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PERFORMANCE STUDY OF STRENGTH AND DURABILITY PROPERTIES OF LATERISED CONCRETE MADE WITH GGBS AND SILICA FUME AS A PARTIAL REPLACEMENT OF CEMENT

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Abstract*:* Sand has been utilized in the construction of civil engineering projects for a long time as a fine aggregate. As building costs have been rising over the past few years, the source of high-quality sand has been rapidly depleting. Now, laterite soil is thought to be a potential sand substitute for concrete mixtures. As of now increase in carbon dioxide emission due to cement manufacturing, we need alternate to replace cement. Now, by products like GGBS and silica fume are thought to be a potential substitute for concrete mixtures. In this Paper, GGBS and silica fume is used as a partial cement replacement in laterised Concrete. This research deals with the viability study of GGBS and silica fume as partial replacement of cement in laterised concrete. Mixes to be prepared with replacement content of 5%,10%,15%,20% and 25% by the weight of ordinary Portland cement with GGBS and optimum silica fume (10%). However, the addition increases the strength levels with the aid of super plasticizer. Additional mixing lowers the laterite content to 15%. Same 15% of the weight of laterite soil can be used as partial replacement of sand exhibited the finest outcomes. As a result, it is showing use of laterite as a possible partial replacement for sand. In this research mixes are prepared by keeping optimum silica fume and Laterite soil constant for M1, M2, M3, M4, M5 and M6. Physical and mechanical experiments of M30 grade of concrete were used to analyze how these materials affected such attributes as compressive strength, split tensile strength, and flexural strength. Durability properties like Acid, sulphate and chloride attack are conducted to know how this concrete behaves in environmental conditions.

Key words: Laterised concrete, Ground granulated blast furnace slag (GGBS), Silica fume, Laterite soil, mechanical properties and durability properties.

1.INTRODUCTION

Around the world, the construction industry consumes a large amount of concrete. Natural riverbed sand is used as the fine aggregate in typical concrete made in India. Natural resource depletion creates an environmental issue, therefore government restrictions on sand quarrying led to a shortage and a sharp rise in its price. In river sand, normally, there aren't enough particles present. Sand that is removed in large quantities from riverbeds poses environmental risks. The level of the groundwater is impacted by the deep trenches dug in the riverbed. Sand from relatively far away locations is typically imported at great expense by those who make concrete in these areas, raising the overall cost of producing concrete and homes for the populace. As a result, there is a growing need to find substitute materials that are readily available locally that may be used in place of sand as the fine aggregate in concrete. In developing countries, substituting readily available materials for typical aggregates in concrete would prove to be cost-effective, given the establishment of a dependable design database on concrete made with these resources. Laterite is a naturally occurring soil that is widely distributed in the tropics and subtropics. It has been successfully used as a base course for highway construction and as a fill for foundations. Research has been focused on using laterite as a partial replacement of fine aggregate in concrete. The use of this easily accessible and inexpensive material in concrete work in areas with large deposits could result in a significant reduction in the cost of concrete. Due to its structural stability and strength, concrete is a material that is frequently utilized in building for a variety of constructions. In the field of civil construction, Ordinary Portland Cement (OPC) is a necessary element for the production of concrete, and it has no substitutes. It is unavoidable to either look for another material or partially replace it because the production of cement, regrettably, releases significant amounts of carbon dioxide gas into the atmosphere, which is a key contributor to the greenhouse effect and global warming. When industrial byproducts are used in part place of cement, significant energy and cost savings can be achieved. There are several benefits of replacing silica fume with cement to concrete, including increased strength, durability, and decreased cement output. The addition of pozzolanic minerals to concrete results in the formation of extra calcium silicate hydrate (C-S-H) via reaction between the silica in these materials and the calcium hydroxide generated during cement hydration. This process enhances the mechanical qualities and durability of the concrete.

A vast amount of waste is produced as a result of the industrialization's rapid rise, and this rubbish is disposed of. Waste/by-product usage as an alternative to disposal is one of the main issues with environmental consciousness and the lack of room for landfills. GGBS is among the industrial by-products that can be utilized in concrete to partially replace cement; otherwise, they would be disposed of in a landfill. In this case, replacing cement in concrete with waste materials like GGBS, silica fume, Laterite soil etc. offers a single, multi-benefit solution for the long-term, sustainable growth of the concrete industry. This research aims to determine the ideal proportions of laterite soil, GGBS and silica fume to substitute cement and fine aggregate, respectively. It is examined what the fresh and hardened phases of concrete have in common. A program of experiments was conducted to investigate its impact on the concrete's workability, compressive, flexural, split tensile strength, and modulus of elasticity.

Lekshmy Rajan , Anup Joy, Experimental Investigation on Strength Parameters of Laterised Concrete after replacing Silica Fume with cement, In this paper showed that silica fume at 10% gives the better results in laterised concrete.

Ameer Ali, MTech, CAS student SNGCET, Payyanur, Strength Properties of Laterised Concrete, In this paper showing that laterite soil at 15% with super plasticizer gives better results in Laterised concrete. According to these references, we are keeping both laterite soil and silica fume constant as replacement for cement and fine aggregate, we have developed a Laterised concrete by varying GGBS with partial replacement of cement by 5% for each mix up to 25% in Laterised concrete. M0, M1, M2, M3, M4, M5 & M6 mixes are developed by varying GGBS.M0 mix is control mix, M1 mix is developed by keeping optimum laterite soil and silica fume constant in conventional concrete replacing with cement and fine aggregate. Remaining mixes are developed by varying GGBS by 5% up to 25%.

2.OBJECTIVE

The main objective of this study to investigate the potential use of GGBS and silica fume as partial replacement of cement and Laterite soil as partial replacement of fine aggregate i.e., Laterised concrete. To study about Laterised concrete by making mix by optimum Laterite soil (15% of FA) and optimum silica fume (10%) by varying GGBS content 5% up to 25% by weight of OPC 53 grade. To determine the mechanical and durability properties of Laterised concrete by using byproducts like GGBS and silica fume.

Mechanical properties were investigated by the following tests.

1.compressive strength, 2. Split tensile strength, 3. Flexural strength.

Durability properties were investigated by the following tests.

1. Water absorption ,2. Acid attack,3. Sulphate attack, 4. chloride attack.

To determine the overall environmental effects of concrete production using these materials as partial replacement.

To minimize the cost of cement by utilize this industrial wastage of GGBS, silica fume and natural resource like Laterite soil.

3.EXPERIMENTAL STUDY

3.1. Materials

The following materials were used for preparing the laterised concrete mix.

1) Cement
2) Fine Aggregates
3) Coarse aggregate
4) Laterite soil
5) GGBS
6) Silica fume
7) Super plasticizer

3.1.1. Cement

In this research, BIRLA-A1 Ordinary Portland Cement (OPC) 53 grade was used in total mixes. The cement was of uniform in colour i.e., grey with a light greenish and was free from hard lumps. Laboratory tests conducted on cement are initial setting time and final setting time, specific gravity, fineness test, and compressive strength etc. Testing of cement was done as per Indian Standard code IS:12269-1987 and IS:5516 1996 as shown in the below table no:1.

Figure :3.1 cement

Table 1: Physical properties of cement

S. No.	Physical Tests	Results obtained	Standard value as per IS code 12269- 1987
1	Fineness	3.75%	Not >10% as per IS: 4031-part 1
2	Standard Consistency	34%	IS: 4031-part 4
3	Initial setting time	45 min	Not less than 30 min as per IS: 4031-part 5
4	Final setting time	220min	Not less than 600 min as per IS: 4031-part 5
5	Specific gravity	3.04	IS: 2720-part 3

3.1.2. Fine Aggregate

The Fine Aggregates were used in the present work locally available and has grading of zone-II as per IS:383-1970.The physical properties of fine aggregates are shown in below table no:3.

Table -2 Physical properties of fine aggregates

S.no	Properties	Results
1	Bulk density a)With out compaction b)With compaction	 1403.77 kg/m3 1489.96 kg/m3
2	specific gravity of fine aggregate	2.65
3	Fineness modulus of fine aggregate	2.66
4	Water absorption of fine aggregate	1.2%
5	Type of Zone	Zone II
6	Type of fine aggregate	Medium sand

3.3 Coarse Aggregates

Coarse aggregates were locally available. Specific gravity of coarse aggregates as per Is:2386 part -3 and the physical properties are shown in below table no:3.

Table -4. Physical properties of Coarse aggregates

S.no	Properties	Results
1	Bulk density a) With out compaction b) With compaction	 1279.24 kg/m3 1402.83 kg/m3
2	specific gravity of Coarse aggregate	2.7
3	Fineness modulus of Coarse aggregate	5.17

3.4 Laterite soil

Laterite is a type of soil that is high in iron and aluminum and is generally thought to have originated in tropical regions that are hot and humid. Because of the high iron oxide content, almost all laterites have a rusty-red appearance. Physical properties are showed in table 5&6.

Fig 3.2 Laterite soil

Table 5: Physical properties of Laterite soil

Properties	Values
Specific gravity	2.67
Fineness modulus	2.94

3.5 Ground granulated blast furnace slag (GGBS)

A byproduct of the iron-making process, ground granulated blast furnace slag is created by melting and quenching the slag in water once it has floated on top of the iron in the blast furnace. Its cementitious qualities are improved by the quick quenching, which produces granules that resemble coarse sand. After being dried and processed into a fine powder, these granules become GGBS, which can be used in a variety of construction-related applications. Physical properties of GGBS are showed in table 6

Table 6: Physical properties of Ground granulated blast furnace slag

Properties	Values
Specific gravity	2.92
Specific surface area	532 m^2/kg

3.6 Silica fume

A by-product of making elemental silicon or silicon-containing alloys in electric arc furnaces is silica fume. High-purity quartz is reduced to silicon at a temperature of around 2000°C, producing silicon dioxide vapor, which oxidizes and condenses at low temperatures to form silica fume. Physical properties of silica fume are showed in table 7.

Table 7: Physical properties of silica fume

Properties	Values
Specific gravity	2.2

3.7 Super plasticizer

In this investigation super plasticizer- CONPLAST-SP 430 in the form of sulphonated Naphthalene polymers complies with IS: 9103-1999 and ASTM 494 type F was used to improve the workability of concrete. Conplast SP 430 has been specially formulated to give high water reductions up to 20% without loss of workability or to produce high quality concrete of reduced permeability. Physical properties of super plasticizer are showed in table 8

Table 8. Properties of super plasticizer

S.NO	Physical properties	Result
1	Specific gravity	1.21
2	Chloride content	NIL
3	Air Entrainment	11.73 Lb/Ft3

3.8. Water

The water used in the mix design was tap water is used. So, it was free from suspended solids and organic material, which have affected the properties of fresh and hardened concrete.

DETAILS OF SPECIMENS CASTED AND MIX PROPORTIONS

The experimental work is carried out by partial replacement of fine aggregate with optimum Laterite soil (15%) and combination with partial replacement of cement with silica fume (10%) and named it as M1 mix. Keeping both optimum silica fume and laterite soil constant further cement is replaced with GGBS in various percentages like 0%, 5%, 10%, 15%,20% and 25% by weight. Laterite soil is sieved with 4.75 mm sieve passing laterite soil is then used as partial replacement of fine aggregate. M30 grade of concrete is designed as per IS: 10262. The quantities obtained from mix design are thoroughly mixed to achieve uniform consistency. To evaluate the compressive strength of concrete, 100mm x 100mm x 100mm cubes were cast and cured for 7 and 28 days. For evaluating split tensile strength of concrete is evaluated by 100mm x 200mm cylinders were cast and curing for 28 days and Flexural strength of concrete, 100mm x 100mm x 500mm prisms/beams and cured for 28 days. Percentage of materials used in mixes and Mix proportions of concrete are presented in table 9 and 10.

Table 9. Percentage of materials used in mixes

materials	M0	M1	M2	M3	M4	M5	M6
Cement	100%	90%	85%	80%	75%	70%	65%
Silica fume	-	10%	10%	10%	10%	10%	10%
GGBS	-	-	5%	10%	15%	20%	25%
Coarse aggregate	100%	100%	100%	100%	100%	100%	100%
Fine aggregate	100%	85%	85%	85%	85%	85%	85%
Laterite soil	-	15%	15%	15%	15%	15%	15%

Table 10: Concrete mix proportions for one cubic meter of concrete

Mixes	cement	FA(Kg)	CA(Kg)	Water (Liters)	Laterite soil		Silica fume		GGBS		Water/ binder	Super plasticizer
					%	Kg	%	Kg	%	Kg		
M0	350.48	693.79	1250.91	157.72	-	-	-	-	-	-	0.45	3.5
M1	315.43	589.72	1250.91	157.72	15	104.08	10	35.08	-	-	0.45	3.15
M2	297.90	589.72	1250.91	157.72	15	104.08	10	35.08	5	17.54	0.45	2.98
M3	280.38	589.72	1250.91	157.72	15	104.08	10	35.08	10	35.08	0.45	2.8
M4	262.86	589.72	1250.91	157.72	15	104.08	10	35.08	15	52.57	0.45	2.63
M5	245.33	589.72	1250.91	157.72	15	104.08	10	35.08	20	70.09	0.45	2.45
M6	227.85	589.72	1250.91	157.72	15	104.08	10	35.08	25	87.62	0.45	2.28

4.RESULTS and DISCUSSIONS

4.1 Compressive strength

Compressive strength tests are carried out with a 2000 KN capacity CTM. The test was conducted on the compressive strength of concrete using cubes of 100 x 100 x 100 mm. IS codes referred: IS 516 :1959 for Cube compressive strength test. It calculated by using formulas mentioned . The cube compressive strength is taken by the average of three cubes of compressive strength. The results of compressive strength of various mixes are shownintable.11.

Table 11 Compressive strength of concrete mixes

Mixes	Compressive strength(N/mm^2) after 28 days
M0	42
M1	40
M2	41.66
M3	45.66
M4	48
M5	43.83
M6	39.16

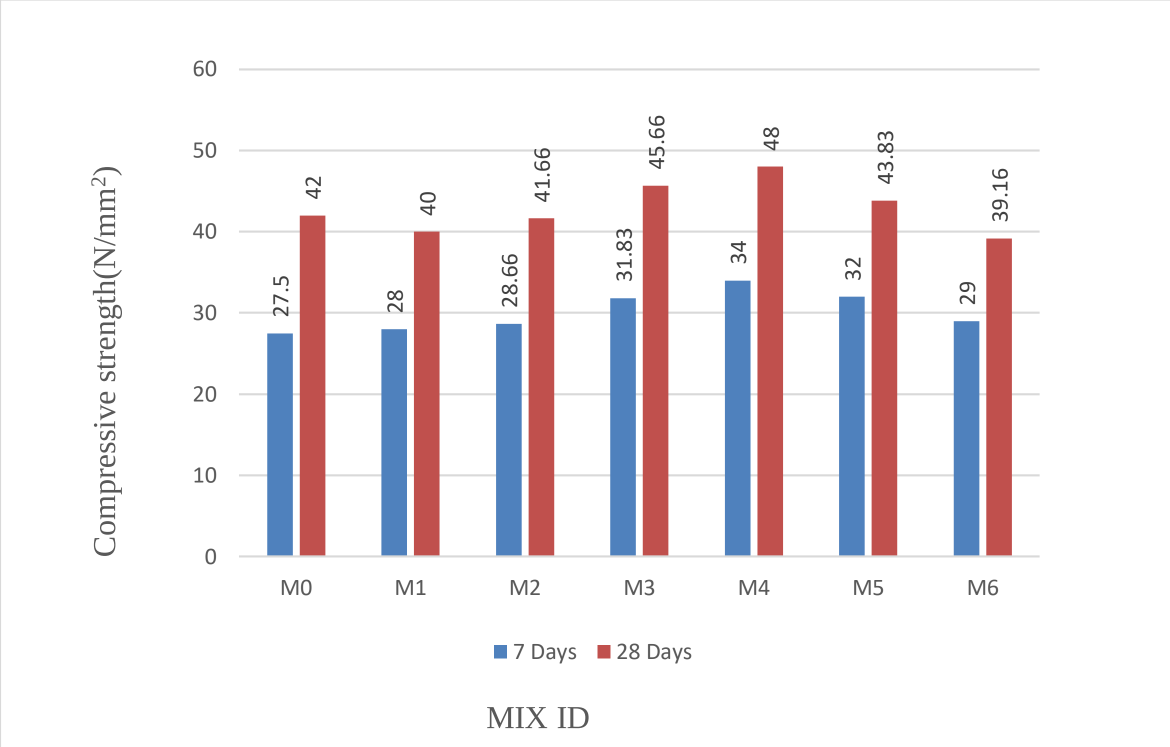

Figure 4.1. Compressive strength of mixes after 7 and 28 days

Figure 4.1 illustrates the compressive strength of concrete after 7 and 28 days when it was made with regular Portland cement, different GGBS percentages, ideal silica fume, ideal laterite soil, fine and coarse aggregate. The results show that the compressive strength at 7 and 28 days increased with further increases in replacement levels until M4 mix i.e., GGBS variation of 15% & optimum silica fume (10%) with cement replacement and optimum laterite soil (15%) with fine aggregate. Initially, the compressive strength decreased slightly with the replacement of cement and fine aggregate by silica fume and laterite soil. The compressive strength of the cube decreases as after 15% GGBS substitution increases. The mix demonstrated cube compressive strength of 34 MPa and 48 MPa at 7 days and 28 days correspondingly at M4 mix (Table 9& 10).

4.2 Split tensile strength

Split tensile strength tests are carried out with a 2000 KN capacity CTM. The test was conducted on the split tensile strength of concrete using cylinder of 100 mm x 200mm. IS codes referred: IS 516 :1959 for Cylinder split tensile strength test. It calculated by using formulas mentioned . The split tensile strength is taken by the average of three cylinders of split tensile strength. The results of split tensile strength of various mixes are shown in table.12

Table 12. Split tensile strength of concrete mixes

Mixes	Split tensile strength(N/mm^2)
M0	3.97
M1	4.13
M2	4.29
M3	4.45
M4	4.61
M5	4.29
M6	4.13

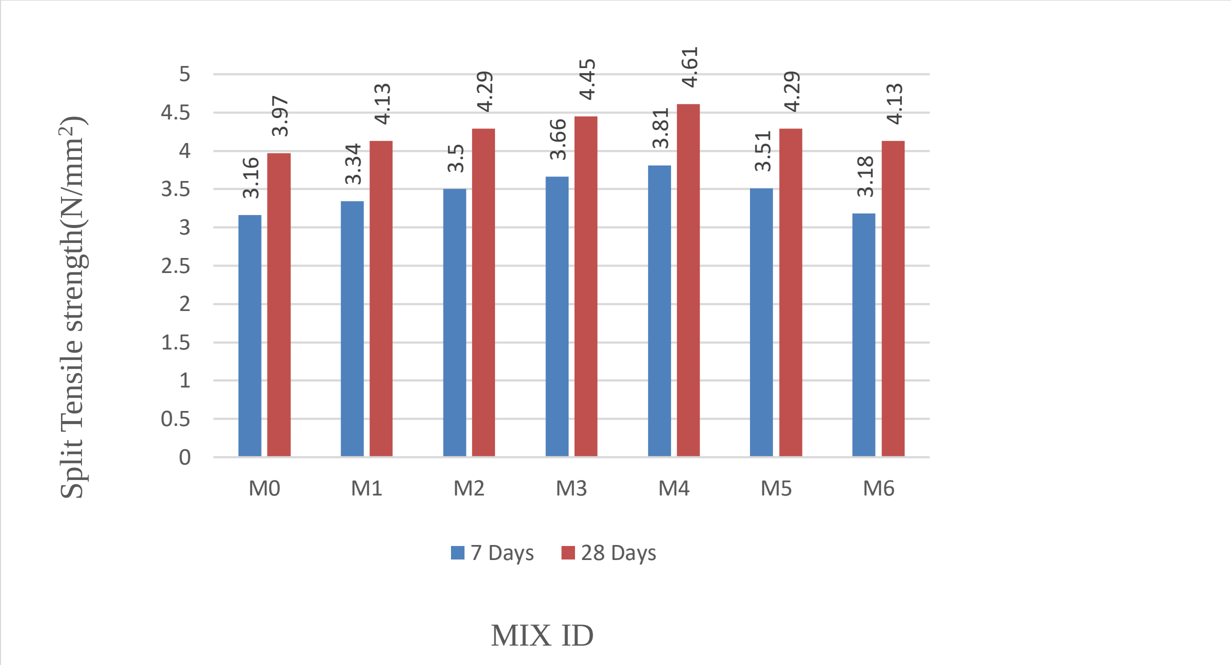

Figure 4.2 . split tensile strength of mixes after 7 and 28 days

Figure 4.2 displays the concrete's split tensile strength after 7 and 28 days when it was made with regular Portland cement, varied GGBS concentrations, the ideal amounts of Silica fume and Laterite soil, as well as fine and coarse aggregate. The results show that the split tensile strength at 7 and 28 days decreased slightly at first when cement and fine aggregate were replaced with silica fume and Laterite soil, but then increased with further increases in replacement levels until M4 mix i.e., GGBS variation of 15% & optimal silica fume (10%) with cement replacement and optimal laterite soil (15%) with fine aggregate. The cylinder's split tensile strength decreases with further GGBS substitution. At M4 mix i.e, 15% GGBS with optimum silica fume and optimum laterite soil content, the mix showed the split tensile strength of cylinder, with better strengths which is on par with the conventional mix.

4.3 Flexural strength

The Flexural strength of all mixtures was obtained at the age of 28 days and the values are summarized in figure 5.3. The flexural strength was performed by using digital UTM having capacity of 10000kN. The Beam dimension is 100mm X 100mm X 500mm were used to determine the flexural strength. The flexural strength is taken by the average of three beams of flexural strength. The results of flexural strength of various mixes are shown in table.12

Table 12. Flexural strength of concrete mixes

Mixes	Flexural strength(N/mm^2)
M0	5.87
M1	6.18
M2	6.23
M3	6.28
M4	6.45
M5	6.25
M6	6.05

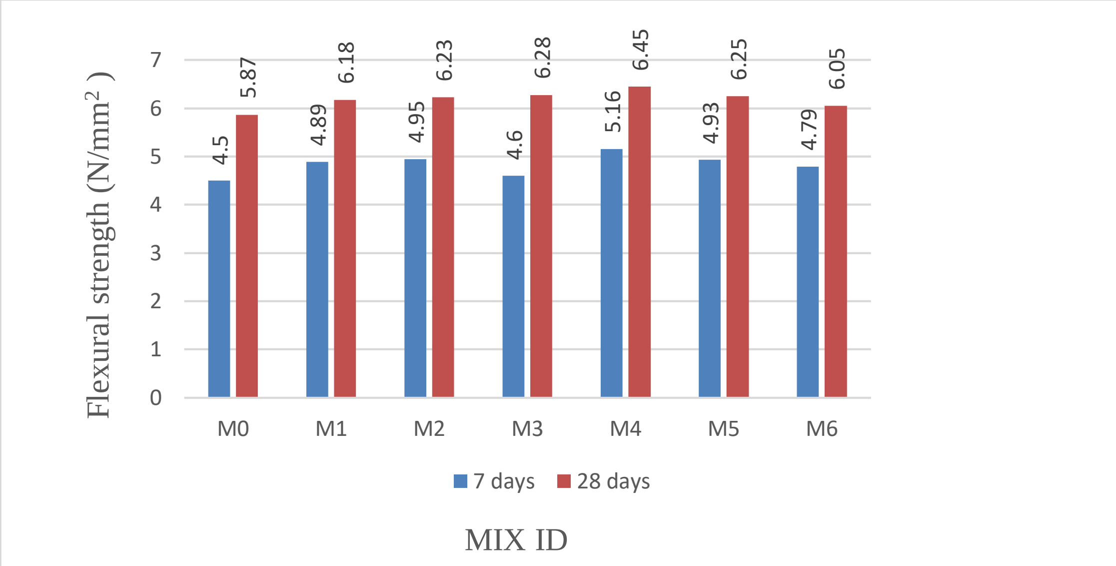

Figure4.3 Flexural strength of mixes after 7 and 28 days

Figure 4.3. shows the 7 and 28days Flexural strength of concrete developed with ordinary Portland cement, various percentages of GGBS, optimum Silica fume, optimum Laterite soil, fine aggregate and coarse aggregate. It can be observed from results that, with the replacement of cement and fine aggregate by silica fume and Laterite soil, the flexural strength of beam both at 7 and 28 days decreased slightly, initially, and then increased with further increase in replacement levels till M4 i.e., GGBS variation of 15% & optimum silica fume (10%) with cement replacement and optimum laterite soil (15%) with fine aggregate. Further increase of replacement of GGBS shows decrease in flexural strength pf beam. At M4 mix i.e., 15% GGBS with optimum silica fume and optimum laterite soil content, the mix showed the flexural strength of beam, gives the better strength, which is on par with the conventional mix.

4.4 Durability Properties

An analysis of concrete's durability is crucial to maintaining any concrete's quality. Recording the concrete's durability performance under various environmental circumstances is the primary goal of durability studies on concrete. The primary tests used to assess the longevity of high-performance concrete are the acid, sulphate and chloride attack tests. Both M0 and M4 concrete cubes of size 100mm*100mm*100mmwerecastto test durability against acid, sulphate and chloride.

4.4.1 Acid attack

A duration of 28 days was used to cure concrete cubes with a size of 100mm*100mm*100mm. Samples were allowed to cure for 28 days before their surfaces were cleaned and weighed. The materials were submerged in an HCL hydro chloric acid solution. Regular checks were made on the solution. The samples were taken out of the solution after 28 days. Table 13 displays the percentage loss in strength and the percentage loss in weight that were calculated. Hydrochloric acid (5% by volume) was combined with regular water to conduct this test.

Table 13 Acid attack test values

Mix	Acid attack Saturated dry weight		% Weight loss	Compressive strength in MPa		%strength loss
	Weight Before exposure	Weight After exposure		Strength Before exposure	Strength After exposure	
M0	2.638kg	2.09kg	20.77	42	23.5	44.04
M4	2.666kg	2.16kg	18.97	48	31.5	34.37

4.4.2 Sulphate attack

The process of sulphate assault on concrete is multifaceted, involving both chemical and physical attacks by sulphates from soil, groundwater, or seawater, as a result of salt crystallization. Concrete may expand, crack, lose strength, and spall as a result of sulphate attack. Concrete cubes measuring 100 mm were cast and left to cure for 28 days in order to conduct this test. 28 days following after the samples were cured, the cubes' surfaces were cleaned and weighed. A magnesium sulphate solution was used to submerge the samples. The solution was routinely examined. 28 days later, the samples were taken out of the solution. Table 14 displays the percentage strength decrease that was calculated. Magnesium sulphate (5% by volume) was combined with regular water to conduct this test.

Table 14: sulphate attack test values

Mix	Sulphate attack – Saturated dry weight		% Weight loss	Compressive strength in MPa		% Strength loss
	Weight before exposure	Weight after exposure		Strength before exposure	Strength after exposure	
M0	2.620kg	2.519kg	2.51	42	35.6	15.2
M4	2.656kg	2.565kg	3.426	48	43.33	9.72

4.4.3 CHLORIDE ATTACK

The worst opponent when it comes to concrete durability is chloride attack. Nearly 40% of concrete structural failures are caused by it. Chloride attack weakens and corrodes steel in the presence of oxygen and water, reducing the structure's strength and longevity. 28 days were spent curing 100mm *100mm*100mm concrete cubes in order to conduct this test. The samples were cured for 28 days, and then the cubes' surfaces were cleaned and weighed. The samples were submerged in a sodium chloride solution. Regular checks were made on the solution. The samples were taken out of the solution after 28 days. Table 15 displays the percentage of strength loss that was calculated. This test was conducted by mixing 5% by sodium chloride with water.

Table15 chloride attack test values

Mix	Chloride attack – Saturated dry weight		% Weight loss	Compressive strength in MPa		% Strength loss
	Weight before exposure	Weight after exposure		Strength before exposure	Strength after exposure	
M0	2.628kg	2.554kg	2.81	42	37.66	10.33
M4	2.652kg	2.582kg	2.639	48	44.66	6.9

5.3.4 Water absorption

One of the most important properties of a good quality of concrete is low permeability. We followed the resistant to freezing and thawing is used to determine the rate of water absorption by concrete specimen it is led to measure the increased mass of the specimen resulting from absorption of water as a function of time when only surface of the specimen is exposed to water as in below Table 16.

Table 16 : Water absorption test values

Mix	Water absorption		% of water absorption
	Weight before exposure (kg)	Weight after exposure (kg)	
M0	2.586	2.610	0.919
M4	2.620	2.642	0.83

5. Conclusion

Based on above study, the following observations are made regarding the strength properties of concrete on partial replacement of cement by Laterite soil and minerals admixture such as GGBS and silica fume.

The present research is intended to find the effective ways to utilize the natural resources and industrial wastages i.e., Laterite soil, silica fume and GGBS.

1. At 15% GGBS with optimum silica fume and laterite soil shows the better results than the conventional concrete.

2. Use of superplasticizer increases the workability of concrete.

3. As evident from the results and discussion presented, increasing GGBS content in Laterised concrete with optimum silica fume and optimum laterite soil showed decreasing trends in the strength parameters. Hence, the amount of GGBS content to be adopted in the mix certainly depends on the nature of construction and strength requirements.

4. This replacement of cement and fine aggregate by GGBS & silica fume and locally available laterite soil can reduce the construction cost and also it reduces the over exploitation of natural resources.

5. For the Mix designated by M4, the mechanical properties increase by 12%,14% & 9% respectively for compressive strength, split tensile strength and flexural strength compared to control mix.

6. Laterised concrete (M4) has less % strength loss compared to conventional concrete(M0) in acid attack after 28 days which cubes are impressed in 5% HCL solution with water.
7. Maximum compressive strength at M4 mix i.e., 48N/mm^2 for 28 days
8. Laterised concrete has given better results when compared to conventional concrete with super plasticizer.
9. Laterised concrete (M4) has less % strength loss compared to conventional concrete (M0) in sulphate attack after 28 days which cubes are impressed in 5% $MgSO_4$(Magnesium sulphate) solution with water.
10. Laterised concrete (M4) has less % strength loss compared to conventional concrete (M0) in sulphate attack after 28 days which cubes are impressed in 5% NaCl (sodium chloride) solution with water.

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