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Study on properties of Concrete using GGBS

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Abstract: Throughout the world, the most widely used construction material is concrete. It is the second most consumed substance on the earth after water. As concrete being used for construction of most of the buildings, bridges etc., it has been labeled as the backbone to the infrastructure development of the nation. It is commonly made by mixing Portland cement with sand, crushed rock and water. It is very clear that among all the components, aggregate and water is largely available material in India at very low cost. As cement is comparatively high cost it would be advisable to use other locally available industrial and agricultural waste material to replace the cement partially. Ground Granulated Blast-furnace Slag (GGBS) is a non-metallic and non-hazardous waste material of the Iron Industry. Therefore, the minimization of this waste material without a harmful effect on nature has a vital importance. The present work focused on the utilization of GGBS in concrete which can be suitably used under the Indian conditions. For this purpose, the various tests on properties of green and hardened concrete have been performed. The properties of green concrete have been analyzed by workability of concrete in terms of slump value whereas the properties of hardened concrete have been analyzed in terms of mechanical and physical properties of concrete. The mechanical properties of hardened concrete include the compressive strength, flexural strength and split tensile strength whereas physical properties include the dry & moist density and water absorption of hardened concrete. On the basis of present work, we found that GGBS in concrete improves workability, compressive strength, flexural strength, split tensile strength and decreases the density & water absorption characteristics of hardened concrete. As a result, the cost of concrete decreases. Also, GGBS leads to the significant reduction in the quantity of cement which enables the reduction in CO_2 emission and reduction in energy consumption in production of cement.

Index Terms: **GGBS, cement, fine and coarse aggregate and concrete**

I. INTRODUCTION

`Ground granulated blast furnace slag (GGBS) is a sustainable material which helps in a greener environment by reducing the energy consumption and carbon dioxide (CO_2) gas emission. The cement industry alone accounts for around 5% of global carbon dioxide emissions. It emits CO_2 gasses both directly and indirectly. Direct emission of CO_2 occurs through the chemical process called calcination whereas burning of fossil fuels to heat the kiln indirectly results in CO_2 gas emission. It has been reported that the manufacture of one ton of Portland cement would require approximately 1.5 tons of mineral extractions together with 5000 MJ of energy, and would generate 0.95 tons of CO_2 equivalent. As GGBS is a by-product of the iron manufacturing industry, it is reported that the production of one ton of GGBS would generate only about 0.07 tons of CO_2 equivalent and consume only about 1300 MJ of energy.

GGBS is obtained from iron manufacturing industries, when Silicate and aluminate impurities from ore and coke are combined with flux to lower the viscosity of slag. Molten iron is then tapped off, the remaining molten slag, which consists of mainly siliceous and aluminous residue, is then water-quenched rapidly below 800oC in order to prevent the crystallization of merwinite and melilite, resulting in the formation of a glassy granulate. This glassy granulate is then dried and grounded into fine powder, which is known as ground granulated blast furnace slag (GGBS). The main components of blast furnace slag are CaO (30-50%), SiO_2 (30-40%), Al_2O_3 (8 -24%) and MgO (1-18%) which is close to the chemical composition of Portland cement. It is commonly used in combination with Portland cement in concrete for many applications. Concrete made with GGBS has many advantages, including improved strength, durability, workability, economic and environmental benefits. The only drawback in the use of GGBS concrete is that its strength development is considerably slower under the standard curing conditions than that of Portland cement concrete, although the ultimate strength is higher for the same water– binder ratio. In the construction of large structural concrete elements where heat dissipation is slow, there can be a significant rise in temperature within the first few days after casting due to the exothermic reaction of the binder.

II. AIM & OBJECTIVES OF STUDY

The main objective of the present work is to develop a high-performance concrete (HPC) using GGBS. Therefore, the experimental program has been undertaken with the objectives to check the compressive, tensile, and flexural strength of concrete grade M30. In addition to this the density and water absorption characteristics of hardened concrete was also evaluated. In all of the experimental works cement was partially replaced by 40%, 50% and 60% GGBS.

III. Review of Literature

Shalaka Shelke and Prof. R.M. Jadhav (Oct - 2020) has proposed a research paper on Study on Partial replacement of cement by GGBS and fine aggregate by Crusher Dust. Due to rapid development in infrastructure, it turns out to be very necessary to find and adopt some eco-friendly products. It is becoming more and more obvious that gradual evolution in the field of construction has adverse effects on the well-being of the earth and putting future generations in danger. Concrete could also be used for a few special purposes that special properties are more important than those commonly considered. The most important objective of this study is to assess the chances of usage of GGBS (Ground Granulated Blast Furnace Slag) in concrete. This project represents the results of an experimental investigation to understand the suitability of GGBS in production of concrete. In this experimental study the impact of GGBS on strength of referral concrete M20 was prepared using 43 Grade OPC and the other mixes were prepared by replacing part of OPC with GGBS. The replacement levels were 0%, 20%, 30% & 40% (by weight of cement) for GGBS. And replacing fine aggregate with 0%, 20%, 30% & 40% crusher dust.[1]

Sheikh Ibrahim k et. al. (Apr-2018) has proposed a research paper on Ground Granulated Blast Furnace Slag and Fly Ash in Concrete. Fly Ash is a by-product of coal-fired electric generating plants. For immediate combustion the pulverized coal is blown into the burning chamber of the furnace. The study found out that The GGBS and Fly Ash have been fully replaced by the cement in concrete for reducing the carbon dioxide emission in the atmosphere. The M40 grade of concrete has attained the compressive strength of 32Mpa in 28 days and tensile strength of 2.5 MPa in 28 days. This strength of GGBS and Fly Ash in concrete without adding admixtures. To improve the compressive strength by adding admixtures with GGBS and Fly Ash may give more strength.[2]

J. Vengadesh Marshall Raman and V. Murali Krishnan (March - 2017) has proposed a research paper on Study on Partial Replacement of Cement with GGBS in Self Compacting Concrete for Sustainable Construction. The concept of partial replacement of cement which is capable for sustainable development is characterized by application of industrial wastes to reduce consumption of natural resources and energy and pollution of the environment. A presently large amount of ground granulated blast furnace slag is a by-product of manufacturing of pig iron with an important impact on environment and humans. This research work describes the feasibility of using the GGBS in self-compacting concrete production as partial replacement of cement. GGBS can be used as filler and helps to reduce the total voids content in self-compacting concrete. Constant level of Fly ash is also used in all sets of mix proportions to increase the powder content to achieve Workability. The cement has been replaced by GGBS accordingly in the range of 0%, 25%, 30%, 35%, and 40% by weight of cement for M-30mix. After iterative trial mixes the water/cement ratio (w/c) was selected as 0.40. Self-compacting Concrete mixtures produced, tested, and compared in terms of compressive, split tensile strength and flexural strength with the conventional concrete for 7,14,28 days. It is found that 25% of GGBS can be replaced and strength obtained is comparable to the conventional concrete.[3]

Santosh Kumar et. al. (Oct-2015) proposed a study on strength and durability of GGBS Concrete. In this study, the compressive strength of concrete increased when cement was replaced by GGBS for both M20 and M40 grade of concrete. At 40% replacement of cement by GGBS the concrete attained maximum compressive strength for both M20 and M40 grade of concrete. The split tensile strength of concrete is increased when cement is replaced with GGBS. The split tensile strength is maximum at 40% of replacement. The flexural strength of concrete is also increased when the cement is replaced by GGBS. At 40% replacement, the flexural strength is maximum. The compressive strength values of acid affected concrete decreases in comparison with normal concrete, but the effect of acid on concrete decreases with the increase of percentage of GGBS. At 40% replacement of GGBS the resistance power of concrete is more. The compressive strength values of GGBS concrete affected to HCl were greater than the GGBS concrete affected to H_2SO_4. The effect of HCl on the strength of the concrete is lower than the effect of H_2SO_4 on the strength of the concrete.[4]

IV. Methodology

3.1 Material used

The materials used in experimental investigation include:

3.1.1 Cement

Ordinary Portland cement of 43-grade conforming to IS: 8112-1989 was used in this project.

3.1.2 GGBS

Ground Granulated Blast-furnace Slag (GGBS) used in this project is the mixed slag from JSW Steel Go-down, Chembur, Mumbai, India. The physical & mechanical properties of cement and GGBS are given in table 3.1.

Test	Cement	GGBS
Color	Gray	Off white
Consistency	25%	33%
Soundness	4 mm	--
Initial setting time	110 minutes	--
Final setting time	290 minutes	--
Specific gravity	3.13	2.95
Fineness (sieving on 90µm)	8.5 %	0%
Fineness (Blain's air permeability)	302 m^2/kg	320 m^2/kg
Bulk density	1.48 gm/cm^3	1.29 gm/cm^3
Compressive strength 3days 7days 28 days	N/mm^2 23.33 34.33 46.18	 -- --

Table No. 3.1: The above table shows the Physical & mechanical properties of cement & GGBS obtained from different laboratory tests.

3.1.3 Fine and Coarse Aggregate

The aggregate passing through the sieve size 4.75mm is termed as fine aggregate and those which retained on 4.75 mm sieve is termed as coarse aggregate. River sand obtained from Mithi River was used as fine aggregate whereas mechanically crushed angular coarse aggregate from a nearby construction site, Santacruz, was used as coarse aggregate. All the properties of aggregates were tested in accordance with IS: 2386(part I to IV) -1963 and the results obtained were confirmed with IS 383-1970. Table 3.2 summarizes the properties of fine and coarse aggregate.

Test	Fine Aggregate	Coarse Aggregate
Zone/type	II	Crushed angular
Water Absorption	1.10%	0.45 %
Fineness Modulus	2.78	7.25(fraction I- 20mm) 6.29(fraction II- 10mm)
Specific gravity	2.62	2.89

Table No. 3.2: The above table shows the properties of Fine and Coarse Aggregate which were tested in accordance with IS: 2386(part I to IV) -1963 and the results obtained were confirmed with IS 383-1970.

3.2 Experimental procedure

Experimental procedure has been described in the following paragraphs

3.2.1 Mix design

Proportioning of concrete mix for M30 grade of concrete has been achieved by concrete mix design as per IS 10262:2009. The w/c ratio for the mix is 0.45 and the mix ratio for conventional concrete is 1:1.53:2.89:0.45. Composition of constituent material per cubic meter of concrete for different batches is given in table 3.3.

Mix Designation	Cement %	GGBS %	Water (Kg)	Cement (Kg)	GGBS (Kg)	FA (Kg)	CA (Kg)
R_0	100	0	188	425	0	653	1236
R_{40}	60	40	188	255	170	653	1236
R_{50}	50	50	188	213	212	653	1236
R_{60}	40	60	188	170	255	653	1236

Table No. 3.3: Proportioning of the concrete mix. Obtained for M30 grade of concrete with w/c ratio= 0.45 as per IS 456:2000 for maximum size of aggregate as 20mm.

3.2.2 Mixing technique

Hand mixing technique has been adopted in the whole experimental work at temperature of 27° ± 2°C and relative humidity 90 percent. In each batch 6 specimens of cube of dimension 150mm x 150mm x 150mm, 6 specimens of cylinder of dimension 150mm diameter x 300mm height, and 3 specimens of beam of dimension 100mm x 100mm x 500mm have been made.

3.2.3 Properties of fresh concrete

The property of fresh concrete has been assessed by workability in terms of slump value. The test of which has been performed in accordance with IS 1199:1959. The results of which are given below in table 3.4.

Mix type	R_0	R_{40}	R_{50}	R_{60}
Slump (mm)	60	70	73	71

Table-3.4: The above table shows the values obtained using slump cone tests for 0%,40%,50% and 60% replacement of cement with GGBS as per IS 1199:1959.

From the above table, it is observed that the slump value of concrete increases as the percentage of GGBS increases up to 50% replacement and then decreases. The increase in slump value is due to the higher smoothness and fineness of slag increases the entrainment of air in the matrix, subsequently increasing the volume of paste.

3.2.4 Properties of Hardened Concrete

Hardened concrete properties have been analyzed in the terms of compressive, flexural & split tensile strength, dry & moist density and water absorption. As the development of strength is time dependent hence these tests have been performed after a different curing period. One sample each of cube and cylinder has been tested at 7 and 28 days for compressive strength and split tensile strength of concrete respectively while the beam has been tested after a curing period of 28 days for flexural strength of concrete.

3.3 Tests Performed on concrete

1) Slump Test
2) Compressive Strength Test
3) Flexural Strength Test
4) Splitting Tensile Strength Test

IV. Results and Discussions

4.1 Results of Descriptive Statics of Study Variables

Compressive Strength

This test was performed in accordance with IS 516:1959 on the cube of size 150mm x 150mm x 150mm. The result of which is given below in table 4.1.

Mix type	7 days		28 days	
	Avg. Compressive Strength (N/mm^2)	% variations over R_0	Avg. Compressive Strength (N/mm^2)	% variations over R_0
R0	26.22	0	38.74	0
R40	23.26	-11.29	47.26	+21.99
R50	22.96	-12.43	49.85	+28.68
R60	21.26	-18.92	47.63	+22.95

Table No. 4.1: Values for Compressive strength of concrete

Table No. 4.1 shows the values for Compressive strength of concrete obtained from CTM for 0%,40%,50% and 60% replacement of cement with GGBS as per IS 516:1959. It shows the average compressive strength and the variation of R40, R50, R60 with respect to R0 for the samples of 7 days and 28 days.

Graph showing the variation of compressive strength of concrete with different percentages of GGBS is presented below in figure 4.1.

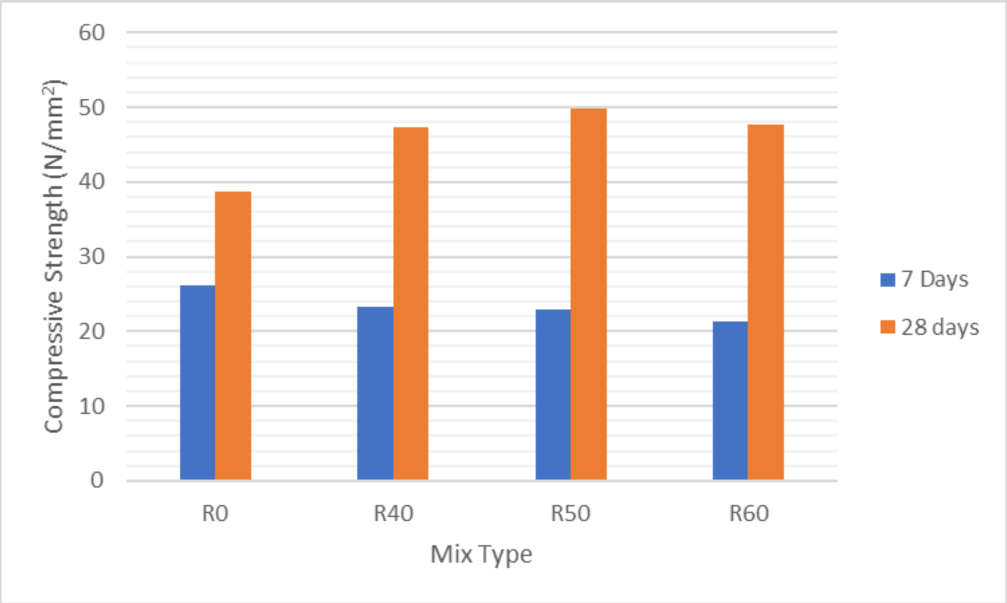


Fig. No. 4.1: Compressive strength of concrete

From the above fig., it is observed that compressive strength of concrete with increasing percentage of GGBS decreases after 7 days but increases after 28 days with optimum percentage of 50% replacement by GGBS. It indicates the slower rate of reaction of the matrix by incorporation of GGBS. At optimum percentage of GGBS the compressive strength is 28.68% higher than that of conventional cement concrete.

Split Tensile Strength

This test was performed in accordance with IS 5816:1999 on the cylinder of diameter 150 mm and height 300mm. The result of which is given below in table 4.2.

Mix type	7 days		28 days	
	Split tensile Strength (N/mm^2)	% variations over R_0	Split tensile Strength (N/mm^2)	% variations over R_0
R0	2.64	0.00	2.93	0.00
R40	1.82	-31.25	3.42	+16.94
R50	1.72	-34.82	3.51	+20.16
R60	1.51	-42.86	3.59	+22.58

Table No. 4.2: Split Tensile Strength of concrete

Table No. 4.2 shows the Split Tensile Strength of concrete obtained for 0%,40%,50% and 60% replacement of cement with GGBS as per IS 5816:1999. It shows the average split tensile strength and the variation of R40, R50, R60 with respect to R0 for the samples of 7 days and 28 days.

Graph showing the variation of split tensile strength of concrete with different percentages of GGBS is presented in figure 4.2.

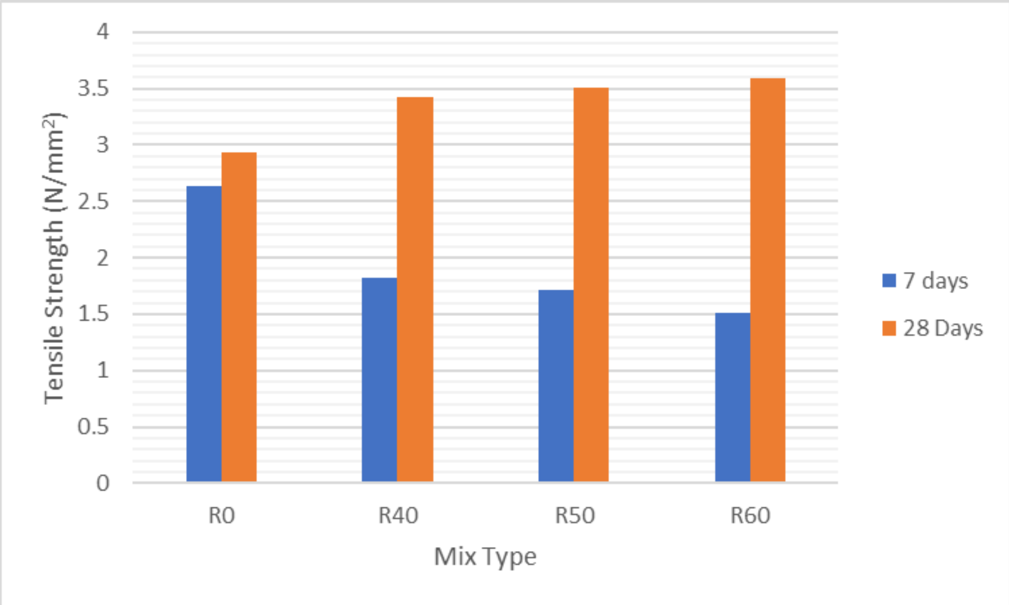


Fig. No. 4.2: Split tensile strength of concrete

From the fig., it is observed that split tensile strength of concrete with increasing percentage of GGBS decreases after 7 days but increases after 28 days with optimum percentage of 60% replacement by GGBS. It indicates the slower rate of reaction of the matrix by incorporation of GGBS. At optimum percentage of GGBS the Split tensile strength is 22.58% higher than that of conventional cement concrete.

Flexural Strength

This test was performed in accordance with IS 516:1959 on the beam of dimension 100mm x 100mm x 500mm which were tested at 28 days curing period and average of which were found out. The result of which is given in table 4.3.

Mix type	28 days	
	Avg. Flexural Strength (N/mm^2)	% variations over R_0
R0	3.87	0.00
R40	4.63	+19.64
R50	4.92	+27.13
R60	4.73	+22.22

Table No. 4.3: Flexural Strength of Concrete

Table No. 4.3 the Flexural Strength of Concrete for 0%,40%,50% and 60% replacement of cement with GGBS as per IS 516:1959. It shows the average flexural strength and the variation of R40, R50, R60 with respect to R0 for the sample of 28 days.

Graph showing the variation of flexural strength of concrete with different percentage of GGBS is given in figure 4.3.

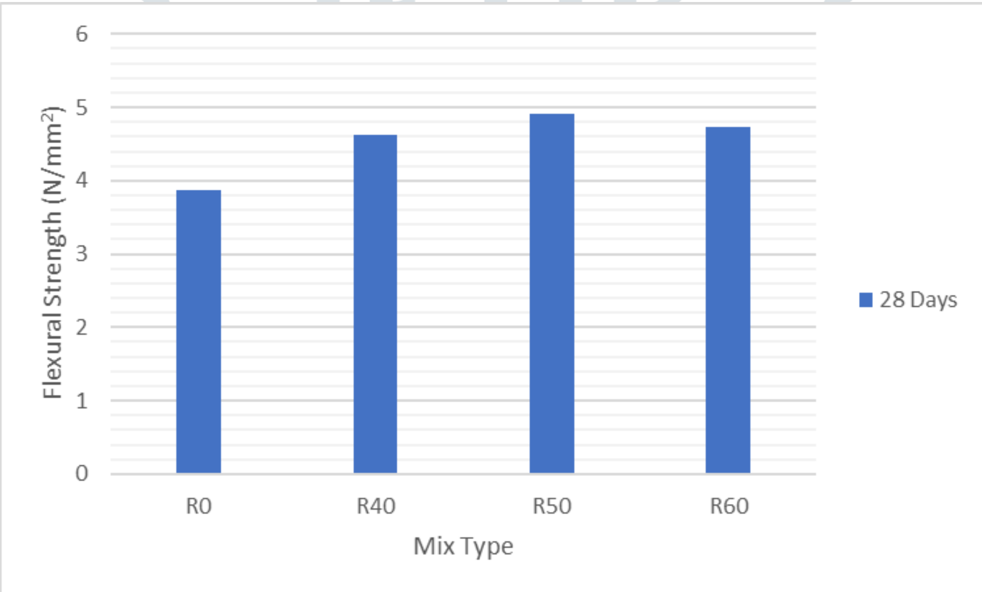


Fig. No. 4.3: Flexural strength of concrete

From the graph, it may be observed that the flexural strength of concrete with increasing percentage of GGBS increases after 28 days with optimum percentage of 50% replacement by GGBS. At this stage of replacement of cement with GGBS flexural strength is 27.13% higher than that of conventional cement concrete.

Water Absorption

Water absorption of concrete has been determined in accordance with ISO: 6275-1982 and NT BUILD 200. The values of which are given in table 4.4.

Mix type	Avg. water absorption %	% variation over R_0
R0	4.50	0.00
R40	3.35	-25.66
R50	2.30	-48.96
R60	2.04	-54.74

Table No. 4.4: Values of Water absorption of hardened concrete

Table No. 4.4: The above table shows the values of Water absorption of hardened concrete for 0%,40%,50% and 60% replacement of cement with GGBS as per ISO: 6275-1982. It shows the average water absorption and the variation of R40, R50, R60 with respect to R_0 sample.

Graph showing the variation of water absorption of hardened concrete with different percentages of GGBS is presented in figure 4.4

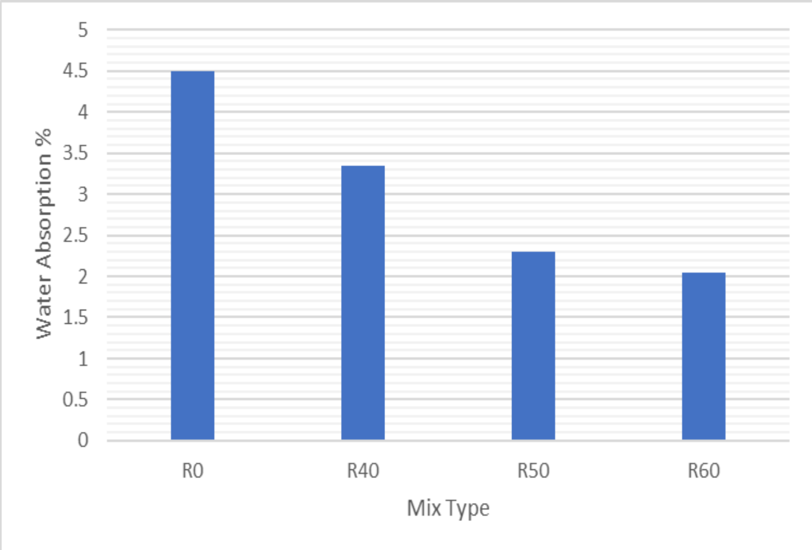


Fig. No. 4.4: Water absorption of hardened concrete.

From the above fig., it is observed that the water absorption of concrete decreases as the percentage of GGBS increases. From this result, it is concluded that the GGBS can be used to improve the water impermeability characteristics of structure. Hence the corrosion of reinforcement may be retarded & durability of R.C.C. structure may be increased.

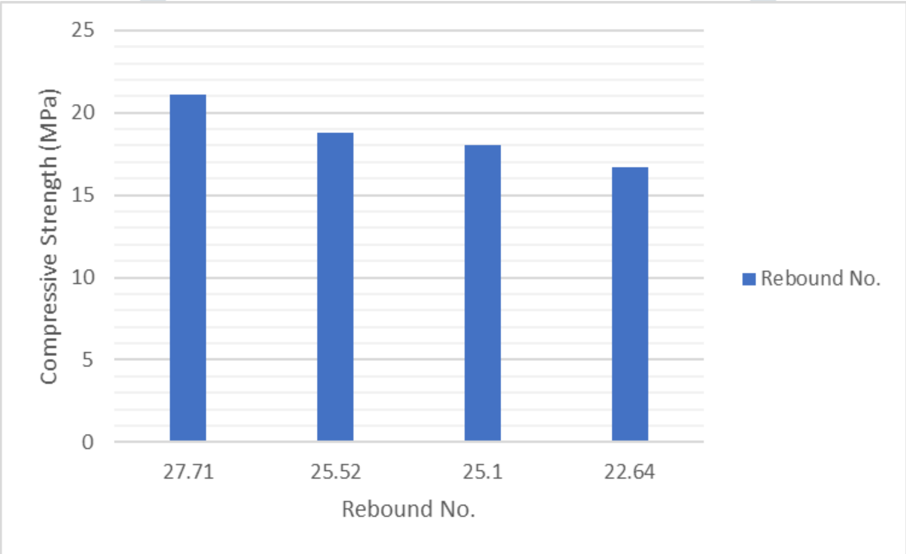
Rebound Hammer Test

This test was performed using Schmidt Rebound Hammer at 90 degrees from the smooth surface of the cubes. The details for the test are given in table 4.5.

Mix type	7 days			28 days		
	Rebound Number	Compressive Strength (MPa)	% Variation over R0	Rebound Number	Compressive Strength (MPa)	% Variation over R0
R0	27.71	21.10	0	30.57	33.48	0
R40	25.52	18.80	-10.57	41.85	40.95	+22.34
R50	25.10	18.05	-14.43	43.40	43.54	+30.07
R60	22.64	16.72	-20.74	41.10	41.61	+24.29

Table No. 4.5: Values of compressive strength obtained from Rebound Hammer Test

Table No. 4.5 shows the values of compressive strength obtained from Rebound Hammer Test of Concrete for 0%,40%,50% and 60% replacement of cement with GGBS. It shows the average compressive strength by using rebound hammer test and the variation of R40, R50, R60 with respect to R0 for the samples of 7 days and 28 days.



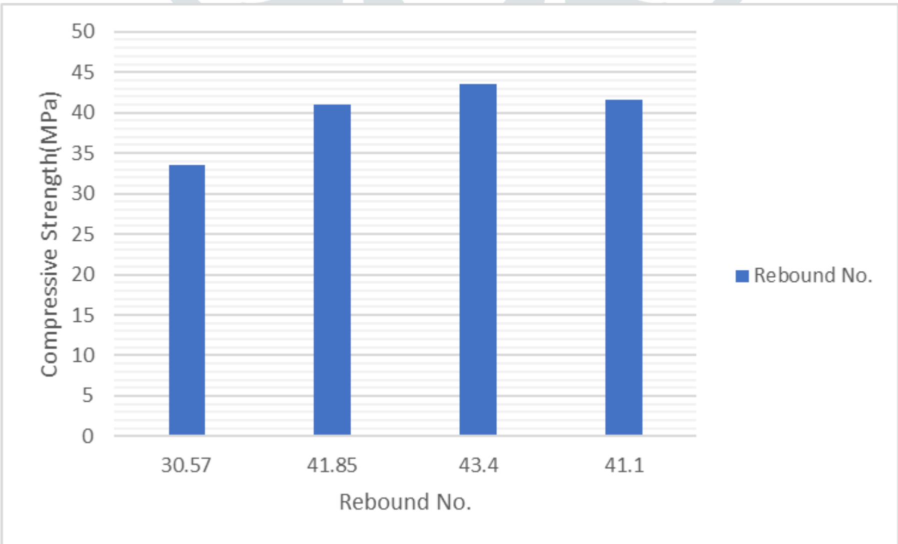


Fig. No. 4.5: Compressive strength of hardened concrete.

CONCLUSION

Slump value of concrete increases as the percentage of GGBS increases up to 50% replacement and then decreases. The increase in slump value is due to the higher smoothness and fineness of slag increases the entrainment of air in the matrix, subsequently increasing the volume of paste.Compressive strength of concrete with increasing percentage of GGBS decreases after 7 days but increases after 28 days with optimum percentage of 50% replacement by GGBS. It indicates the slower rate of reaction of the matrix by incorporation of GGBS. At optimum percentage of GGBS the compressive strength is 28.68% higher than that of conventional cement concrete. Split tensile strength of concrete with increasing percentage of GGBS decreases after 7 days but increases after 28 days with optimum percentage of 60% replacement by GGBS. It indicates the slower rate of reaction of the matrix by incorporation of GGBS. At optimum percentage of GGBS the Split tensile strength is 22.58% higher than that of conventional cement concrete. Flexural strength of concrete with increasing percentage of GGBS increases after 28 days with optimum percentage of 50% replacement by GGBS. At this stage of replacement of cement with GGBS flexural strength is 27.13% higher than that of conventional cement concrete. Water absorption of concrete decreases as the percentage of GGBS increases. From these results, it is concluded that the GGBS can be used to improve the water impermeability characteristics of structure. Hence the corrosion of reinforcement may be retarded & durability of R.C.C. structure may be increased.

FUTURE SCOPE

GGBS can be ideal choice in civil infrastructural applications. Combination of GGBS with different other admixtures can be carried out. Beams with different shear span to effective depth ratios, varying percentages of tensile reinforcement and varying percentages of GGBS, may be investigated. Some tests relating to durability aspects such as water permeability, resistance to penetration of chloride ions, corrosion of steel reinforcement, durability in marine environment etc. need investigation. The study may further be extended to know the behavior of concrete whether it is suitable for pumping purposes or not as present-day technology is involved in ready mix concrete where pumping of concrete is being done to large heights. Future scopes of GGBS are positive due to benefits in durability, sustainability, appearance and strength obtained by partial replacement of GGBS with cement in concrete.

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