Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

Effects of Ground Granulated Blast Furnace Slag and M Sand on the Mechanical Properties of Ordinary Portland cement Concrete

Subramanian .R[1] and Prabaghar .A[2]
[1]Research Scholar, Department of Civil and Structural Engineering, Annamalai University, India.
email: ersubbuphd64@gmail.com
[2]Associate Professor, Department of Civil and Structural Engineering, Annamalai University, India.
email: aprabaghar@gmail.com

ABSTRACT

Utilisation of waste materials obtained as an industrial by products are increasing day by day. Since the waste materials will be cause more hazardous effects to the surrounding environment if simply dumped in the land. To ensure the safe disposal of industrial waste materials such as Ground Granulated Blast Furnace Slag (GGBFS), fly ash and etc., many researches are beginning to study the effect of these materials as partial replacement for cement. Using such materials will reduce the carbon footprint due to the production of cement. In this study the replacement of cement using GGBFS is studied to extract the effects of partial replacement of GGBFS on cement concrete. In addition to this, river sand is fully replaced using M – Sand to overcome the high demand and unavailability of river sand as fine aggregate for concrete. M 20 grade of concrete is designed and a mix proportion of 1:2.01:3.62 and 1:1.99:3.62 for conventional concrete and concrete with GGBFS and M Sand respectively. The GGBFS is used as partial replacement for cement with a gradual increase in the percentage of GGBFS from 0 %, 30%, 40%, 50% and 60%. The strength properties such as compressive strength, flexural strength, modulus of elasticity are conducted and observed an increasing trend in strength up to 40% replacement of GGBFS and a decreasing trend in strength above 40 % of GGBFS replacement. Concrete with 40 % of GGBFS as replacement for cement can be suitable for practical applications and will significantly reduce the carbon footprint.

Key Words: Cement, Compressive Strength, Flexure Strength, GGBFS, Modulus of Elasticity, M Sand, Replacement, River Sand.

1. Introduction

The main focus of the construction industry is on the reduction of cement as a binder material due to the high emanation of carbon dioxide and consumption of energy during the production of cement. The idea of replacing cement with the industrial by-products such as fly ash, silica fume, GGBFS and etc., is emerging vastly due to the possibilities of reducing the emanation of carbon dioxide and cost of the production of concrete. Addition to this, the incorporation of industrial waste materials can improve the mechanical and durability properties of concrete [1]. The usage of the industrial waste materials may also reduce the issues regarding the safe disposal. Almost in all developing and developed counties, the disposal of industrial waste materials is a huge burning issue. Failing to dispose these materials safely will lead to many hazardous effects to the surroundings. The requirement for the production of concrete is increasing day by day and also it is estimated to be increased in future due to the continuous development in the infrastructure such as sky scrapers, bridges, tunnels, under ground structures and etc. The main reason for utilising concrete over other material is due to its cost effectiveness. The main issue in using concrete is, it requires cement as a binder material. The production of cement produced equal amount carbon dioxide and it requires high energy during calcification process. Also, natural resources like lime, clay, shale are required to produce cement which lead to degradation of such materials. The use of GGBFS, which is similar to cement in the aspects of chemical composition as partial replacement will be a solution to reduce the cement content in concrete. In recent days, the demand for the river sand which is used as fine aggregate for making concrete is very high and its availability is also becoming very scarce and the cost of river sand is also increasing rapidly leading to increase in the cost of concrete. So, the need for an alternative material for river sand is a need of the hour. The sand occupies larger portion of concrete than cement and it fills the voids and pores in concrete and it influence the properties of concrete such as compressive strength, workability. The continuous usage of sand also leads to issues such as degradation of river beds and soil losing its ability to store water [2]. An alternative for river sand is utmost importance and many researches has been in progress to discover a suitable replacement for river sand. Materials such as steel slag, foundry sand, bottom ash (coal), industrial smelting furnace slag, copper slag, palm oil clinker and etc., has been chosen and conducted several tests to find their suitability of replacement material for river sand [2]. A material with similar properties to river sand will be an ideal replacement. Utilisation of M Sand can be a solution to replace the river sand as fine aggregate. Due to the frequent unavailability of river sand, M Sand was recommended for the replacement of river sand but due to the traditional mind setup of users, there is a lag in using it widely in structural applications. In this study, the suitability of M Sand as an alternative for

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

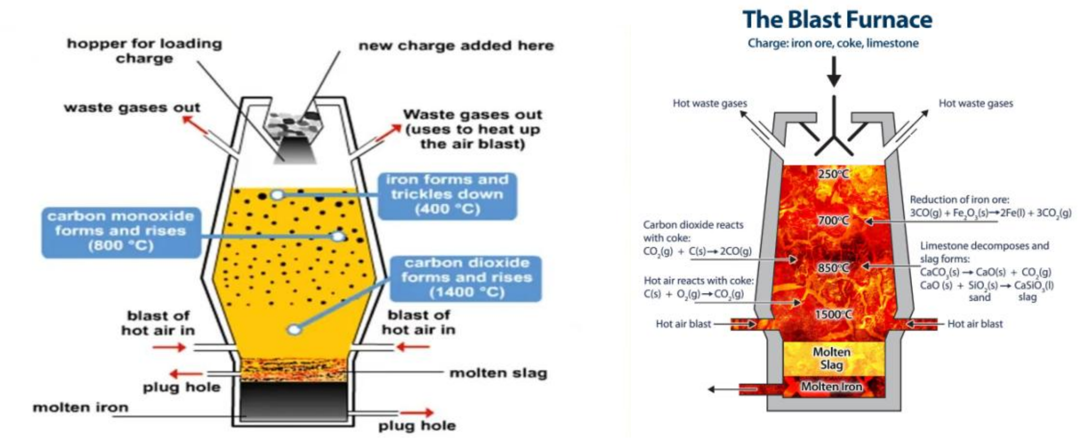
river sand and GGBFS as a partial replacement for cement is undergone to determine the influence in the strength of the concrete.

2. Alternative Materials

The main focus of this study is to replace cement with 0 % to 60% of GGBFS and river sand with 100% M Sand.

2.1 Ground Granulated Blast Furnace Slag (GGBFS)

GGBFS obtained from the industrial waste called molten slag, which is produced in the process of steel as a by-product. The molten slag is cooled to obtain GGBFS. The reactivity of the GGBFS is greatly influenced by the cooling or quenching process. To obtain high reactive or hydraulic GGBFS rapid cooling or quenching process is required. Rapid cooling is achieved by the jetting of high stream of water and the quenching process is achieved melting of molten slag under 800°C. The GGBFS obtained without proper cooling and quenching process below 800°C, will be less reactive. The hydraulic activity of GGBFS is increased with the increase of aluminium Oxide, calcium oxide and magnesium oxide and decreased with the increase in silicon dioxide. The ratio of CaO + MgO to SiO_2 should be greater than 1 to have better hydraulic activity [3]. After the quenching or cooling process of molten slag, it was converted into particles lesser than 5 mm which is then grinding into powder form to obtain GGBFS [4-6]. Generally, GGBFS is composed with silicate and alumino – silicate of calcium in which calcium oxide and silica s major compound with lesser aluminium and magnesium. The binding and hydration of GGBFS is mainly depends upon the glassy and crystalline phase respectively [7-8]. In study GGBFS is obtained from ASTRAA Chemicals in Chennai. The molten slag obtained in the blast furnace and the grinder machine for producing GGBFS are shown in Figures 1 and 2. Figure 3 shows the GGBFS used for replacing cement. GGBFS is white in appearance and the specific gravity is 2.83. The fineness of GGBFS is lesser than 350 m^2/kg and the bulk density of GGBFS is 1200 kg/m^3.



(a) Schematic Diagram [9] **(b) Representation of Chemical Reactions**

Fig. 1 Blast Furnace

Fig. 2 Grinder Machine for Making GGBFS

Fig. 3 GGBFS

2.2 M - Sand

In recent days, M Sand is emerging as a replacement for river sand for making concrete. The inactive availability of river sands as fine aggregate due to the degradation of sand beds, the need for an alternative material is required to continue the process of construction without any lag and delays. M Sand is more advantageous than river sand since M Sand is artificially produced in the industry unlike naturally made

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

sand. The M Sand can be obtained in required shape and size and it is free from impurities like clay, shale and etc. The shape of M Sand is cubical and can be under control so that the performance of M Sand is better than river sand. The M Sand can also improve the properties of concrete. The manufacturing of M Sand involves three phases such as crushing, screening and washing of rock particles. The silt content present in M Sand (0.2%) is lesser than river sand (0.45%) and the water absorption of M Sand (1.6%) is slightly higher than the river sand (1.15%). The slight increase in water absorption of M Sand is due to its smooth and angular texture [10]. The crushing of M Sand is processed using VSI crusher. The cubical shape of M Sand improves the strength and durability of concrete and the proper gradation reduces the voids, bleeding and segregation in the concrete [11]. The specific gravity of M Sand is 2.63. The particle sizes of M Sand, ranges from 0.3 to 42 micro meter. The bulk density of M Sand is 1825 kg/m^3 and the fineness of modulus of M Sand was 2.87 and the M Sand used was confirming the IS: 383-1970 [12] and falls under the category zone II.

3. Conventional Materials and Properties

Conventional materials such as Ordinary Portland Cement (OPC) as binder, river as fine aggregate and crushed stone as coarse aggregate are used in this study to determine and compare the results of conventional concrete and concrete with GGBFS and M Sand.

3.1 Ordinary Portland Cement (OPC)

OPC is used as binder material for concrete and the grade of OPC is 53 grade. The specific gravity of OPC is 3.13 and the cement used is confirming to IS 12269:1987 [13].

3.2 River Sand

River sand is collected from local market is used for casting concrete specimens. The specific gravity of river sand is 2.66. River sand used in this study falls under the category of zone II. River sand is used and confirming the IS 383:1970 [12].

3.3 Coarse Aggregate

Coarse aggregate is considered as filler material which gives the body and strength to the concrete and also it is considered as inactive material. The selection of coarse aggregate is very important since the size, shape and texture of the coarse aggregate plays a vital role in the strength and durability of concrete. Crushed stone is used as coarse aggregate with specific gravity of 2.80. The size of the coarse aggregate used is 20 mm. Coarse aggregate used in this study confirming to IS 383: 1970 [12].

3.4 Water

Potable water is used for mixing and curing of concrete specimens.

4. Mix Proportioning and Casting of M 20 grade Concrete

4.1Mix Proportions

Mix proportions for M 20 grade conventional concrete and concrete with GGBFS and M Sand are arrived based on IS 10262:2009 [14]. A mix proportion for conventional concrete is arrived as 1:2.01:3.62 and 1:1.99:3.62 for concrete with GGBFS and M Sand. The ratio of water to cement is chosen as 0.55 for both the concrete. The detailed mix proportions for conventional concrete and concrete with GGBFS and M Sand are given in Tables 1 and the percentages of replacement of GGBFS is given in Table 2. River sand is completely replaced with M Sand. Cement is partially replaced with GGBFS gradually to determine the suitable percentage of GGBFS to replace cement. The percentage of GGBFS replaces is 0%, 30%, 40%, 50% and 60%.

Table 1 Mix Proportioning of M 20 Grade Concrete

Sl. No.	Type of Concrete	Binder (kg/m^3)	River Sand (kg/m^3)	M Sand (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)
1	Cement Concrete (CC)	339	684.707	---	1227.21	186
1	GGBFS Concrete (CSRSC)	339	684.707	---	1227.21	186
3	GGBFS Concrete (CSMSC)	339	---	676.98	1227.21	186

*CC – Cement Concrete; CSRSC – Cement concrete with GGBFS and River Sand; CCMSC – Cement Concrete with GGBFS and M Sand.

Table 2 Percentage of GGBFS for Replacing Cement

Sl. No.	GGBFS (%)	Cement (%)	GGBFS (kg/m^3)	Cement (kg/m^3)	Total Volume (kg/m^3)
1	0	100	0	339	339
2	30	70	91.94	237.28	329.22
3	40	60	122.59	203.38	325.97
4	50	50	153.24	169.48	332.72
5	60	40	183.89	135.59	319.48

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

4.2 Casting and Curing of Concrete Specimens

Cubes, cylinder and prism moulds are cleaned and prepared for casting concrete specimens. Cube moulds of size 100 x 100 x 100 mm and 150 x 150 x 150 mm are used to cast mortar cubes and concrete cubes. Cylinder moulds of 150 mm diameter and 300 mm length is used to cast concrete cylinder specimens and prism moulds of size 500 x 100 x 100 mm is used to cast concrete prism specimens. Initially the raw materials are mixed together in dry condition and after obtaining a uniform mixture water is added and mixed thoroughly to get uniformly mixed concrete. The fresh concrete is poured into respective moulds and compacted thoroughly by using vibrator table in our laboratory. The fresh concrete mix attained a slump value of 50 mm for all mixes. The concrete specimens are left undisturbed for 24 hours and then the moulds are demoulded carefully to avoid damages to the concrete specimens. After demoulding, the concrete specimens are kept under water for curing upto 28 days. Meanwhile seventh day compressive strength for concrete specimen is conducted to study the early age strength. After 28 days, the concrete specimens are tested to determine the strength aspects of concrete specimens. The casting of mortar cubes, concrete specimens and hardened concrete specimens are shown in Figures 4 to 6 respectively.

Fig. 4 Mortar Cubes

Fig. 5 Concrete Specimens

Fig. 6 Hardened Concrete Specimens

5. Experimental Reports of M 20 Grade Concrete with GGBFS, River Sand and M Sand

5.1 Compressive Strength

The compressive strength of conventional concrete and concrete with GGBFS and M Sand are determined by testing 150 x 150 x 150 mm concrete cube specimens and cylinder specimens of 150 mm diameter and 300 mm height using compression testing machine in our laboratory. The compression testing is conducted based on the Indian standards – IS 516: 1959 [15]. The load is gradually applied to the face of the concrete cube perpendicular to the direction of compaction. The ultimate load at the ultimate failure point of the concrete cubes are noted and the compressive strength is arrived. The area of the concrete cubes is 22500 m^2. The compression testing on concrete cube and cylinder is shown in Figures 7. The compressive strength of cement mortar cubes obtained at 7 days and 28 days are 51.16 N/mm^2 and 53.90 N/mm^2 respectively. The compressive strength of concrete cubes and cylinders specimen are given in Table 3.

Fig. 7 Compression Testing on Concrete Specimens

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

Table 3 Compressive Strength of M 20 Concrete Cube with GGBFS and River Sand

Sl. No.	Specimen Designation	7th Day Compressive Strength (N/mm^2)	14th Day Compressive Strength (N/mm^2)	28h Day Compressive Strength (N/mm^2)
1	CC	22.32	24.28	31
2	CSRSC30	21.91	32.91	33
3	CSRSC40	21.6	31.07	33.03
4	CSRSC50	17.8	21.85	25.58
5	CSRSC60	22.13	23.50	20.5

*CCRS – Cement Concrete with River Sand; CSRSC30 – Cement concrete with 30% of GGBFS and 100% of River Sand; CSRSC40 – Cement concrete with 40% of GGBFS and 100% of River Sand; CSRSC50 – Cement concrete with 50% of GGBFS and 100% of River Sand; CSRSC60 – Cement concrete with 60% of GGBFS and 100% of River Sand.

Table 4 Compressive Strength of M 20 Concrete Cube with GGBFS and M Sand

Sl. No.	Specimen Designation	7th Day Compressive Strength (N/mm^2)	14th Day Compressive Strength (N/mm^2)	28h Day Compressive Strength (N/mm^2)
1	CCMS	18.37	23.35	33.03
2	CSMSC30	21.97	28.16	33.62
3	CSMSC40	17.95	24.13	34.12
4	CSMSC50	17.80	25.55	26.78
5	CSMSC60	17.45	21.88	25.12

*CCMS – Cement Concrete with M Sand; CSMSC30 – Cement concrete with 30% of GGBFS and 100% of M Sand; CSMSC40 – Cement concrete with 40% of GGBFS and 100% of M Sand; CSMSC50 – Cement concrete with 50% of GGBFS and 100% of M Sand; CSMSC60 – Cement concrete with 60% of GGBFS and 100% of M Sand.

Table 5 Compressive Strength of M 20 Concrete Cylinder with GGBFS and River Sand

Sl. No.	Specimen Designation	7th Day Compressive Strength (N/mm^2)	14th Day Compressive Strength (N/mm^2)	28h Day Compressive Strength (N/mm^2)
1	CC	16.32	15.86	16.95
2	CSRSC30	14.69	15.70	19.18
3	CSRSC40	15.02	17.55	22.03
4	CSRSC50	15.03	13.40	13.63
5	CSRSC60	8.96	14.06	15.55

Table 6 Compressive Strength of M 20 Concrete Cylinder with GGBFS and M Sand

Sl. No.	Specimen Designation	7th Day Compressive Strength (N/mm^2)	14th Day Compressive Strength (N/mm^2)	28h Day Compressive Strength (N/mm^2)
1	CCMS	15.71	16.62	22.34
2	CSMSC30	15.84	19.07	23.50
3	CSMSC40	16.03	20.02	25.23
4	CSMSC50	11.42	11.31	21.85
5	CSMSC60	11.57	16.01	14.76

5.2 Tensile Strength

5.2.1 Flexural Strength

Flexural strength is also known as modulus of rupture and it is a way to measure the tensile strength of concrete. The flexural strength is determined by testing concrete prism of size 500 x 100 x 100 mm confirming to IS 516: 1959 [15]. After 28 days of curing, the specimen is kept under water for two days at room temperature. The specimen is tested as early as possible in wet condition. The prism specimen is supported by roller supports and simply supported condition is maintained. Three-point loading method is used to test concrete prism specimen. A distance of 400 mm is maintained between inner roller supports. The distance between the inner roller support and the outer nearer support is l/3. Load is gradually applied through the roller supports until the breaking point of the specimen. The flexural strength testing of concrete prism specimen is shown in Figures 8 and 9. The flexural strength of conventional concrete and concrete with GGBFS and M sand are given in Tables 7 and 8.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

Fig. 8 Flexural Testing of Concrete

Fig. 9 Closer view of Flexural Testing of Concrete

Table 7 Flexural Strength of M 20 Concrete with GGBFS and River Sand

Sl. No.	Specimen Designation	Flexural Strength (N/mm^2)
1	CCRS	3.67
2	CSRSC30	3.73
3	CSRSC40	4.16
4	CSRSC50	3.42
5	CSRSC60	2.16

Table 8 Flexural Strength of M 20 Concrete with GGBFS and M Sand

Sl. No.	Specimen Designation	Flexural Strength (N/mm^2)
1	CCMS	3.8
2	CSMSC30	3.83
3	CSMSC40	4.26
4	CSMSC50	3.65
5	CSMSC60	2.70

5.2.2 Split Tension

Tensile strength of a concrete is a resistance of concrete against the tensile stress and is measures as the force per cross sectional area. Split tensile strength of the concrete is determined by testing the concrete cylinder specimen under the compression testing machine in our laboratory. The cylinder specimen is placed horizontally and the load is applied gradually upto the breaking point of the cylinder specimen and the cracks develops through the diameter axis. The cylinder specimen of 150 mm diameter with 300 mm height is tested under the compression testing machine in our laboratory confirming to IS 5816: 1999 [16]. Figure 10 shows the testing of tension on concrete. Tensile strength of M 20 concrete with river sand and M Sand are given in Tables 9 and 10.

Fig. 10 Tension Testing on Concrete

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

Table 9 Tensile Strength of M 20 Concrete Cylinder with GGBFS and River Sand

Sl. No.	Specimen Designation	Split Tensile Strength (N/mm^2)
1	CCRS	2.53
2	CSRSC30	2.59
3	CSRSC40	2.67
4	CSRSC50	2.52
5	CSRSC60	2.06

Table 10 Tensile Strength of M 20 Concrete Cylinder with GGBFS and M Sand

Sl. No.	Specimen Designation	Split Tensile Strength (N/mm^2)
1	CCMS	2.65
2	CSMSC30	2.75
3	CSMSC40	3.07
4	CSMSC50	2.59
5	CSMSC60	2.22

5.3Modulus of Elasticity

Modulus of elasticity of concrete is a measure of resistance of concrete under the action of stress. Modulus of elasticity is one the main parameter to define the strength of the concrete. To determine the modulus of elasticity of concrete, cylinder specimen of 150 mm diameter with 300 mm height is tested under the compression testing machine in our laboratory confirming to IS 516: 1959 [15]. To measure the strain in concrete under the gradual increment of load, the concrete cylinder specimens are connected with a extensometer. Figures 11 and 12 show the testing of modulus of elasticity of concrete and closer view of testing respectively. Modulus of elasticity of M 20 concrete with river sand and M Sand are given in Tables 11 and 12.

Fig. 11 Modulus of Elasticity Test on Concrete

Fig. 12 Closer view of Testing

Table 11 Modulus of Elasticity of M 20 Concrete with GGBFS and River Sand

Sl. No.	Specimen Designation	Modulus of Elasticity (N/mm^2)
1	CCRS	25600
2	CSRSC30	26100
3	CSRSC40	26300
4	CSRSC50	24500
5	CSRSC60	24100

Table 12 Modulus of Elasticity of M 20 Concrete with GGBFS and M Sand

Sl. No.	Specimen Designation	Modulus of Elasticity (N/mm^2)
1	CCMS	26700
2	CSMSC30	26900
3	CSMSC40	27200
4	CSMSC50	26000
5	CSMSC60	25800

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

6. Result and Discussions

The role of GGBFS plays a vital role in the strength of cement concrete. As the percentage of GGBFS is increased the strength of the concrete is also increased upto 40 % replacement of cement. Above 40% of replacement of cement with GGBFS, the strength of concrete such as compressive strength, tensile strength and modulus of elasticity are decreased. The presence of M Sand in the concrete specimens slightly increased the compressive strength, tensile strength and modulus of elasticity than that of the concrete specimens with river sand. The comparison of concrete specimens is shown in Figures 13 and 14 and the compressive strength of concrete cube and cylinder specimen with 40 % replacement of cement by GGBFS and 100 % replacement of river sand by M Sand higher than all other concrete specimens. All the concrete cube specimen achieved strength higher than nominal strength of M 20 grade, i.e. 20 N/mm^2 and the cube specimens other than CSRSC50, CSRSC60 and CSMSC60 achieved higher compressive strength than the target strength of M 20 grade, i.e. 26.6 N/mm^2. The compressive strength of cylinder specimens show similar tend like cube specimens but the concrete with M Sand shows higher compressive than concrete with river sand. The difference in the compressive strength of cube specimens with and without m sand is almost similar but the compressive strength of cylinder specimens shows slightly higher percentages of differences in the compressive strength of concrete with and without M Sand. At the same time the cylinder specimens exhibit lesser compressive strength than cube specimens. The tensile strength of the concrete is obtained by conducting flexure test and split tension test and the comparison of results of flexural strength and split tensile strength of concrete specimens are shown in Figures 15 and 16. It indicates that the flexural strength and split tensile strength of concrete with GGBFS and River sand and M Sand are slightly higher than conventional concrete. The cement concrete with GGBFS and M Sand exhibit higher flexure and split tensile strength than Concrete with river sand. Similar to compressive strength, the flexural strength and tensile strength decreased when the percentage of GGBFS is increased beyond 40%. Similarly, the results of modulus of elasticity of concrete also shown similar trend as expressed in flexure and tensile strength and the comparison of results of modulus of elasticity of all the specimens are shown in Figure 17. The decrease in the strength of the concrete above 40% may be due to lack of total cementitious material in the concrete. As the percentage of GGBFS is increased the total quantity of cementitious material is decreased and it is clearly observed from the Table 2. It is suggested that when the percentage of replacement of cement with GGBFS is 50% and 65%, then an additional 10% and 20% of cementitious material should be added in total cementitious content [17] [18]. The use of GGBFS and M sand shows better compressive strength and can be suitable for practical construction purposes. From the results observed in this study, the optimum percentage of GGBFS for replacement of cement is 40% and the use of M Sand as an alternative to river sand is recommended. The usage of GGBFS will reduce the use of cement and thus reducing the carbon emission. Replacement of cement with GGBFS more than 50% can be utilised but care should be taken in the total quantity of cementitious material.

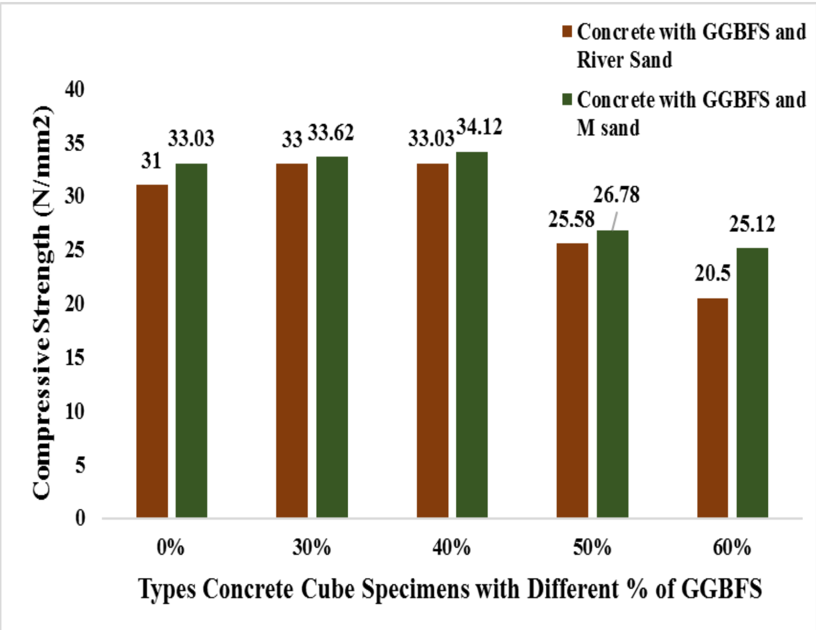


Fig. 13 Compressive Strength of Concrete Cubes with Different % of GGBFS

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

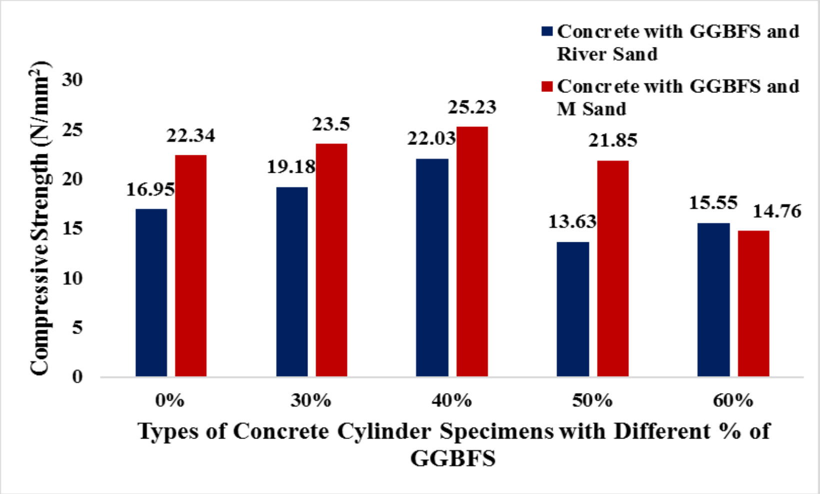


Fig. 14 Compressive Strength of Concrete Cylinders with Different % of GGBFS

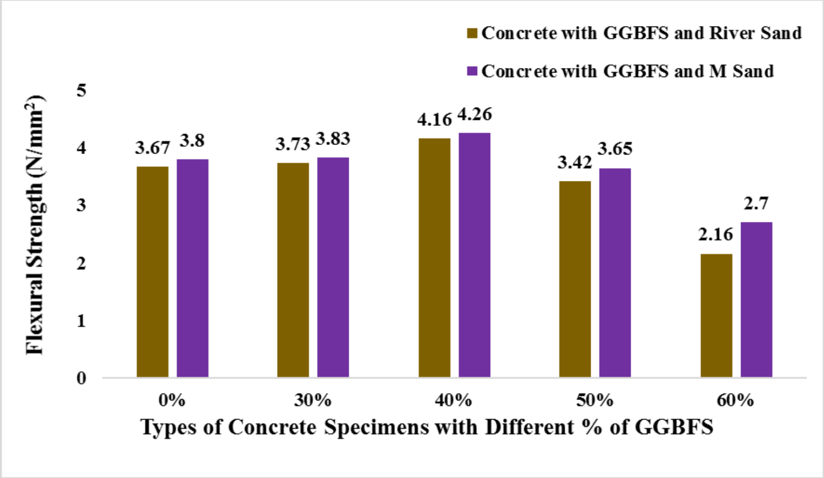


Fig. 15 Flexural Strength of Concrete with Different % of GGBFS

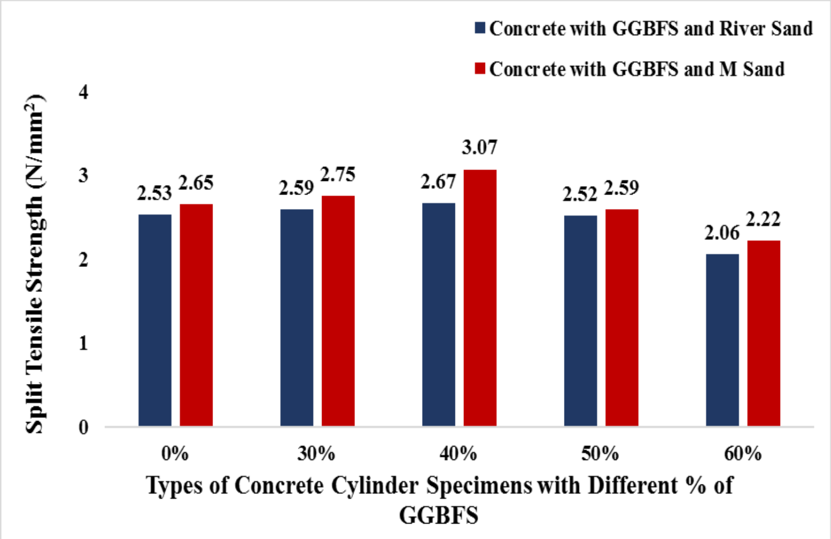


Fig. 16 Split Tensile Strength of Concrete with Different % of GGBFS

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

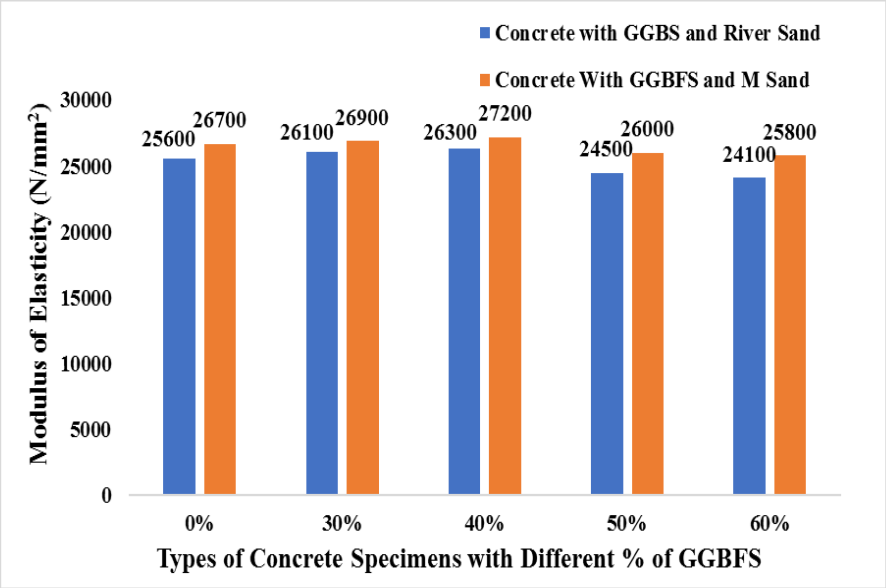


Fig. 17 Modulus of Elasticity of Concrete with Different % of GGBFS

7. Conclusions

The experimental investigations on compressive strength, tensile strength and modulus of elasticity of concrete with GGBFS and M Sand are determined and compared with conventional concrete as well as concrete with GGBFS and river sand. The following results are conveyed.

1. The concrete with 40 % of GGBFS and M Sand yielded higher strength than all other concrete specimens of M 20 grade.
2. The compressive strength of concrete cube and cylinder with 40% of GGBFS and M Sand are 34.12 N/mm^2 and 25.23 N/mm^2 respectively.
3. The flexural strength and split tensile strength of concrete with 40% of GGBFS and M Sand are 4.26 N/mm^2 and 3.07 N/mm^2 respectively.
4. The modulus of elasticity of concrete with 40% of GGBFS and M Sand are 27200 N/mm^2.
5. The use of M Sand can be used as an alternative material for river sand since the contribution of M Sand in the strength of the concrete is similar to river sand.
6. The partial replacement of cement by GGBFS can be ideal upto 40% and above 40% of replacement of cement by GGBFS can be suitable for construction of structural elements.
7. The utilisation of GGBFS and M Sand can lead to reduce the carbon emission and degradation of river sand respectively.

References

1. Talib khalid, W.T., Obaidullah Qazi, Abdirizak, A.M. and Raizad S.M. Rashid, (2019), "Comparison of Different Waste materials used as Cement Replacement in Concrete", *IOP Conference Series Earth and Environmental Science – Sustainable Civil and Construction Engineering Conference,* August. doi:10.1088/1755-1315/1/012010.
2. Manoj Kumar Dash, Sanjaya Kumar Patro and Ashoke Kumar Rath, (2016), "Sustainable use of industrial – waste as partial replacement of fine aggregate for preparation of Concrete – A Review", *International Journal of Sustainable Built Environment,* Vol. 5, April. DOI: http://dx.doi.org/10.1016/j.ijsbe.2016.04.006.
3. Pavia, S. and Condren, E, (2018), **"**Study of the Durability of OPC Versus GGBS Concrete on Exposure to Silage Effulent", *Journal of Materials in Civil Engineering,* Vol. 20, No. 4, April, pp 313 – 320. DOI: 10. 1061/(ASCE)0899-1561(2008)20:4(313)
4. Kumar, S., Kumar, R., Bandopadhyay, A., Alex, T.C., Kumar, B.R., Das, S.K., and Mehrotra, S.P., (2008), " Mechanical Activation of Granulated Blast Furnace Slag and its Effect on the Properties and Structure of Portland Slag Cement", *Cement and Concrete Composites,* Vol. 30, No. 8, pp. 679 – 685. DOI: 10. 1016/j. cemcoccomp.2008.05.005
5. Bellmann, F and Stark, J (2009), "Activation of Blast Furnace Slag by a New Method", *Cement and Concrete Research*, Vol.39, No. 8, pp. 644 – 650. DOI: 10. 101/j.cemconres.2009. 05. 012
6. Grist, E.R., Paine, K.A., Health, A., Norman, J. and Pinder, H. (2015), "The Environmental Credentials of Hydraulic Lime-Pozzolan Concretes", *The Journal of Cleaner Production*, Vol. 93, pp. 26 – 37.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 25, Issue 6, 2021, Pages. 7464 - 7474
Received 25 April 2021; Accepted 08 May 2021.

7. Oner, A and Akyuz, S (2015), “An Experimental Study on Optimum Usage of GGBS for the Compressive Strength of Concrete, *Cement and Concrete Composites*, Vol. 29, No. 6, pp. 505 – 514.
8. Nagaratnam, B.H., Rahman, M.E., Mirasa, A.K., Mannan, M.A., Lame, S.O., (2015), “Workability and Heat of Hydration of Self-Compacting Concrete Incorporating Agro-Industrial Waste”, *The Journal of Clear Production*, Vol. 112, No. 1, pp. 882 – 894.
9. Deshmukh Dnyan, “How GGBS used for Replacing Cement in Concrete is made inside Steel manufacturing Factory”, *CIVIL4M*, 28th August 2018. https://civil4m.com/threads/how-ggbs-used-for-replacing-cement-in-concrete-is-made-inside-steel-manufacturing-factory.5686/
10. Krunal Rajput, “Difference Between M Sand Vs River Sand| What is M sand & River Sand”, *CivilJungle*, 2021, civiljungle.com, https://civiljungle.com/difference-between-m-sand-vs-river-sand/
11. Vani Paspula, “ M Sand [Manufactured Sand] – A Substitute to River Sand”, *BuildersMART*, 6th July 2019, https://www.buildersmart.in/blogs/M-sand/
12. IS 2386: 1963, Methods of Test for Aggreagtes for Concrete, Part IV Mechanical Properties. Bureau of Indian standards, New Delhi, India.
13. IS 12269: 2013, Ordinary Portland Cement, 53 Grade - Specification. Bureau of Indian standards, New Delhi, India.
14. IS 10262: 2009, Concrete Mix Proportioning – Guidelines, Bureau of Indian standards, New Delhi, India.
15. IS 516: 1959, Methods of Test for Strength of Concrete, Bureau of Indian standards, New Delhi, India.
16. IS 5816: 1999, Splitting Tensile Strength of Concrete – Methods of Test, Bureau of Indian standards, New Delhi, India.
17. Swamy, R.N. and Bouikni, A (1990), “Some Engineering Properties of Slag Concrete as Influenced by Mix Proportioning and Curing, *ACI Mater.J*, Vol. 87, pp. 210 – 220.
18. Babu Ganesh, K and Kumar Sree Rama, V (2000), “Efficiemcy of GGBS in Concrete”, *Cement and Concrete Research*, Vol. 30, pp. 1033 – 1036.