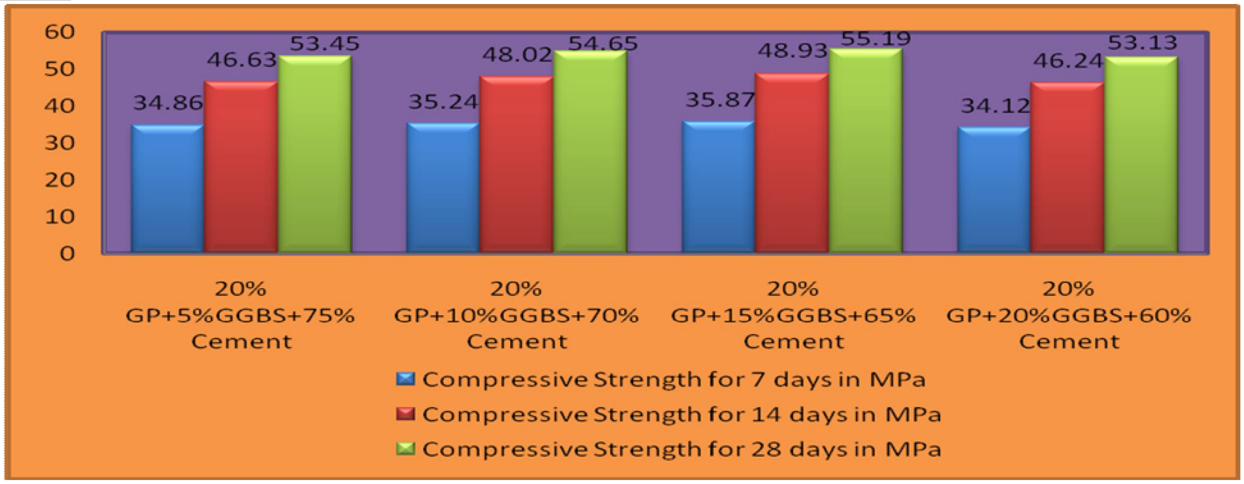
VI. PERFORMANCE TESTING AND RESULTS

Table No. 6.1 Test results of Compressive Strength for 7, 14 & 28 days for M40

Mix % Replacement	Compressive Strength for 7 days in MPa	Compressive Strength for 14 days in MPa	Compressive Strength for 28 days in MPa
0%GP + 100% Cement	29.86	41.63	48.24
5%GP + 95% Cement	31.13	43.05	49.72
10%GP + 90% Cement	31.88	44.72	51.27
15%GP + 85% Cement	32.77	45.18	52.04
20%GP + 80% Cement	33.14	45.88	52.86
25%GP + 75% Cement	30.69	42.20	47.98
20% GP+5%GGBS+75% Cement	34.86	46.63	53.45
20% GP+10%GGBS+70% Cement	35.24	48.02	54.65
20% GP+15%GGBS+65% Cement	35.87	48.93	55.19
20% GP+20%GGBS+60% Cement	34.12	46.24	53.13



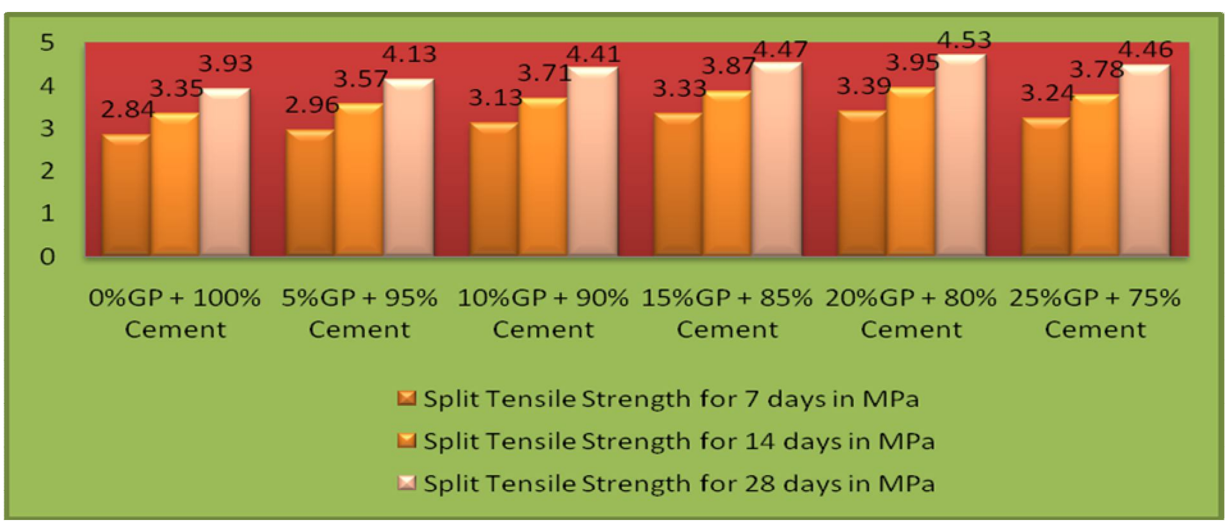
Graph No. 6.1 Development of Compressive strength after curing 7, 14& 28 days for M40



Graph No 6.2 Relation between optimum Glass powder (20%)+%GGBS replacement and Compressive strength

Table no 6.2 Test results of Split Tensile Strength for 7, 14 & 28 days for M40

Mix % Replacement	Split Tensile Strength for 7 days in MPa	Split Tensile Strength for 14 days in MPa	Split Tensile Strength for 28 days in MPa
0%GP + 100% Cement	2.84	3.35	3.93
5%GP + 95% Cement	2.96	3.57	4.13
10%GP + 90% Cement	3.13	3.71	4.41
15%GP + 85% Cement	3.33	3.87	4.47
20%GP + 80% Cement	3.39	3.95	4.53
25%GP + 75% Cement	3.24	3.78	4.46
20% GP+5%GGBS+75% Cement	3.35	4.14	4.69
20% GP+10%GGBS+70% Cement	3.41	4.28	4.97
20% GP+15%GGBS+65% Cement	3.64	4.89	5.26
20% GP+20%GGBS+60% Cement	3.43	4.16	4.72



Graph No 6.3 Development of Split Tensile strength after curing 7, 14 & 28 days for M40

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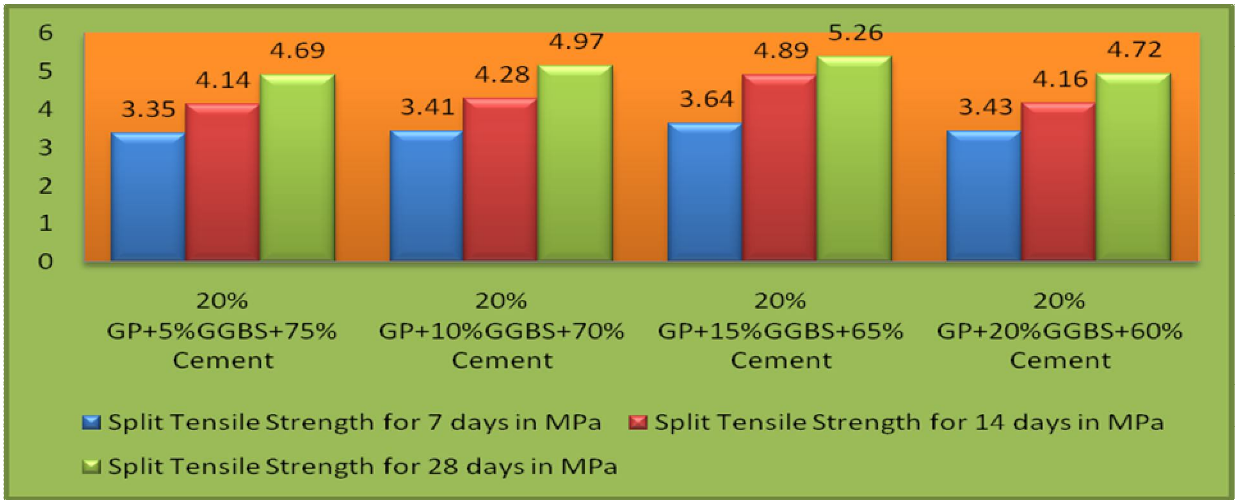
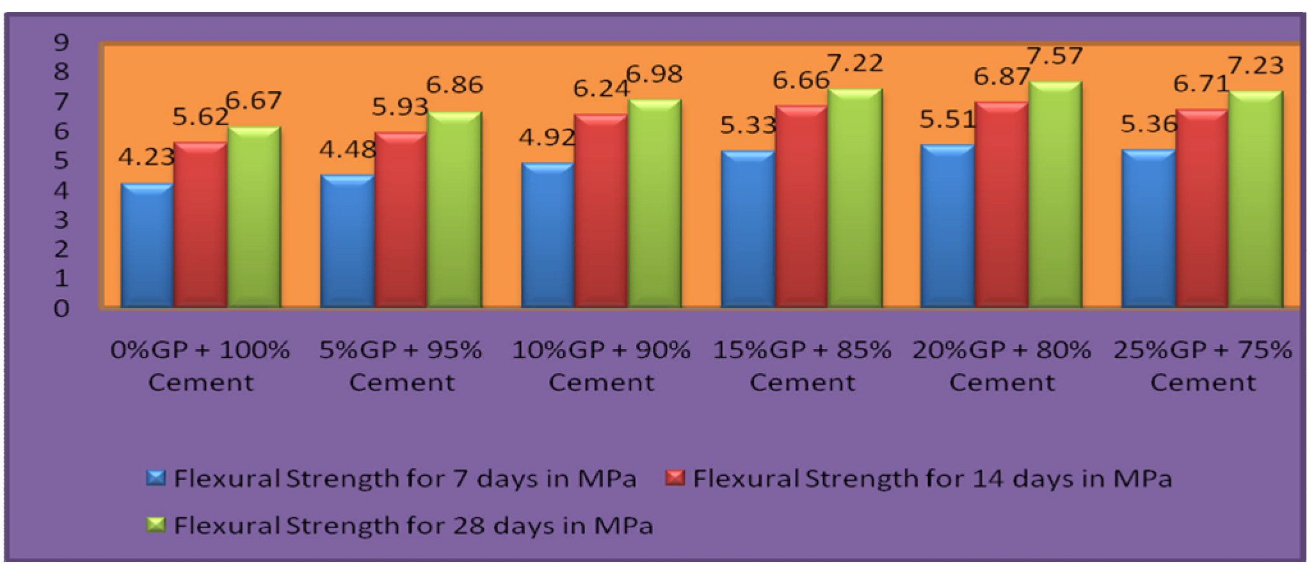


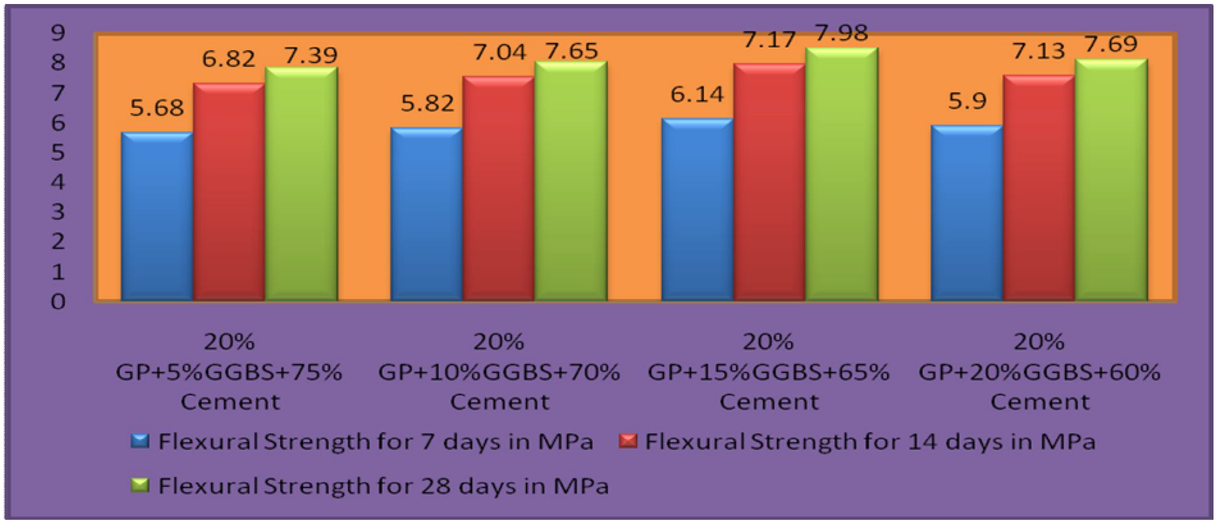
Graph No 6.4 Relation between optimum Glass powder (20%)+%GGBs replacement and Split Tensile strength

Table No 6.3 Test results of Flexural Strength for 7, 14 & 28 days for M40

Mix % Replacement	Flexural Strength for 7 days in MPa	Flexural Strength for 14 days in MPa	Flexural Strength for 28 days in MPa
0%GP + 100% Cement	4.23	5.62	6.67
5%GP + 95% Cement	4.48	5.93	6.86
10%GP + 90% Cement	4.92	6.24	6.98
15%GP + 85% Cement	5.33	6.66	7.22
20%GP + 80% Cement	5.51	6.87	7.57
25%GP + 75% Cement	5.36	6.71	7.23
20% GP+5%GGBS+75% Cement	5.68	6.82	7.39
20% GP+10%GGBS+70% Cement	5.82	7.04	7.65
20% GP+15%GGBS+65% Cement	6.14	7.17	7.98
20% GP+20%GGBS+60% Cement	5.90	7.13	7.69



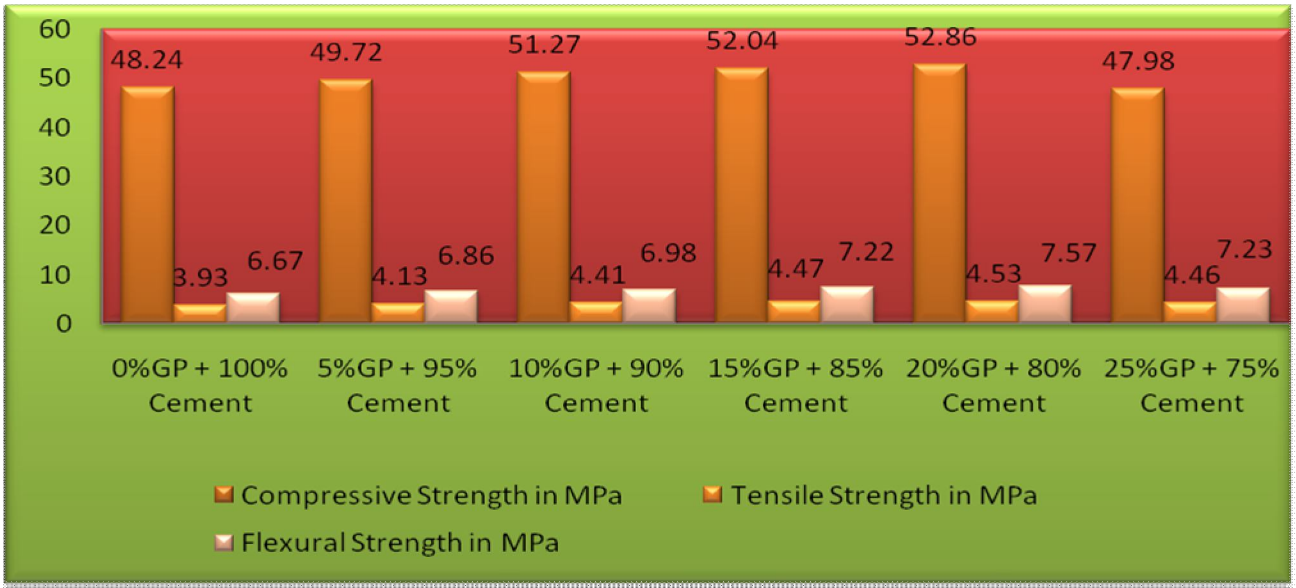
Graph No 6.5 Development of Flexural strength after curing 7, 14 & 28 days for M40



Graph No 6.6 Relation between optimum Glass powder (20%)+%GGBS replacement and Flexural strength

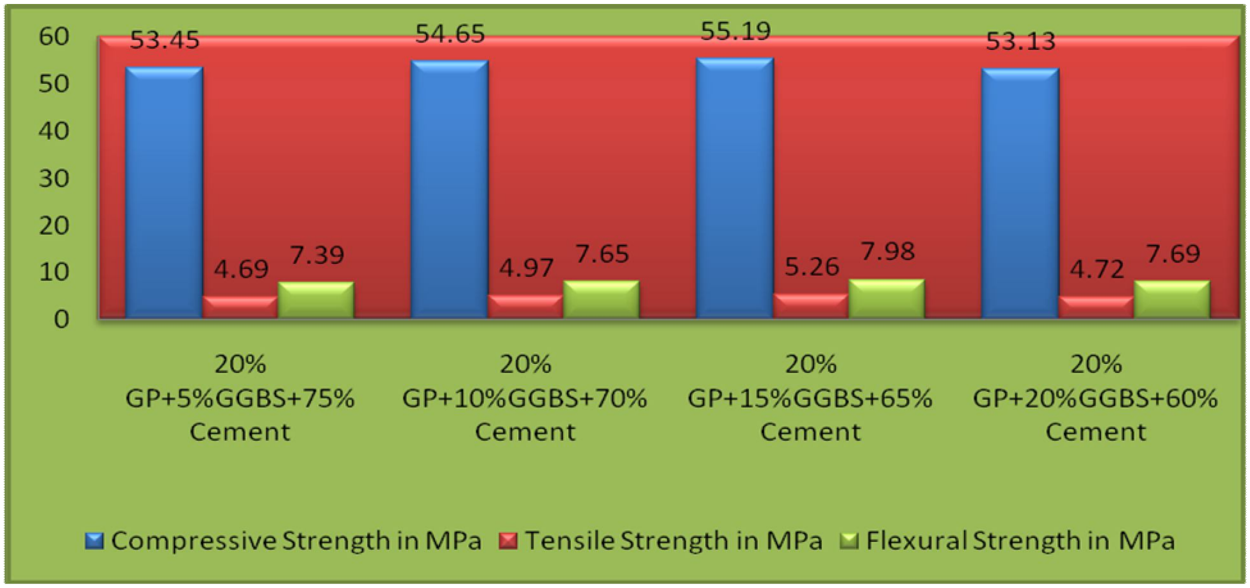
Table no 6.4 Test results of Compressive, Tensile & Flexural Strength for 28 days for M40

Mix % Replacement	Compressive Strength in MPa	Tensile Strength in MPa	Flexural Strength in MPa
0%GP + 100% Cement	48.24	3.93	6.67
5%GP + 95% Cement	49.72	4.13	6.86
10%GP + 90% Cement	51.27	4.41	6.98
15%GP + 85% Cement	52.04	4.47	7.22
20%GP + 80% Cement	52.86	4.53	7.57
25%GP + 75% Cement	47.98	4.46	7.23
20% GP+5%GGBS+75% Cement	53.45	4.69	7.39
20% GP+10%GGBS+70% Cement	54.65	4.97	7.65
20% GP+15%GGBS+65% Cement	55.19	5.26	7.98
20% GP+20%GGBS+60% Cement	53.13	4.72	7.69



Graph No 6.7 Development of Compressive, Tensile & Flexural strength after 28 days for M40

It was found that when cement was replaced with 20% glass powder, the strength properties increased and then decreased. The maximum Compressive strength of the 20% glass powder mixture is 52.86 N/mm2, which is 9.57% higher than the reference mixture where as Tensile strength is 4.53 N/mm2 which is 15.26% higher than reference mixture and Flexural strength is 7.98 N/mm2 which is 13.49% higher than reference mixture. The change in strength properties with different proportions of glass powder replacement cement of class M40 is shown in Graph 6.7.



Graph No 6.8 Relation between optimum Glass powder (20%)+%GGBS replacement and Compressive, Tensile & Flexural strength

Among all GGBS substitutes, the highest strength is achieved when mixed with grade M40, which contains 20% glass powder and 15% GGBS. As the GGBS content of concrete increases, its strength properties first increases up to 15% and then decreases. The maximum strength is achieved when the glass powder content is 20%, and 15% GGBS reaches a compressive strength of 55.19N/mm2 which is 14.40% higher than the composite material where as tensile strength of 5.26N/mm2 which is 33.84% is higher than the composite material and flexural strength of 7.98N/mm2, which is 19.64% higher than the composite materials. The changes in the strength properties of GGBS concrete containing 20% glass powder and above are shown in Graph No 6.8.

VII. CONCLUSIONS

Based on the above research, the following analysis was conducted on the synthetic glass powder and GGBS with mineral additives as partial replacement of cement.

1) Its operation is low according to the glass powder ratio in the transition.
2) The results showed that the maximum percentage of glass powder replacing cement was formed when the glass powder content was 20%.
3) The highest concrete properties were obtained with the concrete mixture containing 20% glass powder and 15% GGBS compared to other mixtures.
4) The test results showed that the strength of the concrete combined with glass powder and GGBS was increased better than that of the glass powder concrete mixture.
5) It is seen that when 20% glass powder is used, the compressive strength increases by 9.57%, the tensile strength increases by 15.26% and the flexural strength increases by 13.49% compared to traditional concrete.
6) Compared to ordinary concrete, using 20% glass powder and 15% GGBS can increase the compressive strength by 14.40%, the tensile strength by 33.84% and the flexural strength by 19.64%.

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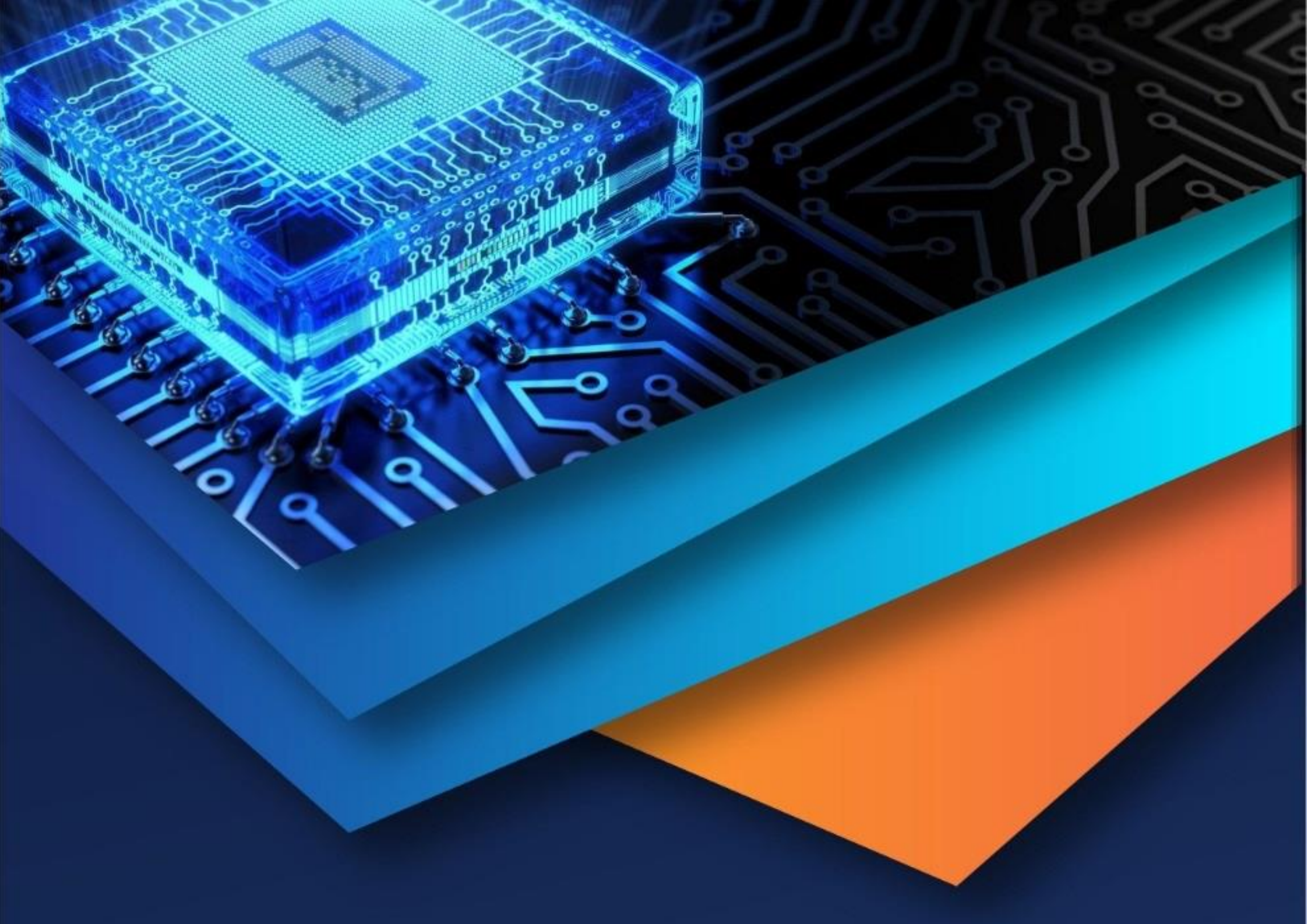

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