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Durability Study on Self Compacting Concrete with Mineral Admixture

Boopathi V[1], Sharmila Devi K[2]

[1]PG student, [2]Assistant professor

[1,2]Civil Engineering Department, Paavai Engineering College, Namakkal, Tamil Nadu, India

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ABSTRACT

Self-compacting concrete can be placed and compacted under its own weight without any vibration and without segregation or bleeding. The use of mineral admixture (such as fly ash, GGBS, etc.) as partial replacement of cement in SCC can bring down cost. The use of industrial waste such as fly ash, GGBS, etc in the binder of concrete reduces the storage, disposal and environmental problems. The most beneficial property with M-SAND addition to the concrete in the hardened state are the tensile strength, impact strength, the toughness and the energy absorption capacity. In the present study the mix design for M50 grade SCC was first carried out in accordance with EFNARC guidelines. The cement will be replaced with GGBS and fine aggregate get replaced with manufacturing sand Test such as slump flow,V funnel were carried out on fresh concrete and the optimum dosage of super plasticizer was found and cubes were cast for 7,28,56 days for the mix ratio 1:1.40:1.27:0.34. The influence of GGBS on the workability, mechanical strength and durability aspects like water absorption test, sulphate attack test, acid resistance test,rapid chloride penetration test , sorptivity test , linear polarization resistivity test and alkalinity test of self-compacting concrete are studied.

Keywords: *SELFCOMPACTING, FLY ASH, GGBS*

1. INTRODUCTION

1.1. GENERAL

Concrete is the most commonly used construction material worldwide. In India, reinforced concrete (RC) is extensively used in the construction of variety of civil infrastructure applications including small and large buildings, houses, bridges, storage tanks, dams and numerous other types of structures in India. The demand for concrete as construction material increases, and the demand for Fine aggregate increases. Some researchers said that the concrete industry globally would consume 48 billion tons annually of natural aggregates. Such large consumption of natural aggregates will cause destruction to the environment. In the last few decades, there has been rapid increase in the waste materials and by-products production due to the exponential growth rate of population, development of industry and technology and the growth of consumerism. The basic strategies to decrease solid waste disposal problems have been focused at the reduction of waste production and recovery of usable materials from the waste as raw material as well as utilization of waste as raw materials whenever possible.

The beneficial use of by-products in concrete technology has been well known for many years and significant research has been published with regard to the use of materials such as coal fly ash, pulverized fuel ash, blast furnace slag and silica fume as partial replacements of Portland cement. Such materials are widely used in the construction of industrial and chemical plants because of their enhanced durability compared with Portland cement. The other main advantage of using such materials is to reduce the cost of construction. Several efforts are in progress to reduce the use of natural river sand as fine aggregate in concrete in order to address the ground water issues and natural aggregate depletion. Over recent decades, intensive research studies have been carried out to explore all possible reuse methods. M-Sand, Construction waste, Blast furnace, steel slag, coal fly ash and bottom ash have been accepted in many places as alternative aggregates in embankment, roads, pavements, foundation and building construction, raw material in the manufacture of ordinary Portland cement.

1.2. SELF COMPACTING CONCRETE (SCC)

Making concrete structures without vibration have been done in the past. For examples, placement of concrete under water is done by the use of tremie without vibration. Mass concrete, and shaft concrete can be successfully placed without vibration. But the above examples of concrete are generally of lower strength and difficult to obtain consistent quality. Modern application of self-compacting concrete (SCC) is focussed on high performance, better and more reliable and uniform quality. Recognising the lack of uniformity and complete compaction of concrete by vibration, researchers at the University of Tokyo, Japan, started in late 1980's to develop SCC. By the early 1990's, Japan has developed and used SCC that does not require vibration to achieve full compaction. By the year 2000, the SCC has become popular in Japan for prefabricated products and ready mixed concrete.

Several European countries recognised the significance and potentials of SCC developed in Japan. During 1989, they founded European federation of natural trade associations representing producers and applicators of specialist building products (EFNARC).The utilisation of self-compacting concrete started growing rapidly. EFNARC, making use of broad practical experiences of all members of European federation with SCC, has drawn up specification and guidelines to provide a framework for design and use of high quality SCC, during 2001. Self-compacting concrete has been described as "the most revolutionary evolutionary development in concrete construction for several decades". Originally developed in Japan to offset a growing concrete shortage of skilled labour, it has proved to be beneficial from the following points.

Self-compacting concrete (SCC) is a concrete mix which has a low yield stress, high deformability, good segregation resistance (prevents separation of particles in the mix), and moderate viscosity (necessary to ensure uniform suspension of solid particles during transportation, placement (without external compaction), and thereafter until the concrete sets). In everyday terms, when poured, SCC is an extremely fluid mix with the following distinctive practical features - it flows very easily within and around the formwork, can flow through obstructions and around corners ("passing ability"), is close to self-levelling (although not actually self-levelling), does not require vibration or tamping after pouring, and follows the shape and surface texture of a mold (or form) very closely once set. As a result, pouring SCC is also much less labour intensive compared to standard concrete mixes. Once poured, SCC is usually similar to standard concrete in terms of its setting and curing time (gaining strength), and strength. SCC does not use a high proportion of water to become fluid - in fact, SCC may contain less water than standard concretes. Instead, SCC gains its fluid properties from an unusually high proportion of fine aggregate, such as sand (typically 50%), combined with superplasticizers (additives that ensure particles disperse and do not settle in the fluid mix) and viscosity enhancing admixtures (VEA).

Ordinarily, concrete is a dense, viscous material when mixed, and when used in construction, requires the use of vibration or other techniques (known as compaction[*disambiguation needed*]) to remove air bubbles (cavitation), and honey comb like holes, especially at the surfaces, where air has been trapped during pouring. This kind of air content (unlike that in aerated concrete) is not desired and weakens the concrete if left. However, it is laborious and takes time to remove by vibration, and improper or inadequate vibration can lead to undetected problems later. Additionally some complex forms cannot easily be vibrated. Self-compacting concrete is designed to avoid this problem, and not require compaction, therefore reducing labour, time, and a possible source of technical and quality control issues.

1.3. GROUND GRANULATED BLAST FURNACE SLAG

Ground-granulated blast-furnace slag (**GGBS** or **GGBFS**) is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. The chemical composition of a slag varies considerably depending on the composition of the raw materials in the iron production process. Silicate and aluminate impurities from the ore and coke are combined in the blast furnace with a flux, which lowers the viscosity of the slag. In the case of pig iron production, the flux consists mostly of a mixture of limestone and forsterite or in some cases dolomite. In the blast furnace, the slag floats on top of the iron and is decanted for separation. Slow cooling of slag melts results in an unreactive crystalline material consisting of an assemblage of Ca-Al-Mg silicates. To obtain a good slag reactivity or hydraulicity, the slag melt needs to be rapidly cooled or quenched below 800°C in order to prevent the crystallization of marinate and melilite. To cool and fragment the slag a granulation process can be applied in which molten slag is subjected to jet streams of water or air under pressure. Alternatively, in the pelletization process the liquid slag is partially cooled with water and subsequently projected into the air by a rotating drum. In order to obtain a suitable reactivity, the obtained fragments are ground to reach the same fineness as Portland cement

1.4. M-SAND

Manufactured sand (M-Sand) is a substitute of river sand for concrete construction. Manufactured sand is produced from hard granite stone by crushing. The crushed sand is of cubical shape with grounded edges, washed and graded to as a construction material. The size of manufactured sand (M-Sand) is less than 4.75mm. Manufactured sand is an alternative for river sand. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word. Due to the depletion of good quality river sand for the use of construction, the use of manufactured sand has been increased.

1.5. FLY ASH

Fly ash, also known as "pulverised fuel ash" in the United Kingdom, is a coal combustion product composed of fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as **coal ash**. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata. Constituents depend upon the specific coal bed makeup but may include one or more of the following elements or substances found in trace concentrations (up to hundreds ppm): arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with very small concentrations of dioxins and PAH compounds. In the past, fly ash was generally released into the atmosphere, but air pollution control standards now require that it be captured prior to release by fitting pollution control equipment. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, often used as a pozzolan to produce hydraulic cement or hydraulic plaster and a replacement or partial replacement for Portland cement in concrete production. Pozzolans ensure the setting of concrete and plaster and provide concrete with more protection from wet conditions and chemical attack. After a long regulatory process, the EPA published a final ruling in December 2014, which establishes that coal fly ash is regulated on the federal level as "non-hazardous" waste according to the Resource Conservation and Recovery Act (RCRA). Coal Combustion Residuals (CCR's) are listed in the subtitle D (rather than under subtitle C dealing for hazardous waste, which was also considered). In the case that flies or bottom ash is not produced from coal, for example when solid waste is used to produce electricity in an incinerator (see waste-to-energy facilities), this kind of ash may contain higher levels of contaminants than coal ash. In that case the ash produced is often classified as hazardous waste.

1.6. SUPERPLASTICIZER

Super plasticizers, also known as **high range water reducers**, are chemical admixtures used where well-dispersed particle suspension is required. These polymers are used as dispersants to avoid particle segregation (gravel, coarse and fine sands), and to improve the flow characteristics (rheology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-compacting concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. The strength of concrete increases when the water to cement ratio decreases. However, their working mechanisms lack a full understanding, revealing in certain cases cement-superplasticizer incompatibilities. The addition of superplasticizer in the truck during transit is a new development within the industry. Admixtures added in transit through automated slump management systems, such as Verify, allow concrete producers to maintain slump until discharge without reducing concrete quality.We know that the main action of Super Plasticizer is to fluidity the mix and improve the workability of concrete. Portland cement, being in fine state of division will have a tendency to flocculate in wet concrete.

1.7. USES AND ADVANTAGES OF SCC

At present self-compacting concrete (SCC) can be classified as an advanced construction material. The SCC as the name suggests, does not require to be vibrated to achieve full compaction. This offer benefits and advantages over conventional concrete.

- Faster construction
- Improved quality of concrete and reduction of onsite repairs.
- Reduction in site manpower
- Better surface finish
- Easier placing
- Improved durability and reliability of concrete structures
- Greater freedom in design
- Thinner concrete sections
- Reduced noise level
- Safer working environment

1.8. OBJECTIVES

To study the fresh, mechanical and durability properties of concrete by varying the percentage of GGBS by weight of cement and partial replacement of M-Sand.

To study the influence of M-Sand and GGBS in the improvement of quality and durability of self-compacting concrete for various proportions.

1.9. SCOPE

This project work involves casting of cubes with and without GGBS and to determine the ultimate load carrying capacity. Cubes are cast in two different ways
i) without GGBS ii) with GGBS.

1.10. NEED FOR THE RESEARCH

Self compacting concrete is concrete mixture that is able to consolidate under its own weight. Use of SCC can also help minimize hearing related damages on the worksite that are induced by vibration of concrete. Another advantages of SCC is that the time required to place large sections is considerably reduced.

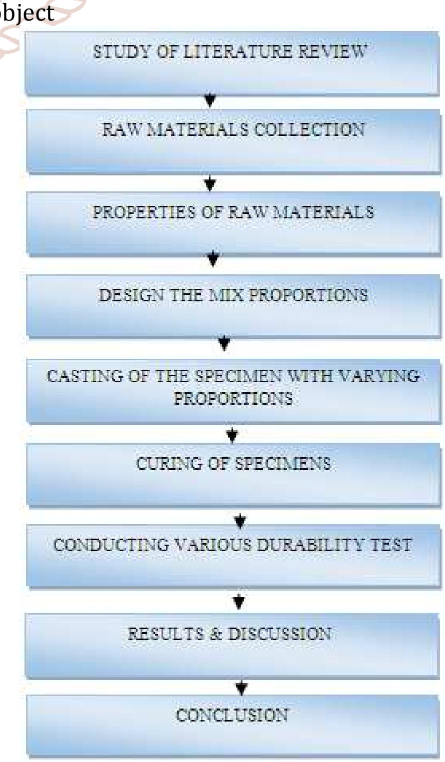
By adding of GGBS in self compacting concrete, cement content can be reduced. To assess the effectiveness of GGBS in SCC some of the parameters like chemical composition and fineness have been carefully examined earlier.

SUMMARY OF LITERATURE REVIEW

In the above literatures the fresh properties of SCC was explained in detail and some of the hardened properties on SCC was also been mentioned. In some literatures the effective use of granite dust in SCC as a replacement material was explained. Similarly the effect of GGBS in fresh and hardened properties of SCC was shown. Therefore in this project it has been planned to partially replace cement with GGBS and M-sand with fine aggregate on SCC.

METHODOLOGY

The following methodology has been adopted to achieve above object



EXPERIMENTAL INVESTIGATION

TEST PROGRAME

The project deals with study of the strength and durability behaviour of concrete cube with varying percentage of GGBS and with M-Sand replacement of 80% of Fine aggregate. To find out the effect of maximum strength of the SCC. This chapter presents the materials properties as found by laboratory tests. All the material tests were conducted in the laboratory as per relevant Indian Standard codes. Basic tests were conducted on the fine aggregate, coarse aggregate and cement to check their suitability for concrete making.

RESULT AND DISCUSSION

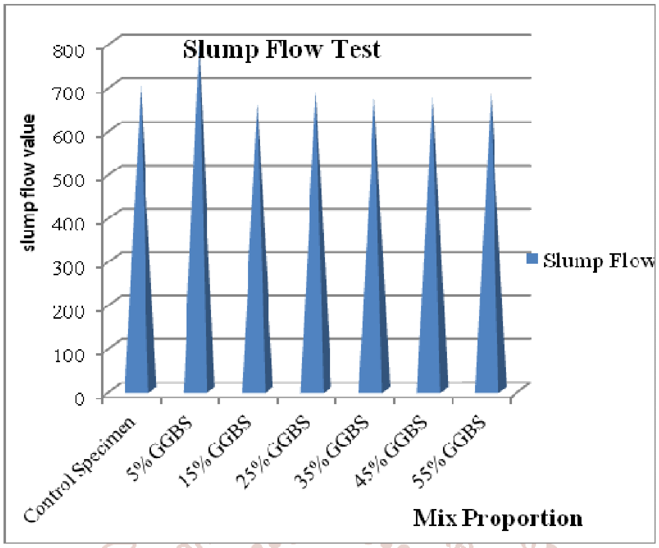


Fig 7.1 Slump Flow Test

Method	Slump Flow	T50cm Slump Flow	V-Funnel	V-Funnel @ T5mins
Unit	Mm	sec	sec	sec
Typical Range	650 to 800	2 to 5	8 to 12	8 to 15
Control mix	700	3	9	13
5% GGBS	720	4	9	13
15% GGBS	660	2	10	13
25% GGBS	690	3	11	14
35% GGBS	675	5	12	15
45% GGBS	700	4	9	12
55% GGBS	685	3	9	13

Table Fresh Properties of SCC

COMPRESSIVE STRENGTH

S. No	Mix Proportion	Compressive Strength		
		7 Days	28 Days	56 Days
1	Control	33	50	52
2	5% GGBS + 80% M-Sand	32	51	51
3	15% GGBS + 80% M-Sand	27	52	53
4	25% GGBS + 80% M-Sand	24	54	55
5	35% GGBS + 80% M-Sand	23	38	39
6	45% GGBS + 80% M-Sand	23	27	36
7	55% GGBS + 80% M-Sand	22	30	35

- At 7 days of compressive strength the maximum and minimum compressive strength was obtained at Control Specimen and 55% replacement of GGBS with 80% M-Sand.
- At 28 days of compressive strength maximum and minimum compressive strength was obtained at 25% replacement of GGBS with 80% M-Sand and 45% replacement of GGBS with 80% M-Sand.
- At 56 days of compressive strength the maximum compressive strength was obtained at 25% replacement of GGBS with 80% M-Sand.
- At 56 days of compressive strength the minimum compressive strength was obtained at 55% replacement of GGBS with 80% M-Sand.

SPLIT TENSILE STRENGTH

The minimum split tensile strength was obtained at 45% replacement of GGBS with 80% M-Sand.

The maximum split tensile strength was obtained at Control Specimen.

Table Split Tensile Strength

S. No	Mix Proportion	Split Tensile Strength
1	Control	3.8
2	5% GGBS + 80% M-Sand	3.5
3	15% GGBS + 80% M-Sand	3.4
4	25% GGBS + 80% M-Sand	3.5
5	35% GGBS + 80% M-Sand	2.8
6	45% GGBS + 80% M-Sand	1.9
7	55% GGBS + 80% M-Sand	2.2

WATER ABSORPTION TEST

Among the specimen the control specimen shows maximum water absorption at 24 hours and 72 hours.
Among the 45% GGBS and 80% M-Sand specimen shows minimum water absorption at 24 hours.
Among the 35% GGBS and 80% M-Sand specimen shows minimum water absorption at 72 hours.
Water absorption has reduced by adding of GGBS content.

S. No	Mix Proportion	Water Absorption at 24 Hrs (%)	Water Absorption at 72 Hrs (%)
1	Control	1.56	1.66
2	5% GGBS + 80% M-Sand	1.24	1.27
3	15% GGBS + 80% M-Sand	1.05	1.09
4	25% GGBS + 80% M-Sand	1.19	1.49
5	35% GGBS + 80% M-Sand	0.81	0.89
6	45% GGBS + 80% M-Sand	0.71	1.07
7	55% GGBS + 80% M-Sand	1.00	1.23

POROSITY TEST

S. No	Mix Proportion	Porosity at 28 Days (%)
1	Control	3.66
2	5% GGBS + 80% M-Sand	2.68
3	15% GGBS + 80% M-Sand	2.39
4	25% GGBS + 80% M-Sand	2.77
5	35% GGBS + 80% M-Sand	1.91
6	45% GGBS + 80% M-Sand	1.67
7	55% GGBS + 80% M-Sand	2.30

S. No	Mix Proportion	Percentage of Strength loss
1	Control	8.16
2	5% GGBS + 80% M-Sand	27.08
3	15% GGBS + 80% M-Sand	28.57
4	25% GGBS + 80% M-Sand	20.00
5	35% GGBS + 80% M-Sand	21.88
6	45% GGBS + 80% M-Sand	13.79
7	55% GGBS + 80% M-Sand	21.74

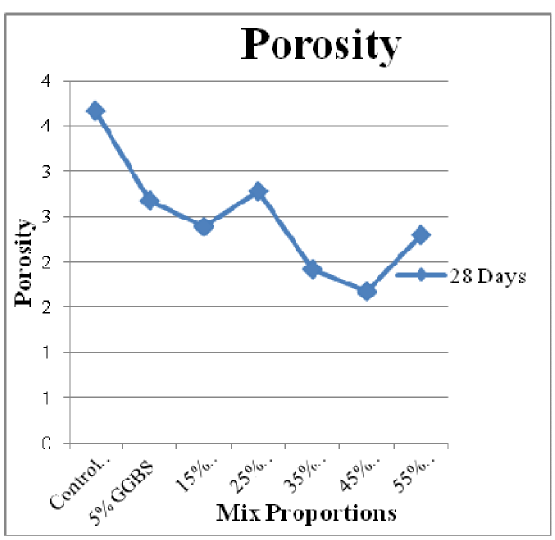


Fig.6 Porosity test

The test result shows that the pores of concrete will reduced by adding of GGBS.

SULPHATE ATTACK TEST

For the Sulphate test after 30 days of immersion it was observed that control specimen had showed the minimum percentage of strength loss.

Sulphate test after 30 days of immersion it was observed that the 15% replacement of GGBS with 80% M-Sand had showed the maximum percentage of strength loss.

S. No	Mix Proportion	Percentage of Weight loss	Percentage of Strength loss
1	Control	5.72	44.90
2	5% GGBS + 80% M-Sand	3.40	60.42
3	15% GGBS + 80% M-Sand	1.65	75.51
4	25% GGBS + 80% M-Sand	1.26	68.00
5	35% GGBS + 80% M-Sand	1.02	31.25
6	45% GGBS + 80% M-Sand	1.24	10.34
7	55% GGBS + 80% M-Sand	1.30	13.04

Acid Test

S. No	Mix Proportion	Charge Passed in Coulombs	Asper ASTM C1202
1	Control	674.1	Very Low
2	5% GGBS + 80% M-Sand	1461.6	Low
3	15% GGBS + 80% M-Sand	845.1	Very Low
4	25% GGBS + 80% M-Sand	971.1	Very Low
5	35% GGBS + 80% M-Sand	310.5	Very Low
6	45% GGBS + 80% M-Sand	306	Very Low
7	55% GGBS + 80% M-Sand	221.4	Very Low

Table Acid Test

From the acid resistance test after 30 days it was observed that the 35% replacement of GGBS with 80% M-Sand had showed the minimum amount of loss in weight compared to Control Specimen.

Acid resistance test after 30 days it was observed that the Control mix had showed the maximum amount of loss in weight.

Acid resistance test after 30 days it was observed that the 15%replacement of GGBS with 80% M-Sand had showed the maximum percentage of strength loss.

5.8 RAPID CHLORIDE PENETRATION TEST

- From the above results, various percentage additions of GGBS showed very low chloride penetration.
- RCPT test result shows that the concrete have minimum pores.
- The chloride penetration will decreased by adding of GGBS

5.9 SORPTIVITY TEST

S. No	Mix Proportion	Sorptivity (mm/sec$^{1/2}$)		
		6 Hours	24 Hours	72 Hours
1	Control	0.013	0.007	0.005
2	5% GGBS + 80% M-Sand	0.012	0.007	0.005
3	15% GGBS + 80% M-Sand	0.012	0.007	0.005
4	25% GGBS + 80% M-Sand	0.012	0.007	0.005
5	35% GGBS + 80% M-Sand	0.012	0.007	0.005
6	45% GGBS + 80% M-Sand	0.012	0.006	0.005
7	55% GGBS + 80% M-Sand	0.011	0.006	0.005

Table Sorptivity Test

- Initial permeability had high compared with 24 hours and 72 hours permeable.

LINEAR POLARIZATION RESISITIVITY TEST

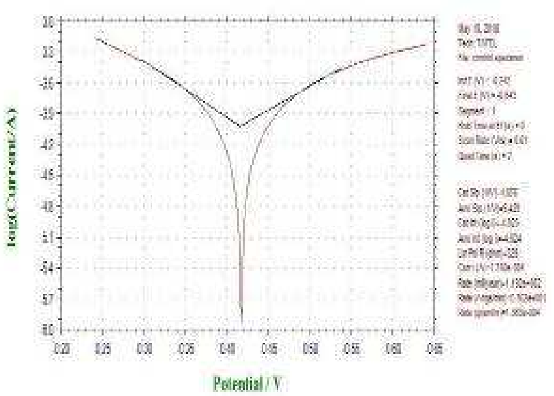


Fig 5.12 LPR Control Specimen

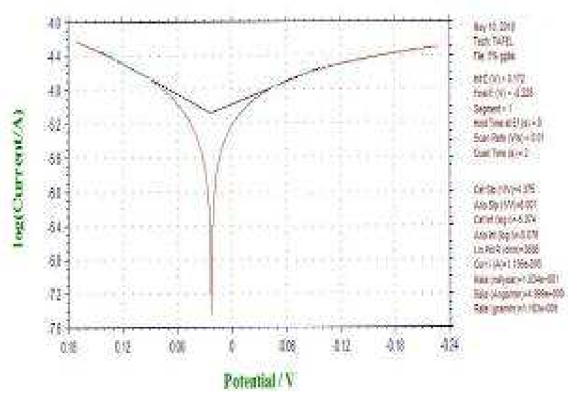


Fig 5.13 5% GGBS Specimen

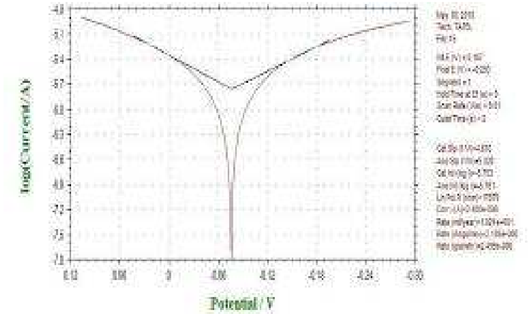


Fig 5.14 15% GGBS Specimen

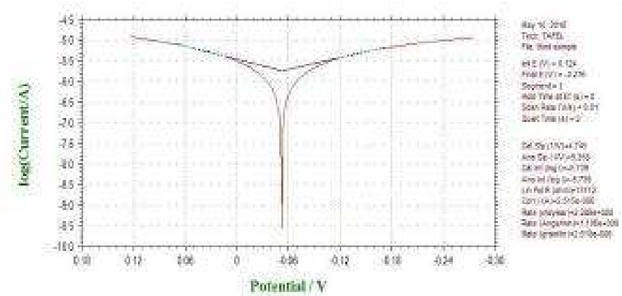


Fig 7.17 45% GGBS Specimen

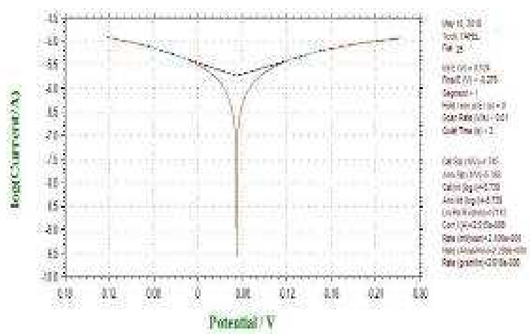


Fig 5.15 25% GGBS Specimen

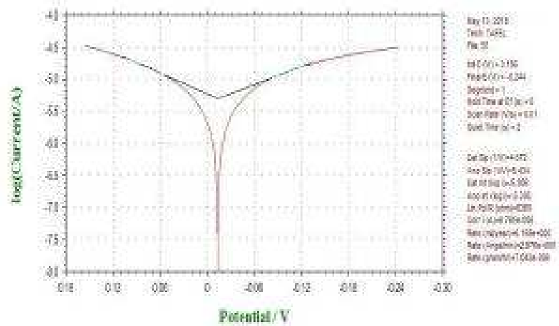


Fig 5.18 55% GGBS Specimen

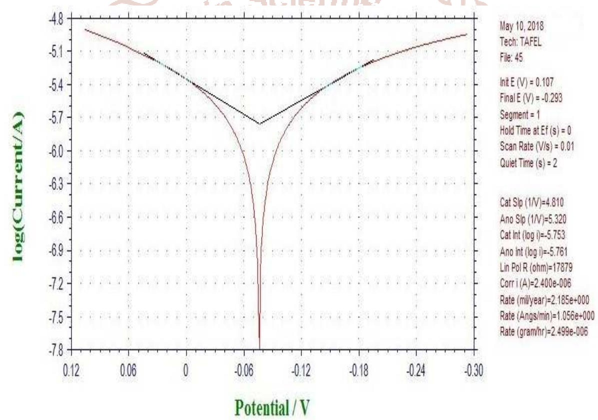


Fig 5.16 35% GGBS Specimen

S. No	Mix Proportion	Corrosion Rate cm/year
1	Control	0.02237
2	5% GGBS + 80% M-Sand	0.00714
3	15% GGBS + 80% M-Sand	0.00579
4	25% GGBS + 80% M-Sand	0.00535
5	35% GGBS + 80% M-Sand	0.00555
6	45% GGBS + 80% M-Sand	0.00581
7	55% GGBS + 80% M-Sand	0.01564

Table LPR Test

The corrosion rate is decreasing by adding of GGBS by compared with control specimen.
Maximum corrosion achieved at control specimen

ALKALINITY TEST

S. No	Mix Proportion	pH Value at 28Days
1	Control	11.65
2	5% GGBS + 80% M-Sand	11.62
3	15% GGBS + 80% M-Sand	11.67
4	25% GGBS + 80% M-Sand	11.56
5	35% GGBS + 80% M-Sand	11.32
6	45% GGBS + 80% M-Sand	11.50
7	55% GGBS + 80% M-Sand	11.08

Table Alkalinity Test

- In normal concrete the pH value is greater than 8.5. The GGBS added specimens are achieved the pH value greater than 11.
- So, the concrete is alkaline in nature.

CONCLUSION

Compressive Strength
- The control specimens are tested for the compressive strength at 7, 28, 56 days after water curing.
- The compressive strength get increased by adding of GGBS upto 25% replacement, then after that the strength get decreased.
- The excess amount of Pozzolanic content will affect the strength.

Split Tensile Strength
- The minimum split tensile strength was obtained at 45% replacement of GGBS with 80% M-Sand. The maximum split tensile strength was obtained at Control Specimen.
- Pozzolanic content will affect the split tensile strength.

Water Absorption Test
- At 24 hours of water absorption the maximum and minimum amount of water was absorbed at Control Specimen and 45% replacement of GGBS with 80% M-Sand respectively.
- At 72 hours of water absorption the maximum and minimum amount of water was absorbed at Control Specimen and35% replacement of GGBS with 80% M-Sand respectively.
- The GGBS added specimen shows the reduce water absorption value compared to Control Specimen.

Sulphate Attack Test
- In sulphate test the minimum and maximum amount of strength loss at control specimen and 15% replacement of GGBS respectively.
- There is a reduction in strength due to sulphate attack in the GGBS added samples compared to control specimen.

Acid Resistance Test
- In Acid test the minimum and maximum amount of weight loss at 35% replacement of GGBS and control specimen respectively.
- In Acid test the minimum and maximum amount of strength loss at 45% and 15% replacement of GGBS respectively.
- In Acid test the weight loss will be decreased and strength loss will increased by adding of GGBS.

Rapid Chloride Penetration Test
- The chloride ion permeability values shows that the GGBS added samples are less prone to corrosion.

Sorptivity Test
- In sorptivity test the permeability of concrete was decreased by adding of GGBS content.
- The sorptivity test shows that the less pores in concrete.

Linear Polarization Resistivity Test
- Corrosion rate will decreased by adding of GGBS.
- Similarly RCPT result also shows the minimum amount of chloride ion penetration.
- Corrosion depended on the chloride penetration.

Alkalinity Test
- Is normal concrete the pH value is greater than 8.5. The GGBS added specimens are achieved the pH value greater than 11.
- So, the concrete is alkaline in nature.

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