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The Effect of Manufactured Sand on Self Compacting Concrete with Partially Replace By Industrial Waste

Deepak Shrivastav
Research Scholar M.Tech.
Civil Engineering
Vikrant Institute of Technology and Management
Gwalior, (M.P.) India
Email: er.ds.7860@gmail.com

Kuldeep Pathak
Assistant Professor
Department of Civil Engineering
Vikrant Institute of Technology and Management
Gwalior, (M.P.) India
Email: hod_civil@vikrantuniversity.ac.in

Anil Rajoot
Assistant Professor
Department of Civil Engineering
Vikrant Institute of Technology and Management
Gwalior, (M.P.) India
Email: ce_anilrajput@vikrantuniversity.ac.in

ABSTRACT

Concrete is a versatile construction material of this century. Concrete has several problems as a result of bad construction procedures and poor constituents in the concrete mix, but it is nevertheless a commonly used material. Poor compaction during construction is the primary cause of concrete deterioration. Honeycomb formations are the result of inadequately compacted concrete. This difficulty is solved with Self-Compacting Concrete (SCC) constructions since no external compaction or vibration is required. The labour required for compaction is also minimised by the development of SCC. SCC is one of the special concrete. It can compact by itself under the action of gravity or by its self-weight without vibration, bleeding, and segregation.

A large amount of industrial waste has been generated as a result of industrialization. Wastes are produced as a result of a variety of industrial activities. They have a wide range of properties and chemical compositions, and they have an impact on human health and the environment. As a result, waste management and disposal must be done safely in order to preserve a sustainable environment. The cement industry consumes much amount of the natural resources for the production of cement, in addition pollutes the atmosphere with the emission of CO2. Hence the waste materials from the industries, having pozzolonic nature can be used along with cement. Because of the rising shortage of river sand and natural aggregates across the country, the construction sector in India is under immense pressure to find alternatives for basic construction materials in order to fulfil the growing demand for infrastructure. Sand mining in rivers has been prohibited in several parts of our country due to its negative environmental impact.

Keywords:—*Industrial Waste, pozzolonic nature, Self-Compacting Concrete, Honeycomb formations, bleeding*

I. INTRODUCTION

The foundation of human development is socioeconomic development. Industrial growth benefits society, but it also causes garbage to contaminate the environment.

Waste disposal pollutes the environment, poisoning the water as a result. The majority of industrial processes generate waste products, as well as both helpful and harmful contaminants. With 4% of particle emissions, the building industry contributes significantly to pollution of the air, water, and noise. Carbon dioxide (CO2) is released when calcium carbonate is heated to extremely high temperatures for the production of lime, especially in the cement industry. This emission directly contributes to greenhouse gases. On the other hand, the sector also uses fossil fuels and other non-renewable energy sources to produce commodities. Once concrete production uses the least amount of energy possible, it will be a sustainable material. In addition, recyclable and ecologically friendly materials must be used to create sustainable materials. Cement use can be reduced by utilising industrial byproducts that directly lower carbon emissions, such as copper slag, rice husk ash, fly ash, and ground granulated blast furnace slag (GGBS). The purpose of the concrete industry's ongoing research into additional cementitious materials is to lessen the problem of disposing of solid waste. When industrial byproducts are used as a partial replacement for portland cement, significant energy and cost reductions are possible. The need for building resources like river sand and natural aggregates has increased significantly throughout India, placing tremendous pressure on the construction sector to find substitutes. Due to its detrimental effects on the ecology, sand mining in rivers has been outlawed in some areas of our nation. Conservation of natural resources is crucial to any modern development. Due to the dearth of natural resources, it is also important to handle alternative building materials well in order to create a comfortable environment.

1.1. Self Compacting Concrete

Okamura & Ouchi (1995) were the first to offer self-compacting concrete (SCC) to the concrete industry in the 1980s. To solve the lack of unskilled employees in the Japanese construction industry, SCC was established. When pouring regular concrete into crowded reinforcements, a number of difficulties in the compaction process were encountered. Self-Compacting Concrete was developed as a solution to this issue. One type of unique concrete is self-compacting concrete. Without vibration, bleeding, or segregation, it can compact on its own when weighted down or under the influence of gravity. Compared to regular concrete, SCC has a significantly higher fluidity without segregation. Its weight can completely fill any formwork corner. Less effort required to execute specific casting tasks and decreased time consumption are the main drivers of the increase in interest in SCC. SCC efficiently assumes the form of any intricate formwork and covers the reinforcement. Limiting the water-cement ratio, adding a potent plasticizer, raising the sand-aggregate ratio, and adding certain viscosity modifying agents are the steps required to produce SCC. The worker's health and safety significantly improve as a result of the removal of vibrator use and a large reduction in environmental noise loading on the site. Mineral admixtures are permitted in the SCC mix due to the presence of fine-grained inorganic components. Let's conduct more study using waste materials as mineral admixtures in SCC, some of which have already found use in actual applications.

1.2. Manufactured Sand

Rock deposits are crushed to make manufactured sand (M-sand). This alternative material can be generated in large quantities and has qualities that are comparable to fine aggregate in fresh and hardened concrete. To achieve quick infrastructure growth, a lot of natural sand is required. Due to this condition, developing nations like India struggle to find high-quality natural sand. Natural sand reserves are being depleted in India, greatly deteriorating the ecosystem. The scarcity of natural resources and environmental protection may be aided, according to many studies, by the use of widely available and cheaply priced substitute materials.

River sand is in scarce supply in India, so to meet demand, numerous alternative materials are used instead, including manufactured sand, copper slag, fly ash, slag, limestone, and siliceous stone powder. They serve as a partial substitute for fine aggregate in concrete mixtures (Shanmugapriya et al. 2014; Raju & Dharmar 2020; Nanthagopalan & Santhanam 2010). According to numerous investigations, M-sand among these materials proven to be an effective replacement for genuine river sand. Due to its higher paste volume, M-sand has been shown through numerous studies on alternative materials to be an acceptable substitute for river sand (Nanthagopalan & Santhanam, 2010). M-sand with a high concentration of micro fines can be used to produce concrete of excellent grade. Up to a certain point, the proportions of microfines generally tend to increase the compressive strength, flexural strength, bond strength, water permeability, impact resistance, sulphate resistance, and abrasion resistance. Insufficient paste to coat the aggregate causes the strength to decline once the limit is reached (Li et al. 2011; Amnon Katz & Hadassa Baum 2006; Li et al. 2009; and Celik & Marar 1996). Due to its higher fine content, M-sand also failed to meet the requirements of the current sand criteria. According to a study (Hameed & Sekar 2009 and Jadhav & Kulkarni 2012), the compressive, split tensile, and flexural strengths increased when 40 to 60 percent of the natural sand was replaced by M-sand. The shape and structure of crushed sand particles enhance the strength and durability of concrete due to improved interlocking between particles, even when the excess micro fines lower the strength of concrete.

1.3. Ground Granulated Blast Furnace Slag

Adding additional cementitious components is suggested to enhance the qualities of concrete and make it more affordable and environmentally friendly. SCC mixes often contain a lot more fine fillers. (2012) Boukendakdji and others. blast furnace crushed into granules Slag is a material waste that comes from blast furnaces used to make iron. It is an eco-friendly material that ensures green building techniques and reduces environmental pollution. issues. GGBS is frequently used as a substitute for 35–65 percent Portland cement in concrete. By substituting 50% Portland cement for every tonne of cement, around 500,000 t of CO2 can be saved. Due to its advantages in terms of enhancing workability and making the mix more mobile and cohesive, GGBS is utilised successfully as a cement substitute in the construction industry all over the world. By forming a denser matrix with GGBS as a partial replacement for regular Portland cement, concrete increases strength and durability and increases the service life of concrete structures. Self-Compacting Concrete has also been successfully used with GGBS. The addition of GGBS to self-compacting concrete has various advantages, including improving its capacity to compact, consistency, and retention for a longer period of time. Dadsetan and others, 2017. The greater strengths of self-compacting concretes including GGBS at different replacement levels ranged from 30 to 100 MPa. (2013) Dinakar et al. The service life of concrete structures is extended and concrete durability is improved by GGBS. To achieve the goal of sustainable development in the production of concrete, this study examines the viability of employing ground granulated blast furnace slag as a partial replacement for cement in concrete.

1.4. Fly Ash

A waste by-product of coal-fired power stations is called fly ash. Class C fly ash and Class F fly ash are the two types of fly ash often employed in the building sector. The proportion of calcium, silica, alumina, and iron in the ash makes a significant distinction between these two classes. To enhance the flow characteristics, fly ash is employed. Fly ash lowers the cement's hydration heat, which considerably reduces concrete's propensity for cracking. Fly ash can be added to self-compacting concrete to increase its fresh and hardened qualities. 2019; Karmegam et al. When fly ash is replaced by up to 35%, the rheological characteristics of SCC significantly improve, with good flow ability and Due to the spherical form of the particles, fly ash is the preferred additive for SCC. Fly ash is also added to the powder content to increase the workability of SCC to its fullest potential. Fly ash performs well in concrete because it has the right physical, chemical, and mineralogical characteristics

1.5. Objectives of the Thesis

This study uses an environmentally friendly additional cementations material to examine the mechanical and durability characteristics of SCC.

- In order to create the SCC, GGBS, fly ash, and M-sand are used. The findings of tests on the effects of GGBS and M-sand on the SCC's fresh and hardened properties are presented in this dissertation. The following were the subjects of a thorough investigation using GGBS and M-sand.
- To research the rheological characteristics of SCC replacement with GGBS admixture.
- To assess the SCC's splitting tensile strength and compressive strength.
- To determine the ideal ratio of M-sand and GGBS in the SCC mixtures.
- This research offers a solution to the environmental issues caused by the disposal of GGBS and cement manufacture.
- This study intends to examine the mechanical and durability characteristics of SCC made from manufactured sand and ground granulated blast furnace slag.

II. Literature Review

Okamura & Ouchi (1995) In terms of flow and possibility, the SCC test approaches were investigated. It was also recommended to use the sensible mix design for SCC. It was researched how mortar behaved as a solid and a fluid under the impact of fine and coarse aggregate. Investigated were a number of on-site acceptability tests. In this investigation, a novel additive type and a segregation inhibitor were used. Additionally, some recommendations for self-compacting concrete applications were provided.

Manu Santhanam *et al*. (2004), SCC, or self -compacting concrete, has been extensively studied. More SCC usage-related topics, such as the design of the materials and mixtures, test procedures, construction-related issues, and properties, were covered in this paper.

Schutter *et al.* (2008) outlined the key elements of SCC, experimental techniques for determining fresh characteristics, mix design techniques, construction procedures, microstructures, and hydration. Engineering properties of SCC like creep, shrinkage, elastic modulus, compressive strength, and binding with reinforcements were also discussed, along with durability characteristics, deterioration mechanisms, and applications.

Girish *et al.* (2010) used fly ash as a filler to conduct an experimental study on the impact of paste and powder on self-compacting concrete mixtures. For each series of trials, water was kept constant among the various water contents w/c ratios investigated. Slump flow, V funnel, and J-ring tests were used to evaluate SCC performance. The results demonstrate that as paste volume increases, SCC's flow characteristics also increase.

Gowda *et al.* (2011) In order to create Self-Compacting Mortar (SCM) mixes, an attempt was made to partially substitute cement and sand with quarry dust (QD) and rice husk ash (RHA), respectively. Instead of cement, RHA substitution ranges from 5 to 20%. In place of natural sand, 40% QD was the ideal amount. To determine whether adding RHA and QD to SCM mixtures would be practical, the results of the compressive strengths tests were compared.

Uysal *et al*. (2012) tried to make SCCs by adding different mineral admixtures, including Fly Ash (FA), Marble Powder (MP), Limestone Powder (LP), Basalt Powder (BP), and Granulated Blast Furnace Slag (GBFS). To assess the viability of SCC, the slump flow, T50 time, L-box, and V-funnel tests were used. Compressive strength and ultrasonic pulse velocity were used to determine the toughened characteristics. The workability of the SCC mixes was significantly improved by the inclusion of FA and GBSF. After 28 days, GBFS replaced 20% of the cement, yielding strength greater than 78 MPa.

Studies on durability, including water and chloride ion permeability, were also conducted. According to test results, SCC might be produced using any filler substance. Additionally, a blend of 60% GBFS and 40% PC offered the highest defence against chloride ion permeability. On the other hand, the results of the impermeability depth tests ranged from 4.42 to 12.58 mm. Ramanathan *et al.* (2013) investigated the workability tests (slump, L-box, U-box, and T50), as well as the strength characteristics of self-compacting concrete containing various mineral admixtures, such as compressive, flexural, and split tensile strength. The performance of mineral admixtures replaced for cement by 30%, 40%, and 50% is compared. Silica fume, fly ash, and powdered granulated blast furnace slag were employed as mineral admixtures. Particle size distribution, particle shape, and surface characteristics all play a significant role in how mineral admixtures affect admixture requirements. Thus, a cost-effective self-compacting concrete can be made by combining silica fume, fly ash, and powdered granulated blast furnace slag in the proper quantities.

Dadsetan *et al*. (2017) Three self-compacting mortars, meta kaolin, ground granulated blast-furnace slag, and fly ash were used in place of cement in the SCC combinations. They investigated SCC's mechanical and microstructural characteristics. By using SCMs, compressive strengths were improved. In contrast to other materials, metakaolin was recommended as an efficient SCM replacement material. With the exception of 10% GGBS, MK and GGBS were able to improve cement replacement levels' modulus of elasticity.

Karmegam *et al.* (2019) The potential for recycling Granite Sawing Waste (GSW) in Fibre Reinforced Self Compacting Concrete (FRSCC) utilising Polypropylene (PP) fibres was experimentally studied. Investigated was the efficacy of GSW at 5, 10, 15, and 20% of weight in place of cement. At volume fractions of 0.05, 0.1, and 0.15%, PP fibres were used. As an extra mineral additive, fly ash was employed. The GSW and PP fibres improve the FRSCC's compressive strength and splitting tensile strength, it is determined.

Celik & Marar (1996) have investigated the effects of different crusher dust content ratios on the characteristics of both fresh and hardened concrete.

Sahu *et al.* (2003) utilised fine aggregate made of crushed stone dust. In this investigation, natural sand was used to partially replace stone dust. M20 and M30 grades of concrete were made and tested. The experiments demonstrate that discarded crushed stone can be used successfully as fine aggregate.

Prakash Rao & Gindar Kumar (2004) used river sand and stone crusher dust to research the characteristics of concrete. The studies revealed that stone crusher dust had a positive impact on concrete's compressive strengths and RC beams' flexural behaviour. Additionally, the failure loads and fracture patterns of concrete containing river sand were compared.

Katz & Baum (2006) The impact of fines in aggregates on the creation of concrete has been experimentally explored. The impact of adding particles to concrete with normal strength was investigated. The concrete compositions were made to always be workable. As long as the admixture is added in the proper amounts to maintain workability, fines can increase concrete strength by up to 30%, lower carbonation rate, and slightly increase volume changes of both fresh and cured concrete. Due to the existence of significant numbers of ultra-fine particles, the properties of the concrete were significantly affected when sufficient admixture dosages were added to maintain workability.

Gonçalves *et al.* (2007) studied how various manufactured fine aggregates produced by impact or cone crushing and natural sand affected the performance of cement mortars. Also performed was an examination of particle shape. The mortars were distinguished by the largest porosities, absorptivities, and lowest unconfined compressive strength, which were most likely caused by their poor particle morphologies. The categorised product from cone crushing also had a low packing density.

Ilangovan *et al*. (2008) investigated if it would be possible to use quarry rock dust as a complete replacement for natural sand in concrete. Studies on mechanical performance and durability were done. The findings indicated that concrete constructed of quarry rock dust had almost 10% greater compressive, flexural, and durability studies than regular concrete.

George *et al*. (2008) utilised synthetic sand and quarry dust in place of river sand while creating concrete. The M30 concrete mix was created. There were four mix ratios created. Both types of replacements increased the concrete's tensile strength.

Kou *et al.* (2009) tested SCC's durability and freshness qualities. Recycled concrete aggregates were used to replace the coarse and fine aggregates. The findings demonstrate that there were minimal changes in the qualities of SCCs formed from crushed fine recycled aggregates and river sand.

Malagavelli *et al.* (2010) We tested the qualities of M30 grade concrete and partially substituted river sand with ROBO sand (crushing dust) and cement with GGBS. The findings showed that the concrete's strength was significantly higher than that of regular mix concrete.

III. MATERIAL AND RESEARCH METHODOLOGY

3.1. Materials

Following is a quick discussion of the materials employed in the current experiment to produce SCC and their properties

3.1.1 Cement

The well-known building ingredient cement has long played a crucial role in construction projects. varying cement brands have varying strength development characteristics and rheological behaviour as a result of variations in compound composition and fineness. As per IS code IS: 12269-2013, ordinary Portland cement of grade 53 was used in this study. The cement was ultra-tech. In Table 1, the physical characteristics are displayed. By using a 90 micron screen, the cement was found to be 1% fine **Cement properties**

Table 1: Physical characteristics fine Cement properties with Values

Properties	Value
Fineness	1 % /330 m^2/kg
Specific gravity	3.14
Initial setting time	35 min
Final setting time	10 hrs
Consistency	38 %

3.1.2 Course Aggregate

For constructions with crowded reinforcement, 10mm CA is the ideal size. The recommended aggregate should also be well-graded and spherical or cubical in shape. In order to lessen the challenges of making, mixing, and putting concrete as well as to prevent aggregate segregation in new concrete, the maximum size of CA chosen in this study was 15mm. Used as coarse aggregate was crushed granite stone that passed 12.5 mm and retained 10 mm. The physical characteristics of the coarse aggregate material are displayed in Table

Table 2: Coarse aggregate properties

Properties	Value
Bulk Density	1463 kg/m^3
Specific gravity	2.73
Fineness modulus	6.89

3.1.3 Fine Aggregate

The fine aggregates used were Ordinary river sand and M-sand, obtained from nearby quarries as shown in Figure 5.1. Both materials were tested as per Indian Standard specification IS 383-1970.

Table 3: Manufactured sand Properties of river sand

Properties	Values
Bulk Density	1600 kg/m^3
Specific gravity	2.56
Fineness modulus	2.72

Table 4: Results of sieve analysis: River sand

Sieve size in mm	Weight re-tained in grams	Cumu-lative Weight retained in grams	Cumula-tive Per-centage retained in grams	Per-cent age pass-ing	Grading for Zone II Con-forming to IS: 383,1970
4.75	21	21	2.1	97.9	90-100
2.36	35	56	5.6	95.7	75-100
1.18	191	247	24.7	78.3	55-90
0.6	309	556	55.6	44.4	35-39
0.3	282	838	83.8	16.2	8-30
0.15	162	1000	100	0	0-20

The most popular choice for fine aggregate is natural sand, however sand mining has had terrible effects on the ecology. Use of M-sand as a fine aggregate in concrete manufacturing can lessen these effects. M-sand is created by crushing rock and gravel to the desired grain size. The M-sand utilised has a specific gravity of 2.53. Figures 3.2 and 3.3, which depict the particle size distribution of the natural sand and M-sand samples used in this investigation, respectively

Table 5: Properties of M-sand

Properties	Value
Bulk Density	1665 kg/m^3
Specific gravity	2.53
fineness modulus	2.62

Table 6. Results of sieve analysis: M-sand

Sieve size in mm	Weight retained in grams	Cumula-tive Weight retained in Grams	Cumula-tive Percent-age re-tained in grams	Percent-age passing	Grading for Zone II Con-forming to IS: 383,1970
4.75	0	0	0	100	90-100
2.36	43	43	4.3	95.7	75-100
1.18	174	217	21.7	78.3	55-90
0.6	314	531	53.1	46.9	35-39
0.3	304	835	83.5	16.5	8-30
0.15	165	1000	100	0	0-20

3.1.4 Fly Ash

One of the most often used industrial waste materials in the manufacturing of concrete worldwide is fly ash. It possesses outstanding pozzolanic characteristics. An unwanted byproduct of coal-fired power plants is called fly ash. In these power plants, coal is ground to the consistency of fine powder before burning. Fly ash is a mineral byproduct of coal combustion that is used and is collected from the exhaust gases of power plants. The IS3812 (part1): 2003 standard was satisfied by the Class F fly ash that was obtained from the "Mettur Thermal Power Plant" next to Mettur Dam in Salem, Tamilnadu, India. In Figure the Fly ash sample is displayed.

Table 7: Properties of Fly ash

Properties	Value
Fineness	325 m^2/kg
Specific gravity	2.16

3.1.5 Ground Granulated Blast Furnace Slag (GGBS)

In this research, GGBS, a waste product from blast furnaces acquired from the iron industry, was employed as cement's replacement material. In the building industry all around the world, GGBS is used as an effective substitute for cement. Self-compacting concrete has been made with success using GGBS. A non-metallic substance called GGBS contains silicates and aluminates of calcium as well as other bases. A non-metallic material made of calcium and other basic silicates and aluminates is known as ground granulated blast furnace slag. In terms of improving its compatibility consistency and retaining it for a longer period of time, the addition of GGBS to self-compacting concrete offers several advantages. According to studies done with a scanning electron microscope, the GGBS is made up of dense, abrasive micro-sized angular particles. The range of particle sizes is roughly between 1 and 60 microns. By volume, 40–50% of the particles have a size close to one micron. Utilised GGBS was purchased from Astra Chemicals in Chennai, India. Slag quality meets the specifications of IS 12089-1987.In Figure 1, the GGBS sample is displayed.

Figure 1: Ground granulated blast-furnace slag

Table 8: Properties of ground granulated blast-furnace slag

Properties	Values
Fineness	390 m^2/kg
Specific gravity	2.85

3.1.6 Super Plasticizer

The flow properties were obtained using the Superplasticizer (SP). The essential elements of SCC are superplasticizers or high-range water-reducing admixtures. It is the responsibility of SP to offer a high level of flow ability and deformability. The chosen sulphonated naphthalene polymers serve as its foundation. The brand name of the item is Conplast SP430. Table provides a list of the Superplasticizer's physical characteristics.

Table 9: Superplasticizer properties

Properties	Values
Specific Gravity	1.1
Appearance	Brown Liquid
Chloride Content	Nil

3.1.7 Water

The most necessary and affordable component of concrete is water. The hydration of cement uses a portion of the water used for mixing. As a lubricant between the fine and coarse aggregates, the residual water is helpful. Concrete may typically be poured with water that is safe for drinking. Concrete mixing and curing require clean water devoid of contaminants like oil, acids, alkalis, vegetable matter, etc. If not, it can damage the concrete and cause the reinforcement to corrode. In this investigation, the common potable water that was accessible in the lab was used. Table 10 provides a list of the characteristics of water.

Table 10: Water properties

Test conducted	Value	Permissible value as per IS 456 – 2000
Chloride content	114.0 mg/l	500 mg/l
pH value	7	Not less than 6.0
Total Dissolved Solids	460 mg/ l	500 mg/l (as per IS 10500-2012)
Total hardness	80 mg/l	200 mg/l

IV. Research Methodology

Initial testing on M-sand and Natural sand were conducted. The trial-and-error method was used to suggest an appropriate concrete mix design based on these results. To get the required flow properties, the mix design was based on powder content and super plasticizer. To evaluate the SCC mix's fresh qualities, slump flow, V-funnel, L-box, and U-box tests were used to measure the mix's passing ability, flow ability, and viscosity. The curing process took place for seven and 28 days after the cubes had been cast. Experimental research was done following cure.

Figure 2 contains the flow chart that shows how the research was conducted.
There are four basic components to the research methodology. According to the method recommended by the EFNARC (European federation of national trade associations) Guidelines, several tests including slump flow, T 50 slump flow, V-funnel, Test, L box, and U-box were

conducted to analyse the fresh properties with GGBS as a partial replacement for cement (0, 10, 20, 30, 40, and 50%) and M-sand replacement (0, 20, 40, 60, and 80%). The cast concrete specimens were used for the mechanical studies. Flexural testing of self-compacting reinforced concrete beams is covered in the next section. One standard beam and three beams built from varied proportions of GGBS and M-Sand were created, each measuring 100x150mm and measuring 1.7m in length. The durability analysis of the concrete specimens is covered in the next section. As an extra mineral admixture to the components, fly ash (FA) was used. To achieve the necessary flow characteristics, super plasticizer was added

Table 11: Mix designations and composition

Mix designations	Ce-ment (kg/ m3)	GGBS (kg/ m3)	Flyash (kg/ m3)	Coarse Aggre-gate (kg/ m3)	Natu-ral Sand (kg/ m3)	M-sand (kg/ m3)
G0MS0 (Control concrete)	476.1	0.0	79.3	716.9	918.3	0.0
G10MS0	422.2	53.8	79.3	716.9	918.3	0.0
G20MS0	368.4	107.7	79.3	716.9	918.3	0.0
G30MS0	314.6	161.5	79.3	716.9	918.3	0.0
G40MS0	260.7	215.4	79.3	716.9	918.3	0.0
G50MS0	206.9	269.2	79.3	716.9	918.3	0.0
G0MS20	476.1	0.0	79.3	716.9	733.2	181.7
G10MS20	422.2	53.8	79.3	716.9	733.2	181.7
G20MS20	368.4	107.7	79.3	716.9	733.2	181.7
G30MS20	314.6	161.5	79.34	716.9	733.2	181.7
G40MS20	260.7	215.4	79.34	716.9	733.2	181.7
G50MS20	206.9	269.2	79.34	716.9	733.2	181.7

V. Result And Discussion

1. Fresh Concrete Properties

Table 12: Results of workability tests of SCC mix

Sl. No	Mix Desig-nation	Slump Flow Spread Diame-ter (mm)	T500 Slump Flow (sec)	V – Fun-nel Test (sec)	L-Box Ra-tio	U-Box (mm)
	Typical Range	**650-800**	**2-8**	**6-12**	**0.8-1**	**0-30**
1	G0MS0	680	3.5	12	0.86	26
2	G10MS0	690	3.9	11.1	0.88	20.5
3	G20MS0	760	4	10.5	0.89	19.1
4	G30MS0	765	4.1	10.8	0.87	15.6
5	G40MS0	770	4.2	11	0.86	13.3
6	G50MS0	780	4.3	11.3	0.85	12.5
7	G0MS20	720	3.9	10.5	0.88	24.6
8	G10MS20	720	3.5	9.4	0.89	19.5
9	G20MS20	775	3.4	8.2	0.9	18.9
10	G30MS20	780	3.6	8.6	0.89	16.2
11	G40MS20	790	3.9	9	0.88	13.2
12	G50MS20	790	3.9	9.5	0.86	11.5
13	G0MS40	780	4	10.6	0.89	22.1
14	G10MS40	790	3.8	9.7	0.9	18.4
15	G20MS40	792	3.5	8.9	0.91	16.8
16	G30MS40	795	3.6	9	0.92	14.2
17	G40MS40	795	3.7	9.2	0.93	12.8
18	G50MS40	798	3.8	9.5	0.89	11.1
19	G0MS60	680	4.5	10.7	0.88	22.8
20	G10MS60	720	4.7	9.9	0.89	17.7
21	G20MS60	790	4.8	9.1	0.9	17.1
22	G30MS60	800	5	9.2	0.91	14.8
23	G40MS60	810	5.1	9.4	0.91	14.1
24	G50MS60	815	5.5	9.6	0.92	13.1
25	G0MS80	700	5.5	10.8	0.87	25.2
26	G10 MS80	710	5.7	9.9	0.89	19.2
27	G20MS80	715	5.3	9.1	0.9	17.8
28	G30MS80	730	5.5	9.4	0.88	16.4
29	G40MS80	735	5.4	9.6	0.87	15.9
30	G50MS80	750	5.6	9.8	0.86	13.4

Table 13: European guidelines for workability of SCC (2005)

S. No	Test conducted	unit	Typical range values
1	Slump flow	mm	650-800
2	T50 slump flow	Sec	2-8
3	V-funnel	Sec	6-12
4	L-box	(H2/H1)	0.8-1.0
5	U-box	(H2-H1)	0-30

4. 2. Slump Flow Results

When compared to the control specimen, the slump flow in mm was determined for all thirty mix proportions with GGBS contents of 0%, 10%, 20%, 30%, 40%, and 50% as well as with GGBS contents of 0%, 20%, 40%, 60%, and 80%. Miguel et al. (2014) claim that compared to other rheological tests, the slump flow is the most important factor in determining a material's ability to self-compact. The preliminary tests' workability is impacted by GGBS's composition of dense, abrasive micro-sized angular particles. Consequently, to enhance the workability and flow characteristics Additionally included in the mix was 20% fly ash. The cohesiveness and flow characteristics are improved by the fly ash particles' spherical shape. As a result, the impact of GGBS was reduced. All mixtures' flow parameters (2005) met the requirements of the European Guidelines. For concretes made with GGBS but without M-sand, the slump flow value ranged from 690 to 780 mm. Figure 8.2 displays the slump flow values for SCC with various GGBS and M-sand contents.These mixes had good flow ability and a high slump flow value. The greatest slump flow was 815mm for a mix of 50% GGBS and 60% M-sand, and the minimum slump flow was 690mm for a mix of 10% GGBS while 0.0% M-sand. Compared to control, most of the mix proportions demonstrate an increase in slump flow. An increase in powder content could be to blame for this. The capacity to flow is increased when GGBS and M-Sand are used together. This shows that there are no evidence of segregation and that all SCC blends have high deformability. With an increase in GGBS and M-sand content, workability improved. The paste volume is increased by the addition of mineral admixtures such GGBS and fly ash. The friction between the aggregate and paste particles is decreased by the increase in paste volume, which improves the mix's fluidity as the GGBS concentration rises. The SCC's fluidity behaviors, such as flow ability, passing ability, and filling ability, have enhanced with the addition of GGBS from 25% to 100%.

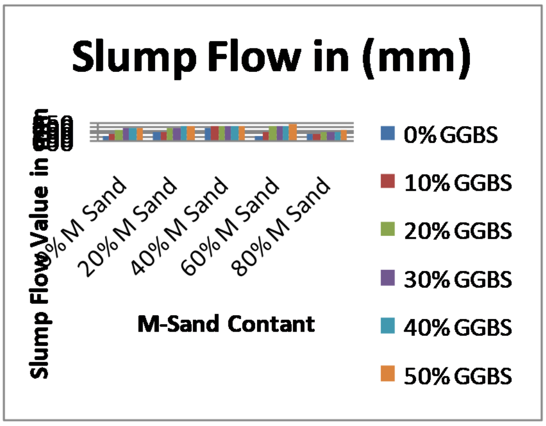

Figure 2: Slump flow values

Flow Rate or T500 Slump Flow Time

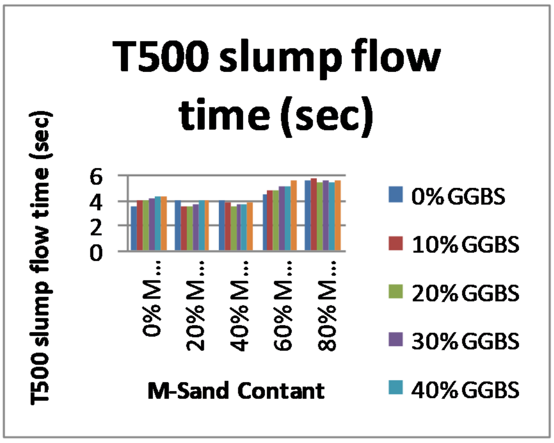

Figure 3: T500 slump flow time

V-Funnel Time

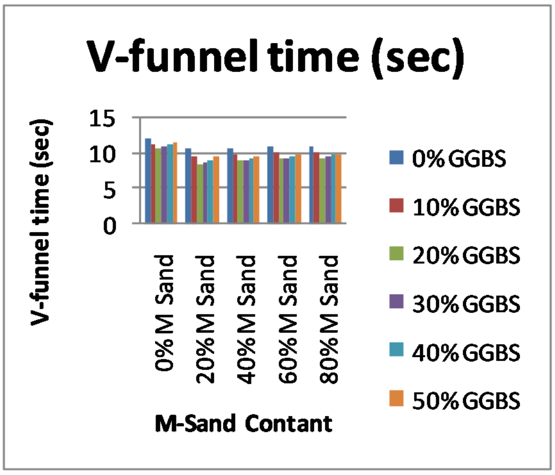

Figure 4: V-funnel time results

L-Box Ratio

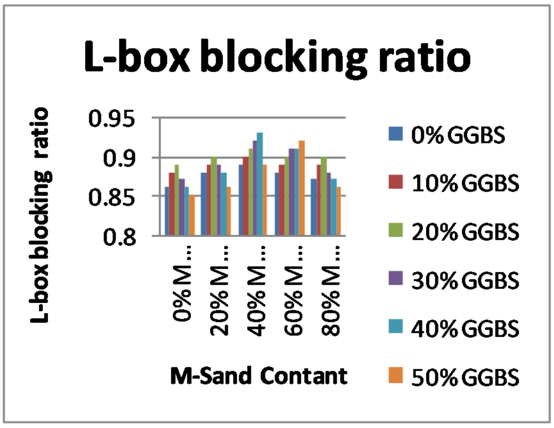

Figure 5: L-box blocking ratio results

U-Box Height

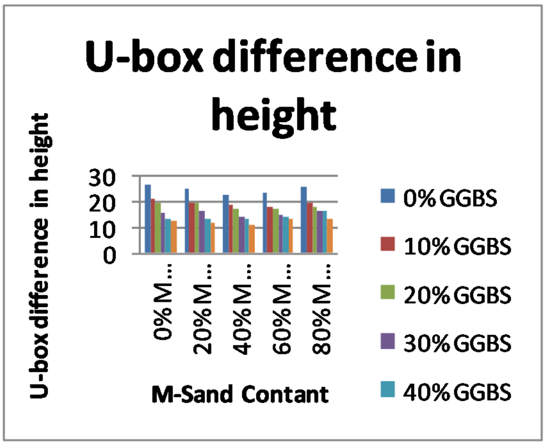

Figure 6: U-box difference in height

3. Bulk Density

Table 14: Bulk density of SCC with GGBS and M-sand

Mix Designation	Bulk density at 28 days (kg/m3)
G0MS0	2474
G10MS0	2465
G20MS0	2481
G30MS0	2479
G40MS0	2450
G50MS0	2400
G0MS20	2465
G10MS20	2456
G20MS20	2476
G30MS20	2470
G40MS20	2420
G50MS20	2387
G0MS40	2460
G10MS40	2445
G20MS40	2471
G30MS40	2460
G40MS40	2415
G50MS40	2357
G0MS60	2431
G10MS60	2432
G20MS60	2450
G30MS60	2420
G40MS60	2356
G50MS60	2329
G0MS80	2426
G10 MS80	2429
G20MS80	2440
G30MS80	2390
G40MS80	2350
G50MS80	2317

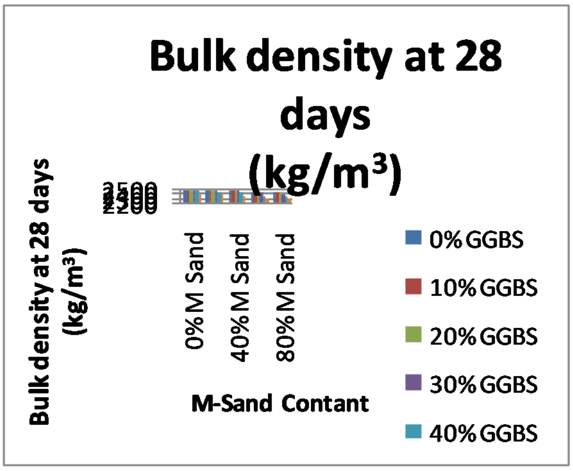

Figure 7: Bulk density

4. Compressive Strength

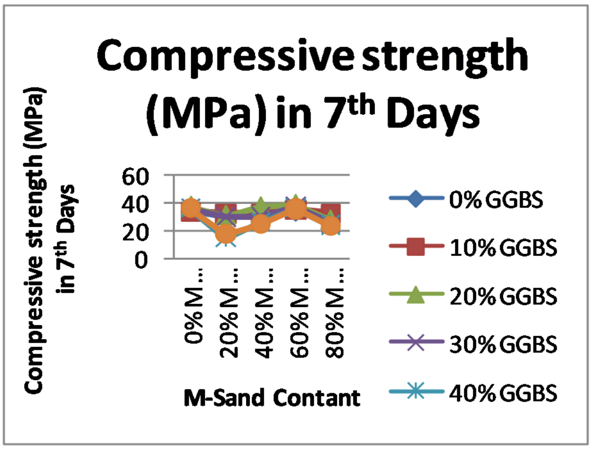

Figure 8: Compressive strength (MPa) 7th Days

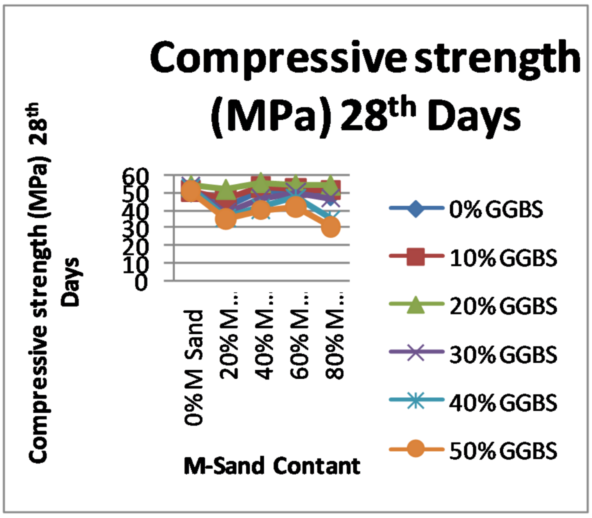

Figure 9: Compressive strength (MPa) 28th Days

Table 15: Compressive strength of SCC with GGBS and M-sand

S. No	Mix Designation	Compressive Strength (MPa)	Percentage increase or decrease at 28 days	
		7 Days	28 Days	
1	G0MS0	33.33	50.22	-
2	G10MS0	34.05	50.66	+0.88
3	G20MS0	37.18	53.88	+7.29
4	G30MS0	36.20	53.11	+5.75
5	G40MS0	35.90	52.77	+5.08
6	G50MS0	35.56	51.00	+1.55
7	G0MS20	30.00	41.50	-17.40
8	G10MS20	32.80	46.11	8
9	G20MS20	30.66	51.77	+3.09
10	G30MS20	29.77	38.60	-23.10
11	G40MS20	14.22	36.22	-27.90
12	G50MS20	17.33	35.11	-30.10
13	G0MS40	30.35	51.11	+1.77
14	G10MS40	32.11	53.30	+6.13
15	G20MS40	36.70	55.55	+10.60
16	G30MS40	29.55	45.90	-8.60
17	G40MS40	26.30	41.18	-18.00
18	G50MS40	24.25	40.00	-20.40
19	G0MS60	33.20	51.30	+2.15
20	G10MS60	35.20	52.60	+4.74
21	G20MS60	38.44	54.40	+8.32
22	G30MS60	37.00	50.00	-0.44
23	G40MS60	36.00	47.00	-6.41
24	G50MS60	35.00	42.00	-16.40
25	G0MS80	31.22	48.11	-4.20
26	G10 MS80	32.10	51.40	+2.35
27	G20MS80	27.20	54.10	+7.73
28	G30MS80	24.80	46.50	-7.41
29	G40MS80	23.60	35.10	-30.10
30	G50MS80	23.30	30.50	-39.30

5. Splitting Tensile Strength

Table 16: Splitting tensile strength

Sl. No	Mix Desig-nation	Average Splitting tensile strength at 28 days	Percentage variationsat 28 days
1	G0MS0	5.45	-
2	G10MS0	5.53	+1.46
3	G20MS0	5.65	+3.66
4	G30MS0	5.20	-4.58
5	G40MS0	4.99	-8.44
6	G50MS0	4.94	-9.35
7	G0MS20	5.32	-2.38
8	G10MS20	5.53	+1.46
9	G20MS20	5.79	+6.23
10	G30MS20	5.56	+2.02
11	G40MS20	5.30	-2.75
12	G50MS20	5.10	-6.42
13	G0MS40	5.42	-0.55
14	G10MS40	5.67	+4.04
15	G20MS40	5.86	+7.52
16	G30MS40	5.65	+3.66
17	G40MS40	5.30	-2.75
18	G50MS40	4.92	-9.72
19	G0MS60	5.38	128
20	G10MS60	5.40	-0.92
21	G20MS60	5.91	+8.44
22	G30MS60	5.75	+5.50
23	G40MS60	5.54	+1.65
24	G50MS60	5.29	-2.94
25	G0MS80	3.10	-43.11
26	G10 MS80	3.30	-39.45
27	G20MS80	3.50	-35.77
28	G30MS80	3.29	-39.63
29	G40MS80	3.21	-41.10
30	G50MS80	2.90	-46.78

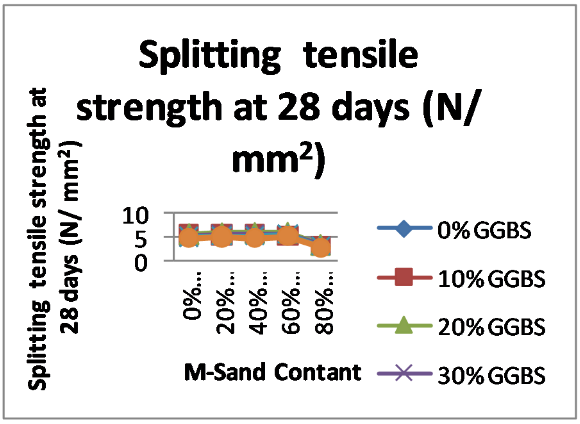

Figure 10: Average Splitting tensile strength at28th days (N/ mm^2)

VI. Conclusion

- The slump flow values for G50MS60 GGBS concrete can reach 815mm. For G10MS0, it reduces up to 690mm.
- As GGBS content and M-sand content rise, so do the T500 mm flow time and V funnel flow time.
- The L box ratio and U box disparity in height passing capabilities are within acceptable bounds. When the L-box test results are examined, it is discovered that all of the mixes may pass through crowded reinforcements without segregation or obstruction.
- Using GGBS and M-Sand together improves the flow properties of self-compacting concrete. The paste volume is increased by the addition of mineral admixtures such GGBS and fly ash. The properties of SCC's flow ability are impacted by the addition of M-sand above 80%.
- When GGBS is replaced with 20% GGBS, the bulk density slightly increased. Additionally, when the amount of M-sand increases, the bulk density decreases.

It was discovered that the 20% GGBS addition was ideal for enhancing mechanical characteristics. For G20MS40 Mix, a compressive strength of 55.55 MPa was attained. For mix G20MS60, a maximum split tensile strength of 5.91MPa was attained.

According to the durability experiments, self-compacting concrete specimens that have been combined with GGBS and M-sand perform better than control specimens.

The findings showed that all concrete sample' chloride ion penetrations were fewer than 1000 coulombs. According to ASTM 1202-12, 1000 coulombs or less are regarded as “very low.” Due to decreased water absorption and porosity, GGBS content of 30% with 40% M-sand content replaces lowers the RCPT values by up to 25% after 90 days.

The paste volume is increased by the addition of mineral admixtures such GGBS and fly ash. The friction between the aggregate and paste particles is decreased by the increase in paste volume, which improves the mix’s fluidity as the GGBS concentration rises. The compressive strength of SCC is influenced by the inclusion of GGBS and M-sand.

The compressive strength is increased by using GGBS and M-sand in lower percentages. When the proportion is larger, the compressive strength is reduced. A stronger strength development results from GGBS that is more finely ground. This is because adding 20% GGBS replaced mix to the 40% M-sand replaced mix produces the best reaction and filling capacity. The 40% M-sand replacement with 20% GGBS demonstrates the highest compressive strengths among the various mixes, according to the experimental data. Due of its higher paste volume and high fines content, M-sand is appropriate for the creation of SCC. The amount and mean size of $Ca(OH)_2$ crystals in the aggregate-mortar Interfacial Transition Zone (ITZ) are significantly reduced by the presence of GGBS, and the microstructure of the ITZ is made denser. The pozzolanic nature of GGBS affects the properties of the paste and creates a nice transition zone. Concrete gains strength and durability by developing a denser matrix and replacing some of the cement with GGBS.

The tensile strength of the concrete specimens was increased as a result of the pozzolanic character of the GGBS and the filling capacity of M-sand and fly ash. In self-compacting concrete, the use of GGBS and M-sand enhances the hydration process and CSH content, hence boosting SCC’s strength. In comparison to traditional concrete, the SCC’s incorporation of GGBS and M-sand reduced water absorption and porosity. Why In a higher proportion of replacements of GGBS, the concrete cannot be cast. This is because there are less voids due to superior packing of manufactured sand and the absence of as many micro particles in it. Since GGBS increases the viscosity of the mix, it was challenging to cast concrete with a high GGBS percentage.

It is feasible to utilise SCC with synthetic sand successfully. Studying the research, it was discovered that M sand requires a considerably higher paste volume than river sand in order to obtain the requisite flow for SCC. Therefore, it is possible for construction sites to increase the amount of SCMs and manufactured sand used in SCC manufacturing.

As a result, GGBS and M-sand-based self-compacting concrete can be utilised to build structures that are sustainable and environmentally beneficial. Steel industry waste was decreased by the use of GGBS. An appropriate substitute for river sand is M-sand. Utilising GGBS and M-sand can significantly minimise pollution from the cement and steel industries as well as the depletion of native river sand (12)

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