EXPERIMENTAL INVESTIGATION ON CHEMICAL ACTIVATION OF SUPPLEMENTARY CEMENTITIOUS MATERIALS FOR MAKING CONCRETE

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ABSTRACT

Supplementary cementitious material (SCMs) is material used as partial replacement of Portland cement to improve both fresh and hardened concrete properties. The SCMs most commonly used in concrete exposed to chlorides are C fly ash, F Fly ash, GGBFS, silica fume, The use of SCMs can improve concrete's durability, resistance to degradation due to multiple mechanisms, and strength gain behaviour. The different types of SCMs will be analysed on the basis of Pozzolanic Reactivity test. Furthermore, SCM will be selected for the chemical activation. Chemical activation of SCM involves the use of different chemical activators to modify its physical and chemical properties. There are some general chemical activators such as, Ferric Chloride, potassium hydroxide, sodium silicate. The evaluation of fresh and hardened concrete obtained by chemical activation shall be carried out and the results shall be compared with the standard properties of concrete

Keyword: SCM's, durability, Strength, Pozzolanic Reactivity Test, Ferric Chloride, Chemical Activation

1.Introduction

1.1SCM's (Supplementary Cementitious Materials)

Supplementary cementitious materials (SCMs) are now often added to concrete, either independently in the concrete mixing process mixing or in blending concrete. A workable way for partially substituting the use of Portland cement (PC) is to employ SCMs such as fly ash produced burning coal or blast-furnace slag, which is a by-products of pig iron manufacture. In addition to utilizing waste products of manufacturing techniques, the application of these substances, in the absence of an additional clinkering process, results in an important decrease of emissions of carbon dioxide per tons of cement-based products (since the energy required for concrete transportation, combining and crushing is much lower than that of clinkering). Supplementary Cementitious Materials (SCMs) are essential elements of contemporary mixtures of concrete, intended to improve a range of physical characteristics. Of them, fly ash which is produced by the burning of coal in power plants stands out as a typical SCM. Its transparent, small particles not only increase practicality but additionally boost for a long time toughness and lower heat of hydration all while recycling a manufacturing by-product. Ground Granulated Slag from blast furnaces (GGBFS), a by-product of the blast furnaces used to produce iron, is another often used SCM. GGBFS is useful in concrete usage because it increases sulphate obstruction, decreases permeability, which and improves durability. The tiny fragments of silica fume, which are produced during the manufacturing of silicate and iron silicon alloys, fill the spaces between the particles in cement. This functions in the role of pozzolanic substance, improving initial strength and lowering the danger of an alkali-silica reactions. It also imparts higher strength, decreased permeability, which and better durability against chemicals assault. enhances durability, lowers permeability, which and increases compression strength. Organic the pozzolans supply a range of qualities that make them viable substitutes, such as improved practicality and improved long-term performance. When taken as a whole, these SCMs that are provide benefits that span from financial benefits to planetary long-term viability which makes them essential components in the creation of long-lasting and sustainable practical solutions.

Supplemental cementitious materials, or SCMs, are added to concrete because they reduce prices, emit less greenhouse gasses, and improve the strength of the material. Prior to being utilized in concrete because it is necessary to ascertain whether a substitute SCMs that are inert substances, invisible the hydraulic or metallic. As a result, it's crucial to determine the response of SCMs, which is here defined as a) the degree to that SCMs that are react to moisture and calcium hydroxide and b) the degree to that SCMs that are interact with moisture after activation. However, because SCM reactions in cement are complicated, this reactivity may not be identical as the amount of response of SCMs in cement. The use of SCMs can delay the hydration of cement because of the release of aluminium during the SCM's dissolution, but it also helps to produce the filler effect, which is a rise in the cement amount of response owing to the SCM's actual presence. A number of factors, such as SCM fineness, replacement rate, water-to-cementitious material proportion, and cement and SCM the subject of chemistry affect how reactive SCMs are in concrete.

1.2 Activation of SCM’s
Activation of supplementary cementitious materials involves treating these additives, such as fly ash, slag, or silica fume, with specific chemicals to boost their ability to react and strengthen concrete when mixed together.
A popular activating technique uses chemical processes. Alkali solutions, calcium hydroxide, and other specific activators can be used in these therapies. The particular SCM and the intended concrete qualities determine which activation is best. By adding these substances, the SCM particle' surface properties are intended to be altered, improving their ability to interact with cementitious materials during the process of hydration. By improving SCMs that are' overall responsiveness, this alteration makes it possible for them to contribute to the strength and lifetime of concrete more successfully.
The pozzolanic processes that occur inside the concrete matrix are influenced by the activating process. Additional cementitious compounds are formed by pozzolanic reactions, which combine reactive SCM particles with calcium hydroxide generated during the hydration of cement. Concrete's mechanical properties are enhanced by the development of denser and more refined microstructures, which is facilitated by activated SCMs. The lifespan of concrete structures can be eventually expanded by the greater reactivity of SCMs, which can also result in decreased permeability, enhanced durability against chemical assaults, and enhanced initial toughness. Study in this area focuses on optimizing doses and activating times in addition to identifying efficient activating agents. Obtaining maximal responsiveness while minimizing any possibility of detrimental impacts on the general efficiency of the concrete is the aim. The microstructural alterations brought about by SCM activating are characterized by the use of sophisticated analytical techniques such as thermogravimetric evaluation (TGA), X-ray diffraction (XRD), and scanning electron microscopy (SEM). Understanding the process of SCM activating is essential for creating high-performing and sustainable concrete. Researchers and industry experts may help promote sustainable construction techniques and create structures with better durability and longevity by realizing the full strength of these materials. Investigation of SCM activation techniques is a dynamic topic of research that is constantly improving our comprehension of the complex function these materials will play in influencing concrete technologies of years to come.

1.3Chemical Activation
Chemical activation refers to the process of enhancing the reactivity of certain materials, like supplementary cementitious materials in concrete, by adding specific chemicals. This augmentation improves their ability to participate in reactions that contribute to the strength and durability of the final product. In order to improve the ability to react and efficiency of these materials in building applications, a complex and important area of current concrete research is the chemically activated state of Supplemental Cementitious Materials (SCMs). Because SCMs may reduce environmental impact and enhance a variety of concrete qualities, they have become essential ingredients in sustainable concrete formulations. Examples of these include fly ash, GGBFS, and silica fume. One

primary objective of chemical activation is to enhance pozzolanic reactions within the concrete matrix. Pozzolanic reactions involve the combination of SCM particles with calcium hydroxide generated during cement hydration, resulting in supplementary cementitious compounds. Activated SCMs contribute to the refinement of microstructures in concrete, fostering improved mechanical properties. This refinement translates into enhanced early strength, reduced permeability, and heightened resistance to chemical aggressors, thereby extending the service life of concrete structures. It is not just an academic endeavour to chemically activate SCMs; there are significant ramifications for concrete with high performance creation and sustainable building methods. Through the process of revealing the latent reactivity of SCMs, scientists and experts in the field advance the field of concrete technology, promoting ecologically conscious building practices and the development of structures that possess outstanding resilience and durability.

2.Literature

- .Beibei Sun a, Yubo Suz, Guang Ye, Geert De Schutter 2017, An environmentally friendly and economically viable concrete type termed bfs/fa-aac was the subject of an investigation research. It is composed of fly ash and blast furnace slag. The difficulty stemmed from the unclear mix design. They conducted studies to examine the effects of curing time and specific material ratios on the concrete. They discovered that the composition and amount of water had a significant impact on the material's workability and compressive strength. Based on their research, they created a workable mix design technique that demonstrates how the paste content and mixture composition greatly affect how simple it is to work with concrete. Additionally, they discovered that when the water concentration is between 160 and 195 kg/m³, certain elements affect the durability of the concrete. Their strength prediction approach turned out to be very precise. Overall, the concrete mixtures created using their technique had favourable environmental benefits and functioned well throughout its fresh and hardened phases.
- Sarah Fernando, Chamila Gunasekara, David W. Law, M.C.M. Nasvi, Sujeeva Setunge, Ranjith Dissanayake 2021: This study concentrated on bfs/fa-aac concrete, which is comprised of blast furnace slag, fly ash, and among other components. This concrete not only reduces money but also benefits the environment. Determining the ideal mixing method was the difficult part. They conducted studies to examine the effects of various factors on the concrete, such as specific ingredient ratios and curing times. They discovered that the composition of the components and the amount of water used had a significant impact on the material's practicality and strength during compression. Based on their newfound knowledge, they developed a workable mix design technique. This technique demonstrated that the amount of paste and ingredients in the mix actually affect how easy the concrete is to deal with. Additionally, they discovered that when the water concentration is between 160 and 195 kg/m3, certain elements affect the strength of the concrete. It turned out that their method of strength prediction was really accurate. Ultimately, their developed concrete mix performed admirably both in its fresh and hardened forms, and it was environmentally friendly.
- Hailong Ye, Le Huang 2021: This work investigated the production of a robust and sustainable cement-like material by alkali-activation, a technique that uses a large amount of fly ash (HVFA). A variety of factors were investigated, including the activation liquid (water, NaOH, Na2SO4, Na2CO3), the addition of silica fume, and the length of time it was left to cure. The strongest HVFA was Na2SO4-activated, followed by Na2CO3, NaOH, and water, according to the data. The material shrank more when alkalis were added, mostly because they changed the material's stiffness and flexibility. After NaOH-activated HVFA shrunk the most, Na2CO3 and Na2SO4 did as well. If silica fume was present, longer curing times significantly decreased shrinkage; otherwise, there was no effect of time to cure on shrinkage. whichever of the liquid utilized, the investigation revealed that silica fume slowed down the process but enhanced the material's strength.

- Gang Xu, Xianming Shi 2019: This work investigates the production of a robust material without the need of heat utilizing specific types of coal fly ashes. To arrange tests and develop models to comprehend the many elements influencing fly ash mixture strength, they employed a design strategy. They also examined the mixture's surface resistivity after 28 days and how simple it is to deal with (lump flow). To increase strength and durability, two various kinds of fly ash and chemicals were added to the first batch of combinations. These combinations exhibited a 28-day strength of 2.9–20.5 MPa in the absence of any chemical activation. The second set of experiments saw an increase in strength (16.8–33.6 MPa) by using a single variety of fly ash with different chemical activators. Under a microscope, the activators were shown to be essential for the dissolution of fly ash particles and the hydration-based formation of robust materials.
- Qing-feng Liu, Yuxin Cai, Hui Peng, Zhaozheng Meng, Shishir Mundra, Arnaud Castel 2015: This study investigates an alternative kind of ecologically friendly concrete to ordinary cement. They concentrated on the durability of alkali-activated fly ash/slag (AAFS) concrete, paying particular attention to problems like corrosion of the steel bars within and penetration of chloride. To investigate the movement of chloride through this concrete and the potential onset of corrosion, they developed an intricate computer model. The study discovered that the primary factors influencing chloride penetration and steel bar corrosion are the quantity of slag and the water to binder ratio. These elements lessen the concrete's porosity. It's interesting to note that relative to other elements, the quantity of aggregate (rocks) in the concrete has less of an effect. Their methodology aids in forecasting the lifespan of these environmentally friendly concrete constructions.

3.Materials

In the critical phase of material selection for the project, the emphasis is placed on choosing supplementary cementitious materials (SCMs) that not only align with availability but also meet the specific requirements of the project. Among the key SCMs under consideration are fly ash, slag, and silica fume, each offering unique properties that can significantly influence the performance and sustainability of the resulting concrete.

3.1Fly Ash Class C:

Definition: Class C fly ash is a by-product of coal combustion that contains a higher percentage of calcium oxide and is generally self-cementing.

Table No 1 Physical properties of Class C fly Ash

Sr No.	**Physical Tests**	**ASTM C 618 limit**	**Results**
1	Fineness	34 Max	15.9
2	Pozzolanic Activity Index	75 Min	79
3	Water Requirement	105 Max	89
4	Soundness	0.8 Max	0.11
5	Specific Gravity	-	2.58

3.2Fly Ash Class F:

Definition: Class F fly ash is a byproduct of coal combustion with pozzolanic properties, typically produced from burning anthracite or bituminous coal.

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Table No 2 Physical properties of Class F fly Ash

Test No.	Test	Unit	IS-3812Part1 Specification	Test Results
1	Fineness- Specific Surface by Blaine's permeability Method (Min.)	m^2/kg	320	382
2	ROS # 500 (25 MIC)	%	Not Specified	-
3	ROS # 350 (45 MIC) Max	%	34	13.24
4	Lime Reactivity (Minimum)	N/mm^2	4.5	5.89
5	Moisture Content (Max)	%	2	0.23
6	Autoclave expansion (Max)	%	0.8	0.026
7	Compressive strength at 28 days Pozzocrete + Cement mortar Plain Cement Mortar	N/mm^2	80% of strength of plain cement mortar cubes (Minimum)	44.5 48.0 92.71 %

3.3 Ground Granulated Blast Furnace Slag (GGBFS):

GGBFS, a by-product of the iron and steel industry, is recognized for its latent hydraulic properties. It not only enhances concrete durability but also contributes to sulfate resistance. The consideration of GGBFS is closely tied to its availability in regions with active iron and steel production, and its inclusion in the material mix aims to optimize both structural and environmental performance.

Table No 3 Physical properties of GGBFS

SrNo.	Characteristics	Requirements	Test Results
1	Fineness (M/kg)	275 (Min)	390
2	Specific Gravity		2.85
3	Particle Size (Cumulative %)	45 Micron	97.10

3.4Silica Fume:

Produced during the manufacturing of silicon and ferrosilicon alloys, silica fume's ultrafine particles impart exceptional strength and durability to concrete. Despite potential limitations in availability, particularly in comparison to more widely used SCMs, its unique properties make it indispensable for projects demanding high-performance concrete.

The following are the physical properties of procured silica fume

Table No 4 Physical Properties of Silica Fume

Sr No	Physical Properties	Results
1	Physical state	Micronized powder
2	Oduor	Odorless

3	Appearance	White colour powder
4	Color	White
5	Pack Density	0.77 gm/cc
6	pH of 5% Solution	6.91
7	Specific Gravity	2.64
8	Moisture	0.055%
9	Oil Absorption	54 ml/100 gms

4.Result/Analysis:
4.1Normal Test On Scm's
1) Normal Consistency- A consistency test on cement is a procedure used to determine the workability or flowability of cement paste, which is a crucial property in the construction industry. The test involves measuring the resistance of the cement paste to deformation and is typically conducted using a device called the Vicat apparatus or a flow table.
Observed: The normal consistency of OPC 53 grade cement was observed to be 32 %, whereas the increase in the content of GGBFS replacement resulted in increase in consistency.

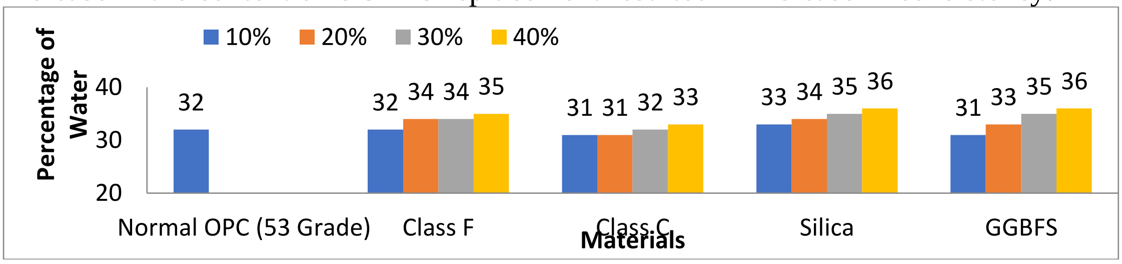

Fig.1 Normal Consistency Result and Analysis

2) Initial and Final Setting Time: The initial and final setting time of ordinary Portland cement was observed to be 227 minutes and 250 minutes respectively. It was observed that the initial setting time had increased with increase in replacement percentage of GGBFS and was maximum of 174 minutes for 40 % replacement, but was less than the time of OPC. Also, there was increase in final setting time with increase in replacement percentage, which was 197 minutes at 30% replacement and there was decrease in final setting after this replacement level of 30%.

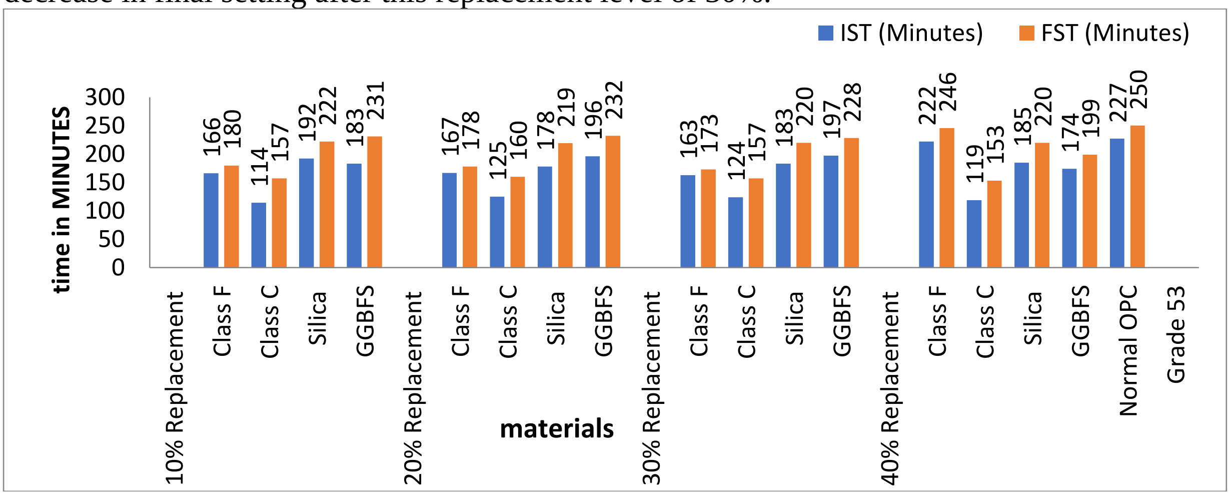

Fig.2 Initial and Final Setting Time Result and Analysis

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3) Loss-on-ignition : Is a standard test for SCMs that is usually used to determine the presence of an excess quantity of moisture and/or undesirable impurities, such as carbon. The test normally refers to a mass loss in a sample heated to up to a maximum of 1,000 °C. The volatile materials lost usually consist of 'combined water' and carbon dioxide from carbonates. It may be used as a quality test.
Observed: The loss on ignition of ground granulated blast furnace slag was observed to be 0.05%, which satisfies the standard criteria of 5%.

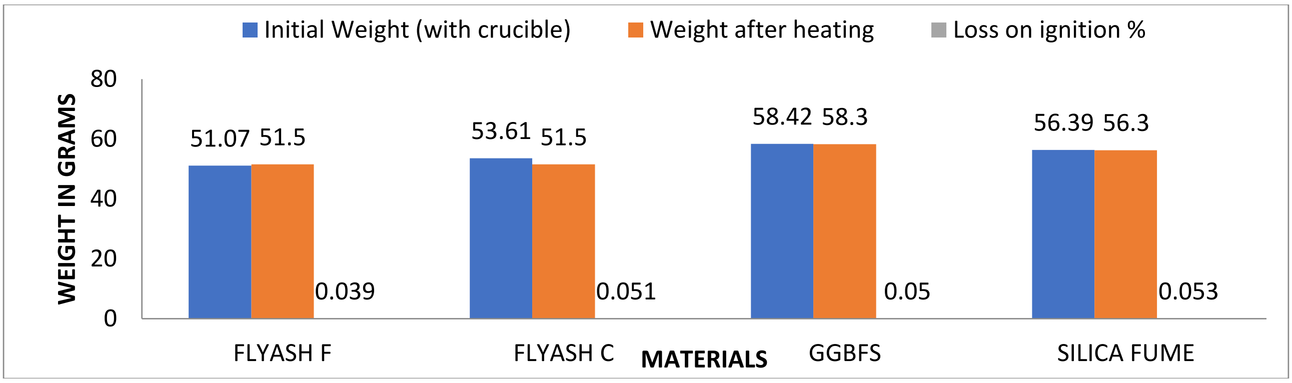

Fig.3 Loss on Ignition Result and Analysis

4) Fineness Test : The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster the development of strength. Wet sieving is used to remove fines of materials that may be difficult to sieve, prior todrying and testing a sample normally
Observed : The fineness of ground granulated blast furnace slag was observed to be 8.6%., which satisfies the standard criteria of 10%.

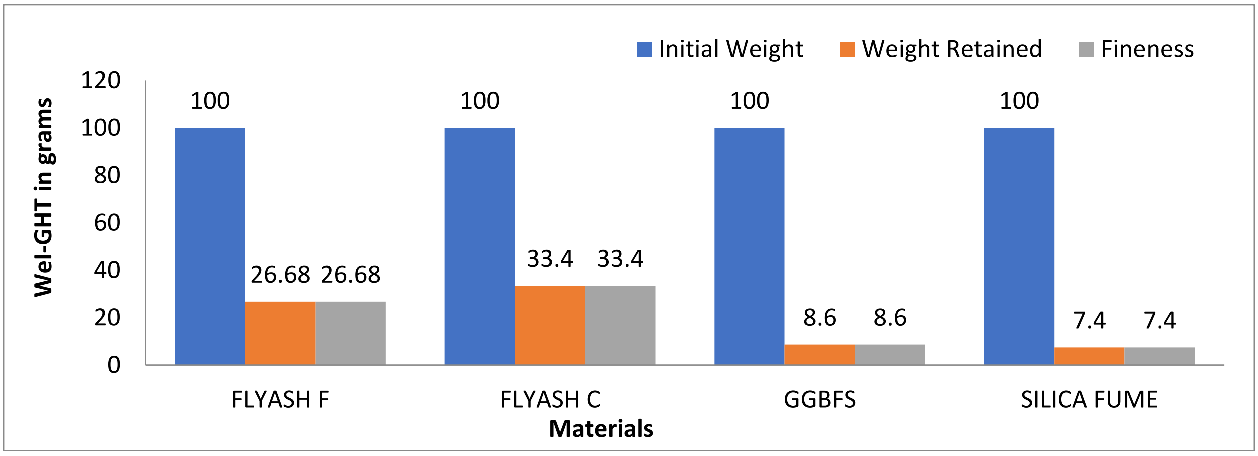

Fig. 4 Fineness Test Result and Analysis

5)Specific Gravity : Specific Gravity test is the ratio of the density of a substance to the density of a reference substance at a fixed temperature. So, if the specific gravity of any substance is known to us we can use the materials in a suitable place for any work. Concrete design is heavily influenced by a number of important parameters, one of the most important being the density of the cement. Due to the volumetric nature of the concrete mix concept, density is the most crucial component to consider. The specific gravity of fly ash usually ranges from **2.1 to 3.0.**
Observed : The specific gravity of ground granulated blast furnace slag was observed to be 2.86, which is in the range of 2.1 to 3.0.

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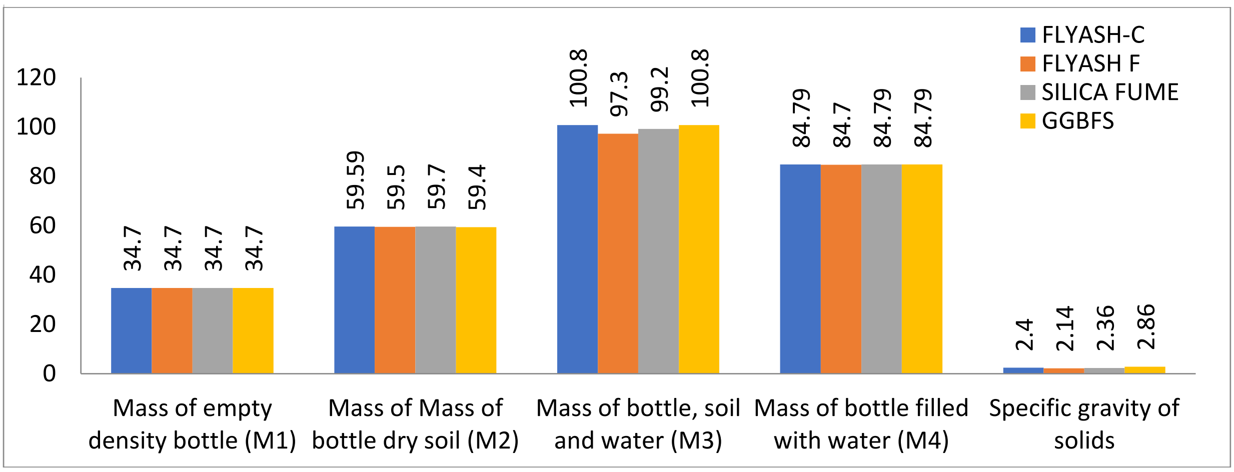

Fig.5 Specific gravity Result and Analysis

6) Strength Activity Index: The average compressive strength of 7 days for controlled specimen was observed to be 5.85 N/mm² and the 7 days strength for Ground Granulated Blast Furnace Slag was observed to be 10.13 N/mm², therefore representing a strength activity index of 173.16%, which is above the standard value of 80 %, thus satisfying the criteria and considered to be developing pozzolanic reactivity.

4.2Result

4.2.1Compressive Strength

A). Normal Cube

Table No 7 Compressive Strength Normal Cube

Sr. No	**Specimen Name**	**7 Day**		**28 Day**		**Average**
		KN/m²	**N/m²**	**KN/m²**	**N/m²**	**N/m²**
1.	1 Cube N	529.8	23.54	_	_	**25.08**
2.	2 Cube N	514.1	22.84	_	_	
3.	3 Cube N	559.8	28.88	_	_	
4.	4 Cube N	_	_	820.4	36046	**39.83**
5.	5 Cube N	_	_	976.7	43.40	
6.	6 Cube N	_	_	892.1	39.64	

B). 20% Replacement

I. Cube

Table No 8 Compressive Strength 20% Replacement Cube

Sr. No	**Specimen Name**	**7 Day**		**28 Day**		**Average**
		KN/m²	**N/m²**	**N/m²**	**N/m²**	**N/m²**
1.	1 Cube 20%	495.7	22.03	_	_	**22.77**
2.	2 Cube 20%	529.1	23.51	_	_	
3.	3 Cube 20%	512.9	22.79	_	_	
4.	4 Cube 20%	_	_	948.9	42.17	**42.65**
5.	5 Cube 20%	_	_	938.8	41.68	
6.	6 Cube 20%	_	_	992.5	44.11	

C). 30% Replacement

I. Cube

Table No 9 Compressive Strength 30% Replacement Cube

Sr. No	Specimen Name	7 Day		28 Day		Average
		KN/m^2	N/m^2	KN/m^2	N/m^2	N/m^2
1.	1 Cube 30%	579.1	25.73	_	_	
2.	2 Cube 30%	544.0	24.17	_	_	**25.25**
3.	3 Cube 30%	581.9	25.86	_	_	
4.	4 Cube 30%	_	_	983.0	43.68	
5.	5 Cube 30%	_	_	1113.0	49.68	**47.28**
6.	6 Cube 30%	_	_	1096.0	48.71	

D). 40% Replacement

I. Cube

Table No 10 Compressive Strength 40% Replacement Cube

Sr. No	Specimen Name	7 Day		28 Day		Average
		KN/m^2	N/m^2	KN/m^2	N/m^2	N/m^2
1.	1 Cube 40%	544.7	24.20	_	_	**23.64**
2.	2 Cube 40%	521.4	23.17	_	_	
3.	3 Cube 40%	530.0	23.55	_	_	
4.	4 Cube 40%	_	_	1002.0	44.53	
5.	5 Cube 40%	_	_	1102.0	48.97	**47.64**
6.	6 Cube 40%	_	_	1112.0	49.42	

5.Conclusion

Promising outcomes were found in the experimental study on the chemical activation of additional cementitious materials for the formation of concrete. The concrete's strength and longevity were strengthened as a result of the activation process' increased responsiveness. This indicates the possibility of using chemically activated additional materials to create more sustainable and effective building techniques. For widespread adoption and effective application in the construction business, more investigation and optimization are advised.

The study emphasizes how using more cementitious ingredients for concrete production might benefit from chemical activation. The improvements in mechanical and durability features that have been seen point to an improvement in the overall performance of concrete. However, further study is required for wider adoption in building procedures due to obstacles including understanding long-term impacts and improving activation agents. All things considered, this study offers insightful information on developing high-performance and sustainable concrete technologies.

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