Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 3, 2021, Pages. 626 - 633
Received 16 February 2021; Accepted 08 March 2021.

# An Experimental Study on Polymer Impregnated Concrete with GGBS.

K. Mukesh[1], Mrs. M. Kalpana[2]
[1]U.G.Student, [2]Assistant Professor,
Department of Civil Engineering
Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai-602105
[1]rahul.mukesh7@gmail.com, [2]rameshkumargb@gmail.com

**Abstract**

Ground granulated blast-furnace slag, commonly known as GGBS, is a material that possesses characteristics akin to cement. It is a substance that is derived as a by-product from the blast furnaces used to produce iron. GGBS is used widely to enhance the quality of concrete by increasing strength, improving durability, providing resistance to sulfate and chloride attacks. In this exploratory research, 15% of the total cement for three grades of concrete, namely, M20, M40 and M60 are replaced with GGBS. The moulds used for this research are cube, beam and cylinder. They are cast in the moulds, allowed to sit for 24 hours and then removed. The concrete specimens are then cured for 7 and 28 days. Furthermore, after the completion of curing, they are made to undergo partial polymer impregnation of concrete. The polymer used for this process is polyester and styrene. Upon the completion of polymer impregnation, the cast moulds are tested for their compressive strength, flexural strength and split tensile strength. The results are then compared with conventional concrete. This research aims to study the contribution of GGBS concrete along with polymer impregnation to the strength characteristics.

Keywords: GGBS, compressive strength, flexural strength, split tensile strength, polymer impregnation, curing.

## 1. Introduction

Throughout history, concrete has been the most prominent material used in the construction industry. It is preferred for its strength, durability, longevity and resistance, among other characteristics. Cement constitutes a significant part of the manufacturing process of concrete. The manufacturing of cement is a tedious process that consumes an extravagant amount of resources. Due to its soaring demand in the establishment of buildings, bridges, airports, roads, structures, etc., various materials are used to substitute the cement while maintaining the performance of concrete. Different materials are used to replace cement to decrease the usage of resources and conserve energy. Ground Granulated Blast furnace Slag abbreviated as GGBS is one among the various materials used to replace cement in varying percentages [1]. This substance is obtained as a by-product from blast furnaces that are used in the process of producing iron. It has low embodied energy, is readily available and economical. It is highly cementitious and contains calcium silicate hydrates which makes it suitable as a pozzolanic material [2]. This material also has low reactivity and can be used in combination with other pozzolanic materials to substitute or replace ordinary portland cement. In this paper GGBS is used to replace 20% of the total constituents of cement and tested for its strength characteristics.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 3, 2021, Pages. 626 - 633
Received 16 February 2021; Accepted 08 March 2021.

GGBS mixed along with ordinary portland cement, aggregates and water can produce durable concrete [3]. The strength and performance of the concrete depend on the grade of concrete, type of cement used, type of aggregates, water-cement ratio and the percentage of GGBS replacing cement. Through the literature review conducted, it is deduced that GGBS contributes to the lifespan of the concrete. This property increases the durability of the structures [4]. GGBS also enhances the strength of the concrete by reducing cracking induced by the thermal reaction, providing resistance to chloride and sulphate attacks, providing higher electrical resistivity and preventing the occurrence of microcracks [5]. Due to its low embodied energy, it consumes only 20% of the resources in comparison with the resources consumed in the manufacturing process of cement. This property of GGBS makes it a sustainable and eco-friendly alternative to ordinary portland cement [6]. Commercially, GGBS replacement of cement is anywhere between 20% - 70%. Studies have shown that by replacement of up to 50% the durability of the structures and concrete can be significantly improved. Complete replacement of portland cement by GGBS mixed with aggregates and water to form concrete is known as geo-polymer concrete. The use of GGBS also contributes to a better aesthetic appeal as it is light in colour when compared with cement which enhances the reflectivity of the finished material. GGBS has finer particles than cement which occupies voids and prevents crystalline deposits from occurring on the surface of the completed structure. Due to its numerous benefits, GGBS is chosen to experiment with and tested for its strength characteristics.

In this laboratory investigation, 15% of cement is replaced by GGBS for M20, M40 and M60 grades of concrete. They have undergone curing for 7 and 28 days for the testing of compressive and split tensile strength. In the case of flexural strength, they have undergone curing for 14 and 28 days. After the completion of curing and before the testing process, the specimens are partially impregnated with the polymer polyester and styrene. After the finishing of partial impregnation, they are dried and tested for their strong results. The second section of this paper constitutes the materials used, design mix ratio and the testing process. The results follow this section, which is presented in a tabulated form. The final section of this paper is the conclusion where the inference derived from the results are shown.

## 2. Experiment Procedure

### 2.1. Procurement of Materials:

**Cement:**

For the carrying out of this investigation, OPC 53-grade cement is used to manufacture concrete. It is a high strength cement with numerous benefits. It has a designed strength of 28 days, being at least 53 MPa. This grade of cement is more substantial than other grades of cement and is more durable.

**GGBS:**

GGBS is the Ground Granulated blast furnace slag used to replace 15% of cement. This material is present in a powder form with particles more refined than that of cement. It is almost white, which results in the concrete having a lighter appearance and finish. This material enhances the durability and strength of concrete.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 3, 2021, Pages. 626 - 633
Received 16 February 2021; Accepted 08 March 2021.

| Property | GGBS |
|---|---|
| Colour | Off-White |
| Specific Gravity | 2.9 |

**Table 1: Properties of GGBS**

**Silica Fumes:**

This is a pozzolanic material used to complete the requirement to design M60 grade of concrete as per IS code rules and regulations. For the M-60 grade of concrete 5% of cement is replaced with silica fumes apart from the 15% of cement replacement by GGBS.

**Super Plasticizer:**

Tech Mix – 550 is used in the M60 grade of concrete to increase the workability of the concrete. 1.5% of this chemical mixture is added along with the water-cement ratio. This superplasticizer enhances the flow of concrete, which in turn eases compaction of concrete.

**Fine aggregates:**

For this laboratory investigation manufactured sand (M-Sand) is used as the fine aggregate. It is easily available and preliminary tests were conducted as per IS code. The aggregates belong to Zone-III area.

**Coarse aggregate:**

12.5 mm size of coarse aggregate is used to carry out this investigation.

| Properties | Coarse Aggregate |
|---|---|
| Specific Gravity | 2.7 |
| Fineness Modulus | 7.39 |
| Water Absorption (%) | 1.41 |

**Table 2: Properties of Coarse Aggregate**

**Polyester and Styrene:**

In this investigation, for the partial impregnation of polymer, a combination of polyester and styrene are used to achieve results. Polyester is a violet coloured resin that has a high viscosity, to reduce its viscosity for impregnation, styrene is added. After the cubes, prism and cylinders mould are cast and hardened, they are made to undergo partial impregnation before testing. The process is done by immersing the specimens in the polymer for a minimum of 8 hours. Through partial impregnation, an impregnation of up to 5mm can be achieved. Whereas in the case of full impregnation, an impregnation up to 15mm can be achieved.

### 2.2.Design Mix Ratio

| Grade | Mix Ratio | Replacement | Water-Cement Ratio | Admixture |
|---|---|---|---|---|
| M20 | 1:2.17:2.35 | 20% GGBS | 0.5 | - |
| M40 | 1:1.58:1.86 | 20% GGBS | 0.4 | - |
| M60 | 1:1.59:2.11 | 20% GGBS | 0.3 | 5% silica fumes and 1.5% super plasticizer |

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 3, 2021, Pages. 626 - 633
Received 16 February 2021; Accepted 08 March 2021.

**Table 3: Design Mix Ratios**

The ratios are calculated as per the IS codes and presented in a tabulated form. Each grade of concrete is replaced with 20% of GGBS. In the case of M-60 grade of concrete to adhere to the IS regulations, further 5% of cement is replaced with silica fumes, and 1.5% of superplasticizer is added to the water-cement ratio. No chemical admixture is added to M20 and M40 grade of concrete.

### 2.3.Testing

Cubes of dimension 15cmX15cmX15cm, prism of size 50cmX10cmX10cm and cylinders of size dia-10cm and height-20 cm are used for this investigation. After the components are mixed as per the design mix ratio, they are put into the moulds and allowed to sit for a day. After the specimens are hardened, they undergo a curing process. In the case of compressive and split tensile strength, the specimens have undergone curing for 7 and 28 days. Whereas, for the determination of flexural strength, the specimens undergo curing for 14 and 28 days. After the curing process, the specimens are dried and exhibited to partial impregnation of a polymer. The specimens are immersed and soaked in a solution of polyester and styrene polymer for a minimum of 8 hours. After which, they are tested for their strength characteristics. Then, the results are tabulated and compared with conventional concrete. The conventional concrete has undergone the same curing process but has no traces of GGBS and has not undergone any polymer impregnation. The results are compared, and graphs are drawn to depict the difference in strength.

## 3. Results

### 3.1. Slump Cone test

| Grade of Concrete | M20 | M40 | M60 |
|---|---|---|---|
| Slump of conventional concrete (mm) | 51 | 46 | 77 |
| The slump of GGBS replaced concrete. | 54 | 50 | 81 |

**Table 4: Slump of Concrete and Fly Ash**

The slump test is conducted to test the workability of the concrete. The approximate slump value is determined as per IS code 1199:1959. The slump cone test for all three grades of concrete M20, M40, and M60 is performed.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 3, 2021, Pages. 626 - 633
Received 16 February 2021; Accepted 08 March 2021.

### 3.2.Compressive strength test

| Grade of Concrete | S.no. | Compression strength in (N/mm²) | | Average Compression strength in (N/mm²) | | Compression strength in (N/mm²) | | Average Compression strength in (N/mm²) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Conventional Concrete | | Conventional Concrete | | GGBS with PIC | | GGBS with PIC | |
| | | 7 days | 28 days | 7 days | 28 days | 7 days | 28 days | 7 days | 28 days |
| M20 | 1 | 15.6 | 21.06 | 15.54 | 22.38 | 16.22 | 30.12 | 16.77 | 31.88 |
| | 2 | 15.33 | 22.35 | | | 16.77 | 31.42 | | |
| | 3 | 15.7 | 23.73 | | | 17.33 | 34.12 | | |
| M40 | 1 | 23.24 | 41.24 | 24.5 | 40.73 | 25.76 | 50.14 | 25.45 | 48.97 |
| | 2 | 25.73 | 41.11 | | | 25.66 | 48.20 | | |
| | 3 | 24.53 | 39.86 | | | 24.93 | 48.57 | | |
| M60 | 1 | 42.8 | 61.8 | 52.8 | 65.87 | 55.2 | 73.88 | 60.3 | 74.46 |
| | 2 | 58.93 | 69.9 | | | 58.83 | 75.15 | | |
| | 3 | 56.93 | 65.93 | | | 6.87 | 74.36 | | |

**Table 5. Comparison of compression strength for GGBS with PIC and conventional concrete.**

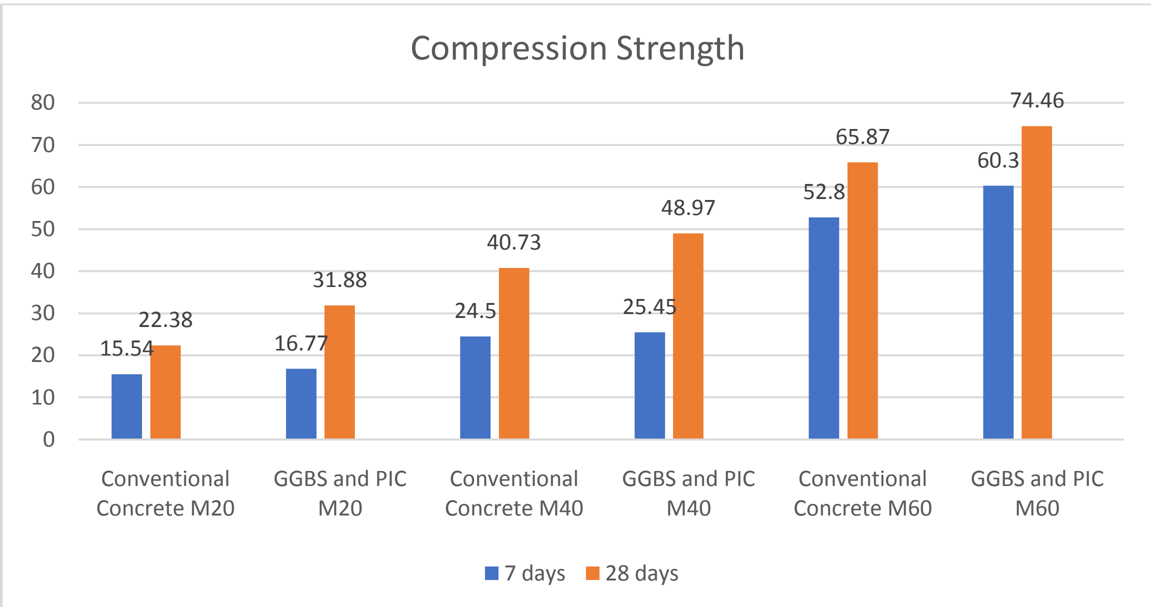


**Fig.1.Graph of Conventional concrete and GGBS with Polymer Impregnated Concrete.**

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 3, 2021, Pages. 626 - 633
Received 16 February 2021; Accepted 08 March 2021.

### 3.3.Flexural Strength test

| Grade of Concrete | S.no. | Flexural strength in (N/mm²) | | Average Flexural strength in (N/mm²) | | Flexural strength in (N/mm²) | | Average Flexural strength in (N/mm²) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Conventional concrete | | Conventional Concrete | | GGBS with PIC | | GGBS with PIC | |
| | | 14 days | 28 days | 14 days | 28 days | 14days | 28 days | 14 days | 28 days |
| M20 | 1 | 5.5 | 10 | 5.75 | 9.58 | 7.11 | 12.66 | 7.41 | 12.33 |
| | 2 | 5.75 | 9.25 | | | 7.25 | 12.12 | | |
| | 3 | 6 | 9.5 | | | 7.88 | 12.22 | | |
| M40 | 1 | 6.25 | 9.25 | 7.41 | 10.5 | 9.76 | 15.22 | 9.73 | 16.30 |
| | 2 | 8.25 | 11.75 | | | 9.55 | 15.12 | | |
| | 3 | 7.75 | 10.5 | | | 9.88 | 15.87 | | |
| M60 | 1 | 10 | 16.5 | 9.16 | 15.3 | 11.21 | 18.66 | 11.76 | 19.07 |
| | 2 | 8.5 | 14.5 | | | 12.31 | 19.12 | | |
| | 3 | 9 | 9 | | | 11.78 | 19.34 | | |

**Table 6. Comparison of flexural strength for GGBS with PIC and conventional concrete.**

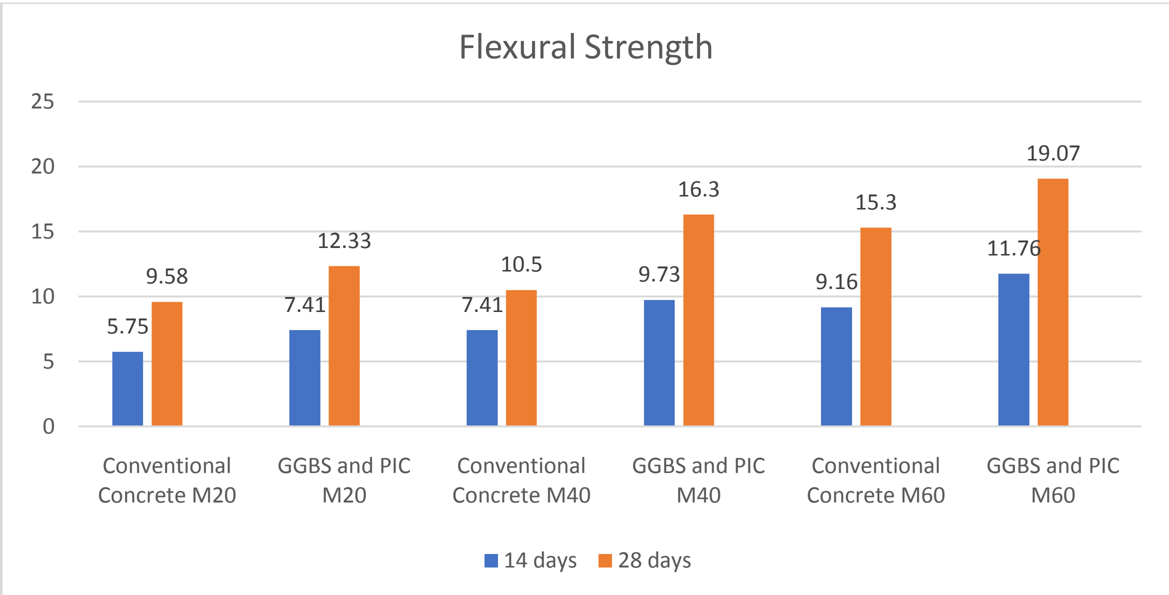


**Fig.2.Graph of Conventional concrete and GGBS with Polymer Impregnated Concrete.**

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 3, 2021, Pages. 626 - 633
Received 16 February 2021; Accepted 08 March 2021.

### 3.4. Split tensile strength

| Grade of Concrete | S.no. | Split tensile strength in (N/mm²) | | Average Split tensile strength in (N/mm²) | | Split tensile strength in (N/mm²) | | Average Split tensile strength in (N/mm²) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Conventional Concrete | | Conventional Concrete | | GGBS with PIC | | GGBS with PIC | |
| | | 7 days | 28 days | 7 days | 28 days | 7 days | 28 days | 7 days | 28 days |
| M20 | 1 | 2.1 | 2.83 | 2.14 | 2.82 | 2.45 | 3.45 | 2.61 | 3.62 |
| | 2 | 2.26 | 2.73 | | | 2.77 | 3.66 | | |
| | 3 | 2.07 | 2.9 | | | 2.62 | 3.76 | | |
| M40 | 1 | 2.57 | 4.58 | 2.55 | 4.28 | 3.66 | 4.22 | 3.40 | 4.28 |
| | 2 | 2.38 | 4.17 | | | 3.44 | 4.51 | | |
| | 3 | 2.7 | 4.1 | | | 3.11 | 4.12 | | |
| M60 | 1 | 4.87 | 6.1 | 4.53 | 6.21 | 5.66 | 7.21 | 5.47 | 7.27 |
| | 2 | 4.14 | 6.25 | | | 5.26 | 7.33 | | |
| | 3 | 4.59 | 6.3 | | | 5.51 | 7.29 | | |

**Table 7. Comparison of split tensile strength for GGBS with PIC and conventional concrete.**

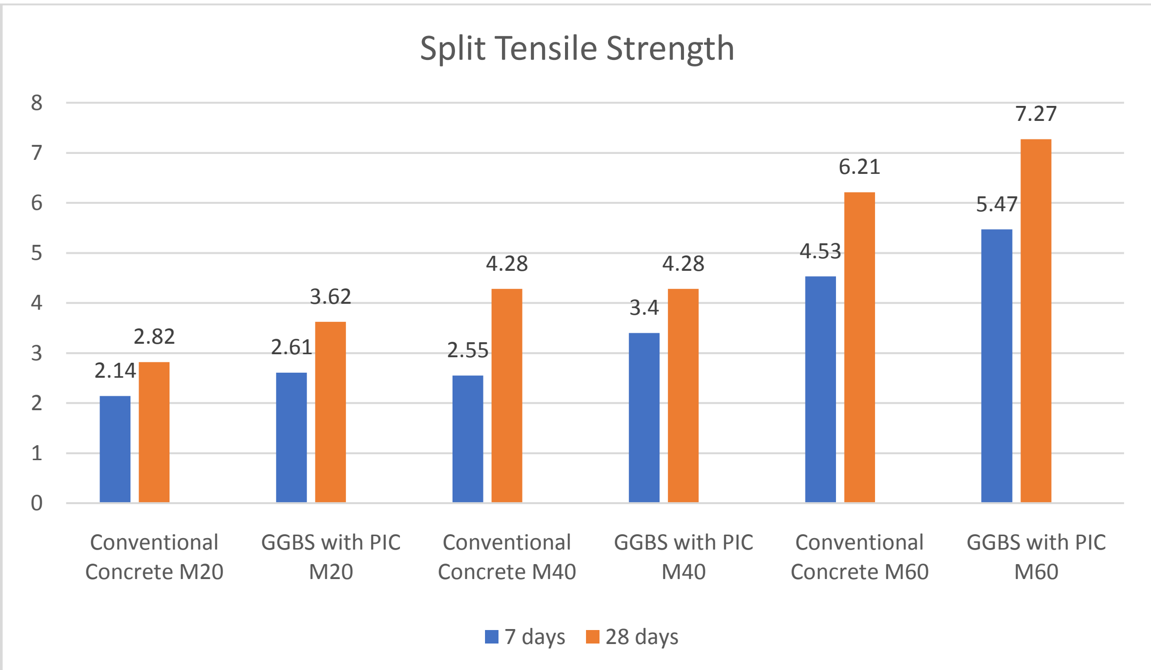


**Fig.3.Graph of Conventional concrete and GGBS with Polymer Impregnated Concrete.**

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 3, 2021, Pages. 626 - 633
Received 16 February 2021; Accepted 08 March 2021.

## 4. Conclusion

For this laboratory investigation, three grades, namely M20, M40 and M60, are used to conduct analysis. For each grade, 12 specimens are cast, i.e., 12 cubes, 12 prisms and 12 cylinders. The grades constitute of 6 samples of conventional concrete, out of which three are cured for seven days and the other 3 for 28 days in the case of cubes and cylinder. For prisms, three specimens are cured for 14 days, and the additional three samples are cured for 28 days. A similar curing process is followed for the other six specimens except they contain GGBS replacing 20% of the cement. After curing, they are made to undergo partial polymer impregnation with the polymers polyester and styrene. The polymer impregnation is performed by immersing the specimens in the solution for a minimum of 8 hours. After the impregnation process, they are tested for their compressive, flexural and split tensile strength. The results are tabulated, and the strength of GGBS with PIC and conventional concrete are compared.

From the strength test results obtained, we can infer that the replacement of 20% of cement by ground granulated blast furnace slag, followed by partial polymer impregnation after curing and drying process contributes significantly to increase in compressive, flexural and split tensile strength. M60 grade has achieved the highest increase in strength. This pattern is observed consistently for all the strength parameters. There is a constant increase in strength with the replacement of GGBS along with polymer impregnation for all three grades of concrete. Hence, we can conclude that using GGBS as a replacement and PIC and conserve resources and energy along with enhancing the properties of conventional concrete.

## References

1. K. Ganesh Babu, V. Sree Rama Kumar. (2000) Efficiency of GGBS in concrete Cement and Concrete ResearchVolume 30, Issue 7, July 2000, Pages 1031-1036.
2. Suresh, D., and K. Nagaraju. "Ground granulated blast slag (GGBS) in concrete–a review." IOSR journal of mechanical and civil engineering 12.4 (2015): 76-82.
3. Siddique, R., 2014. Utilization (recycling) of iron and steel industry by-product (GGBS) in concrete: strength and durability properties. Journal of Material Cycles and Waste Management, 16(3), pp.460-467.
4. Oner, A. and Akyuz, S., 2007. An experimental study on optimum usage of GGBS for the compressive strength of concrete. Cement and Concrete Composites, 29(6), pp.505-514.
5. Cheng, A., Huang, R., Wu, J.K. and Chen, C.H., 2005. Influence of GGBS on durability and corrosion behavior of reinforced concrete. Materials Chemistry and Physics, 93(2-3), pp.404-411.
6. Mathew, B.J., Sudhakar, M. and Natarajan, C., 2013. Strength, economic and sustainability characteristics of coal ash–GGBS based geopolymer concrete. International Journal of Computational Engineering Research, 3(1), pp.207-212.