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EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE EVALUATION OF CONCRETE BINARY BLENDED WITH FLY ASH AND GGBS

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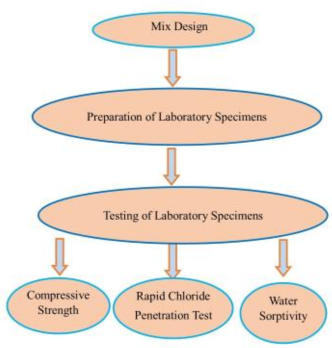
Graphical abstract



Abstract

It is vital for the sustainability of industry to reduce these emissions while still meeting the ever-increasing demand for infrastructure worldwide. This challenge drew the focus of academics, area experts, and researchers to objectivize their work to investigate alternatives to the cement industry. The present study aims to determine how to reduce the amount of cement by using GGBS and fly ash The study adopted the binder ratios of 0.3,0.4, and 0.5 for both Fly ash and GGBS and compared them with conventional concrete (OPC). Further, the RCPT test examines the durability of the resistance to chloride penetration across different durations, such as 28,56 and 90 days. Also, the sorpitivity test is performed for the above binder ratios to determine the susceptibility of the concrete. The results suggest that the binder ratios adopted for the study have shown better results compared to conventional concrete if the supplementary cementitious materials are restricted to specific percentages.

Keywords: Compressive strength, sorpitivity, RCPT, and supplementary cementitious material

1.0 INTRODUCTION

Concrete, recognized for its strength, adaptability, and durability, is one of the building materials utilized globally in the most significant quantity. Several unique benefits may be gained by partially replacing concrete components [1]. It is possible to drastically lower the need for conventional raw materials if alternative materials, such as fly ash, slag, or silica fume, are used as partial substitutes for cement [2]. This not only helps preserve natural resources but also lessens the damage caused to ecosystems and cuts down on the energy required throughout the mining process. These alternative resources, often leftovers of different industries, are considered trash without other uses [3-4]. This strategy contributes to the circular economy, which means that waste is kept to a minimum and resources are used as effectively as possible; as a result, the ecological impact of the construction sector as a whole is reduced [5-6]. For instance, using silica fume or metakaolin as a partial substitute for cement in concrete may significantly increase the material's strength and its resistance to chemical attack [7]. In addition, the employment of partial material substitutions allows more flexibility in building [8]. This versatility makes it possible to create novel approaches to construction, such as lightweight concrete, self-compacting concrete, or high-performance concrete, all of which provide distinct advantages when used in various contexts [9-10].

The use of fly ash as a supplementary cementitious material (SCM) in concrete production offers several benefits, including improved workability, greater strength, and reduced environmental impact [11-13]. Fly ash is used extensively in this capacity. Regarding availability, fly ash is readily accessible worldwide due to the massive output of coal to produce energy [14-16]. In terms of partial replacement, fly ash may be used in the production of concrete as a partial replacement for cement, often taking the place of a percentage of the cement in terms of its weight [17-19]. The reaction between fly ash and the calcium hydroxide already present in the concrete results in the formation of extra cementitious compounds, increasing the concrete's strength and durability [20]. Incorporating fly ash into concrete may increase its workability, reduce heat produced during curing, and boost the material's resilience against chemical and corrosive assaults [21].

Utilizing a waste product and lowering the need for clinker manufacture are two ways fly ash may help reduce the carbon footprint allied with the production of concrete [22]. Based on the findings of prior research, it has been discovered that the use of fly ash, which is a material that has been finely split, may assist in increasing the workability of concrete [23]. Its spherical particles function like ball bearings, increasing the concrete mixture’s flowability while lowering the required amount of water [24]. Because of this, the simplicity of placement and compaction is increased, making it much simpler to reach the appropriate level of consolidation and do away with voids. In addition, regarding the development of higher strength, using fly ash in concrete might lead to increased growth of the power [25]. In the process of hydration of cement, fly ash reacts with the calcium hydroxide that is formed, which results in the formation of additional cementitious compounds. These chemicals contribute to the concrete's long-term strength and durability [26]. According to several studies, adding fly ash to concrete may increase compressive and flexural strengths, particularly at older ages [27]. In addition, research has shown that the durability of concrete that contains fly ash is significantly improved [28]. The consequence of fly ash and calcium hydroxide coming into contact with one another creates more cementitious substances that fill the pore structure and decrease permeability [29]. This leads to better resistance to water penetration, chloride ion invasion, and sulfate assault, enhancing concrete buildings' longevity, particularly in hostile conditions [30].

Another discovery about heat production implies that adding fly ash to concrete can lower the quantity of heat formed during the hydration process [31-33]. This is especially advantageous in giant concrete constructions, such as dams or vast foundations, where excessive heat buildup may lead to thermal cracking. The burning of coal produces fly ash, which may be used as a partial alternative to cement. This helps to lower the demand for virgin raw materials [34-36]. This can be beneficial in terms of cost savings. The cost of fly ash is often lower than cement, making it a more cost-effective choice. In addition to this, the use of it may increase the workability of concrete, which in turn reduces the need for an excessive amount of water and has the potential to lower the total cement content [37-38]. This can potentially result in cost reductions for materials and transportation. Research has shown that the productivity of fly ash in concrete may vary depending on parameters such as the fly ash's quality, the fly ash's composition, the fly ash, the fineness of the fly ash, and the needs of the particular application. As a result, it is advised to carry out mix design experiments, and testing to maximize the dose and guarantee compliance with the concrete attributes sought [39-40].

The term "Ground Granulated Blast Furnace Slag" (abbreviated as "GGBS") refers to a by-product that is abundantly accessible from the iron and steel industries. The granulated and finely ground material is the end product of the manufacturing process for GGBS, which comprises cooling the molten slag produced by a blast furnace with water or steam [41-44]. Because of its pozzolanic and cementitious qualities, ground granulated blast furnace slag (GGBS) is often utilized in concrete as a partial substitute for cement [45]. It is possible to get GGBS in several locations responsible for manufacturing iron and steel [46]. In most cases, cement factories or other specialist suppliers of cementitious materials will be the ones to provide it [47]. The local steel manufacturing sector and the amount of steel it produces both impacts the availability of GGBS. Generally speaking, an ample supply of GGBS may be found in regions that have a considerable spinel sector presence; in areas where there is a lower capacity for the manufacturing of steel, the supply of GGBS may be constrained, and it may be necessary to get it from locations farther away [49]. When GGBS is used as a partial substitute for cement in concrete mixers, the proportion of cement that GGBS replaces may vary based on several variables, including the qualities of concrete that are sought, the requirements of the project, and the applicable standards [50-52].

Additionally, the use of GGBS helps to increase the durability properties of concrete by decreasing the material’s permeability and increasing its resistance to chemical assaults and other types of degradation [53-54]. The improvement's magnitude is contingent on several elements, including the percentage of replacement, the curing conditions, and the exposure environment [55-56]. In addition, GGBS must match the other concrete components, such as aggregates and admixtures. It is essential to be sure that adding GGBS does not have any unfavorable impact on the workability, setting time, or performance of any other concrete additives [57-

58]. And lastly, quality control methods must be implemented to guarantee that GGBS will always have the same high-quality standards. To determine whether or not GGBS is appropriate for use in the manufacturing of concrete, it is necessary to carry out the tests, which include analyzing its fineness, chemical composition, and pozzolanic activity [59-60]. However, while choosing and altering binder ratios for broader mixing in concrete, it is essential to carefully consider a variety of parameters, including the development of strength, workability, durability, and compatibility. An enormous amount of literature is available in the field of utilisation of fly ash and GGBS as supplementary cementitious materials in concrete. Limited research was available to assess the impact of fly ash and GGBS on the chloride ion penetration and sorpitivity properties using different water binder ratios. The present research uses different water binder ration to evaluate sorpitivity and chloride ion penetration using GGBS and fly ash as supplementary cementitious materials. It also helps in the computation of performance-based design specifications of the durability of concrete.

2.0 MATERIALS & METHODOLOGY

The current study is undergoing a qualitative research approach to evaluate the partial replacement of the conventional concrete with materials such as Fly ash and GGBS. Since the availability of the materials is abundant, the cost of traditional concrete and partially replaced concrete is expected to reduce by 30 to 40 %. Further, all the materials are collected. Table 1. displays the chemical composition of cementitious materials. The present research used the binder ratio of 0.3, 0.4, and 0.5 for both fly ash and GGBS mixes. The concrete mix design was prepared as per IS10262. All the preliminary tests for the materials are performed per the Indian code of practice. The compressive strength (CST), RCPT, and sorpitivity tests were conducted for all mixes. A set of control specimens were prepared for comparison. The entire procedure has utilised standard procedures as per the BIS standards. All results are collected per the scheduled time, and the figures are plotted using the origin software by following error graphs.

Table 1 Displays the chemical composition of cementitious materials

S. No	Component	Cement	Fly Ash	GGBS
1	CaO	66.2	8.6	36
2	SiO_2	19.9	57.5	38
3	Al_2O_3	9.2	10.5	18
4	Fe_2O_3	2.2	15.4	0.8
5	MgO	0.8	1.4	1.2
6	SO_3	0.5	0.8	0.8
7	LOI	0.9	4.3	3.7

3.0 RESULTS AND DISCUSSION

The below section illustrates the results obtained from various tests performed on conventional mix design followed by partial replacement with cementitious materials. Mixing proportion with a binder ratio starting from 0.20 to 0.70 was observed for fly ash—likewise, GGBS was another replacement with a similar percentage from 0.20 to 0.70. Further, the results obtained from sorpitivity and RCPT are covered to check the durability and susceptibility of the SCM concrete.

3.1 Compressive Strength

The CST of concrete is a critical feature that defines its load-bearing capability. It can also boost by utilizing high-quality cement, although expensive. A different method is to employ fly ash as a partial replacement for cement. This is an alternative strategy. Fly ash is a waste product produced when coal is burned. Because it is pozzolanic, it forms a cementitious compound when combined with the calcium hydroxide in cement. Fly ash is a waste product. Although the strength of this combination cannot compare to that of cement by itself, it can nevertheless increase the CST of concrete. During this research, the CST of concrete was examined using various percentages of fly ash as a replacement. The typical mix design did not include any fly ash replacement and had a ratio of water to cement of 0.3. This mix design had a CST of 55.56 N/mm2 when tested. The CST was reduced to 54.67 N/mm2 when 20% of the cement was substituted with fly ash. Figure 1 illustrates how the CST of the material continued to diminish up until the 28-day mark as the ratio of fly ash used in replacement increased. As shown in Figure 1, the CST of concrete modified by adding fly ash at 56 and 90 days of age increases up to a point when the fly ash replacement level is 30% but then begins to drop. It has been determined that the content of thirty percent fly ash in concrete at 56 and ninety days will offer acceptable CST while also increasing the benefits of fly ash, such as an improvement in the material's workability and a reduction in its permeability.

The CST of concrete increases up to a replacement level of 30 percentage points worth of fly ash, but afterward, it deteriorates. This is because fly ash needs more time to hydrate than cement does. Because the fly ash has not had sufficient time to hydrate and develop its strength at the end of the 28 days, the concrete that contains fly ash has a CST that is lower than the concrete that does not include fly ash. However, after 56 and 90 days, the fly ash has had time to hydrate and develop its strength, and as a result, the CST of the concrete that contains fly ash is equal to or even higher than that of the concrete that does not have fly ash. The percentage of fly ash that should be present in concrete should be at least 30 percent.

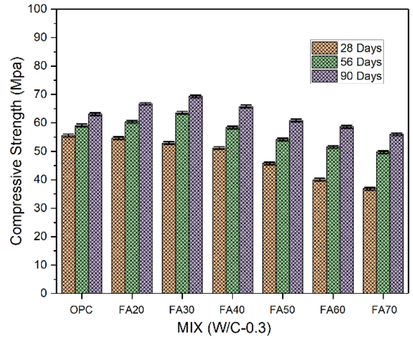


Figure 1 Fly Ash vs. OPC - Compressive Strength of MIX (W/C – 0.3)

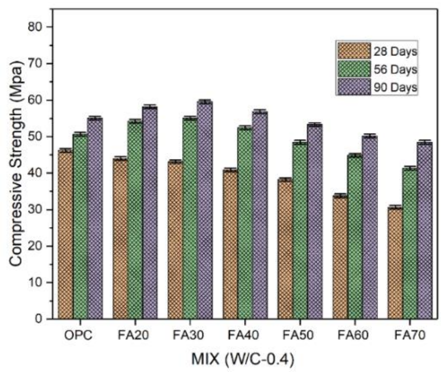


Figure 2 Fly Ash vs. OPC - Compressive Strength of MIX (W/C – 0.4)

The CST of concrete increases up to a replacement level of 30 percentage points worth of fly ash, but afterward, it deteriorates. This is because fly ash needs more time to hydrate than cement does. Because the fly ash has not had sufficient time to hydrate and develop its strength at the end of the 28 days, the concrete that contains fly ash has a CST that is lower than the concrete that does not include fly ash. However, after 56 and 90 days, the fly ash has had time to hydrate and develop its strength, and as a result, the CST of the concrete that contains fly ash is equal to or even higher than that of the concrete that does not have fly ash. The percentage of fly ash that should be present in concrete should be at least 30 percent.

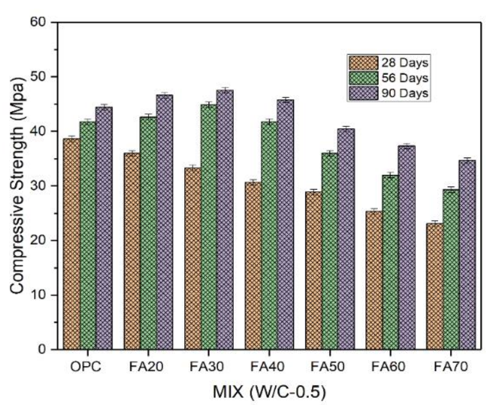


Figure 3 Fly Ash vs. OPC - Compressive Strength of MIX (W/C – 0.5)

Compressive strength is still sufficient for most applications at this degree of replacement, while the additional benefits of fly ash, such as increased workability and lower permeability, are maximized. Fly ash and calcium hydroxide in the cement undergo a chemical process known as the pozzolanic reaction, which forms a cementitious compound. This material, known as tobermorite, is analogous to the cementitious mixture produced when cement hydrates and has the same chemical formula. Because the pozzolanic reaction is a slow process, it takes more time for concrete that contains fly ash to attain the same level of strength as concrete that does not include fly ash. However, because the pozzolanic process can continue for years, concrete containing fly ash may eventually have a CST that is even greater than concrete that does not. According to Figure 2, the CST of the concrete increases up to a 30% fly ash replacement before it begins to decrease. A water-to-cement ratio of 0.4 was utilized in the second mix. The reason behind this is that fly ash takes a longer time to hydrate than cement does. At 28 days, the fly ash in the concrete has not had sufficient time to hydrate and increase its strength; as a result, the CST of the concrete with fly ash is lower than the CST of concrete without fly ash. Because the fly ash has had time to hydrate and become more robust, the CST of the concrete that contains fly ash is comparable to or even higher than the CST of the concrete that does not have fly ash after 56 and 90 days. When paired with a water-to-cement ratio of 0.4, the optimal amount of fly ash for concrete is 30 percent. The third mix had a water-to-cement ratio of 0.5, as shown in Figure 3. As can be seen from this figure, the CST of the concrete increases up to 30% fly ash substitution, but after that, it begins to decrease. This is because fly ash needs more time to hydrate than cement does. At the end of 28 days, the concrete containing fly ash has a lower CST than the concrete that does not. This is because the fly ash has yet to have the time to hydrate and build up its strength. However, after 56 and 90 days, the fly ash has had time to hydrate and establish its strength. As a result, the CST of the concrete that contains fly ash is comparable to or even greater than that of the concrete that does not include fly ash. For a water-to-cement ratio of 0.5, the concrete should have a fly ash content of at least 30 percent. Figure 4 demonstrates a correlation between the percentage of GGBS in the concrete and an increase in its CST when the water binder ratio is set at 0.3. The proportion of GGBS can range from 0 to 70%. After reaching a specific threshold, the amount of GGBS in concrete no longer increases the material's CST; instead, the opposite is true. A GGBS concentration of 20% is optimal for CST. This is because GGBS is a pozzolanic material that combines with the calcium hydroxide in the cement to generate a cementitious compound. The reason for this is that GGBS is a pozzolanic material.

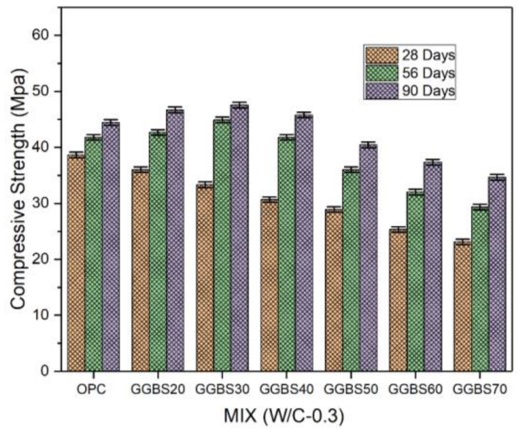


Figure 4 GGBS vs. OPC - Compressive Strength of MIX (W/C – 0.3)

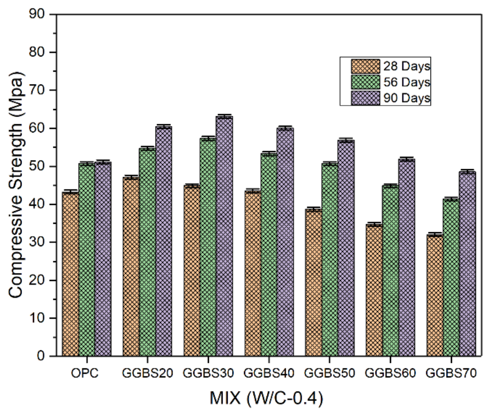


Figure 5 GGBS vs. OPC - Compressive Strength of MIX (W/C – 0.4)

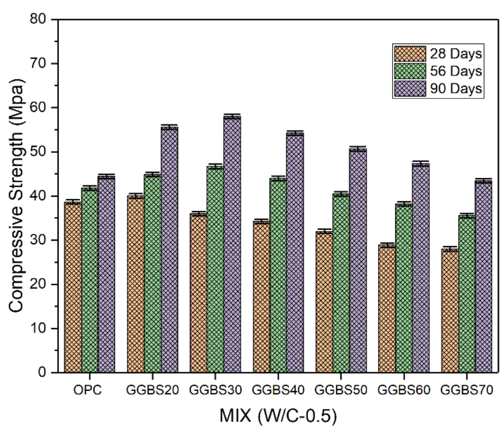


Figure 6 GGBS vs. OPC - Compressive Strength of MIX (W/C – 0.5)

The addition of this ingredient results in concrete that is both more robust and long-lasting. The water-to-binder ratio in concrete (W/C-0.3) is another factor that impacts the concrete's CST. Concrete with a higher strength is produced by using a lower water-to-binder ratio. Because there is less water available to hydrate the cement when there is a lower water-to-binder ratio, the resulting concrete is denser and more durable than one with a higher percentage of water-to-binder. As shown in Figure 5, the amount of ground granulated blast furnace slag (GGBS) included in the concrete mix directly impacts the concrete's CST. The CST of the concrete improves up to a particular point in proportion to the amount of ground granulated blast furnace slag (GGBS) used. After reaching this point, an increase in the amount of GGBS will result in a decline in the CST of the concrete. The ideal percentage of GGBS for CST falls somewhere in the range of 20% to 30%. Figure 6 demonstrates that the addition of ground granulated blast furnace slag (GGBS) to concrete results in an increase in the CST of the concrete up to a certain degree, after which it results in a drop. GGBS percentage of between 20% and 30% is the optimal range for CST. This is because GGBS is a pozzolanic material that combines with the calcium hydroxide in the cement to generate a cementitious compound. The reason for this is that GGBS is a pozzolanic material. The addition of this ingredient results in concrete that is both more robust and long-lasting. On the other hand, if there is excessive GGBS in the concrete, it will become more porous and have a lower strength. GGBS is a filler ingredient that does not contribute to the strength of the concrete. This is the reason why this is the case. The water-to-binder ratio of the mixture also impacts the CST of the concrete. Concrete with a higher strength is produced by using a lower water-to-binder ratio. Because there is less water available to hydrate the cement when there is a lower water-to-binder ratio, the resulting concrete is denser and more durable than one with a higher percentage of water-to-binder. The ideal water balance for the CST binder is usually 0.3 and 0.4. The water-to-binder ratio is 0.5 in Figure 6, which is already a low value. Because of this, there is not as much water available to hydrate the cement, and as a result, the increase in CST caused by the addition of GGBS is not as significant as it would be if there were a higher water-to-binder ratio. Figure 6 demonstrates that adding GGBS results in an increase in CST that is maintained until the GGBS content reaches 20%. After that point, the CST will decrease as the percentage of GGBS in the material will rise. The ideal percentage of GGBS for maximum CST Figure 4 demonstrates a correlation between the percentage of GGBS in the concrete and an increase in its CST when the water binder ratio is set at 0.3. The proportion of GGBS can range from 0 to 70%. After reaching a specific threshold, the amount of GGBS in concrete no longer increases the material's CST; instead, the opposite is true. In most cases, a GGBS concentration of 20% is optimal for CST. This is because GGBS is a pozzolanic material that combines with the calcium hydroxide in the cement to generate a cementitious compound. The reason for this is that GGBS is a pozzolanic material. The addition of this ingredient results in concrete that is both more robust and long-lasting. The water-to-binder ratio in concrete (W/C-0.3) is another factor that impacts the concrete's CST. Concrete with a higher strength is produced by using a lower water-to-binder ratio. Because there is less water available to hydrate the cement when there is a lower water-to-binder ratio, the resulting concrete is denser and more durable than one with a higher percentage of water-to-binder.

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3.2 Rapid Chloride Penetration Test

3.2.1 Fly Ash

Figures 7a, 7b, and 7c show the RCPT (Rapid Chloride Penetration Test) results for varying percentages of fly ash in concrete at various water-to-binder (w/b) ratios and curing times. These results were acquired using the Rapid Chloride Penetration Test. Lower RCPT values imply more excellent performance and increased durability in concrete; higher values suggest that the concrete is more susceptible to chloride penetration. According to the findings, the RCPT values tend to drop when the quantity of fly ash in a mixture rises, which shows that the combination has more excellent resistance to chloride penetration. This pattern is consistent across various curing times, including 28 days, 56 days, and 90 days. For example, assuming a ratio of water to binder of 0.3, a curing time of 28 days, and no fly ash at all (0%), the following would be the results: The value of the RCPT is currently 1617 Coulombs. The value of the RCPT drops to 1162 Coulombs when there is 20% fly ash present. The RCPT value goes down even further to 1044 Coulombs when there is 30% fly ash present. When a higher percentage of fly ash is present, the RCPT values continue to drop, which is a sign of improved durability. A similar pattern is shown for the other ratios of water to binder in the table, which are 0.4 and 0.5, respectively. An increase in the percentage of fly ash in a material typically results in lower RCPT readings, demonstrating increased resistance to chloride penetration. In addition, the RCPT values tend to drop as the curing length increases. This shows that more extended curing periods enhance concrete durability, as evidenced by the lower chloride penetration. This may be inferred from the fact that longer curing durations reduce chloride penetration. The results are not abnormal and the same behaviour was observed while compared with the literature [35].

3.2.2 GGBS

The data presented in the images are divided into three different water-to-binder ratios: 0.3, 0.4, and 0.5. A larger water-to-binder ratio indicates that there is a more significant amount of water compared to the content of the binder, which can affect the concrete's workability and strength—taking a look at the particular RCPT values that result from the different permutations of GGBS concentration, water-to-binder ratio, and curing time.

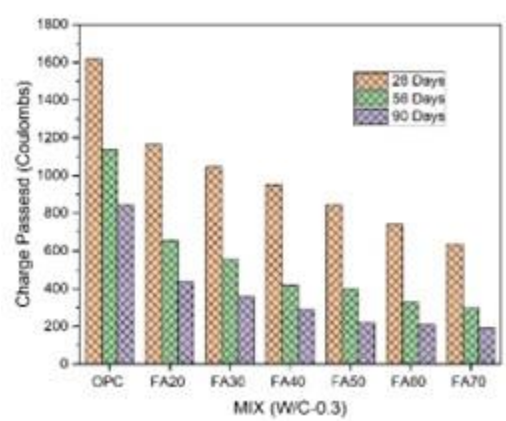

Figure 7a Fly Ash vs. OPC - RCPT of MIX (W/C – 0.3)

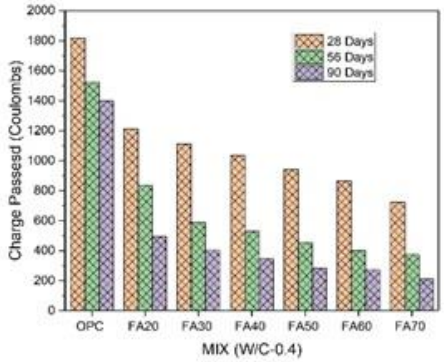

Figure 7b Fly Ash vs. OPC - RCPT of MIX (W/C – 0.5)

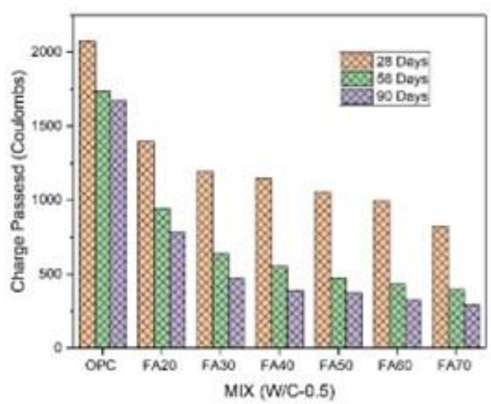

Figure 7c Fly Ash vs. OPC - RCPT of MIX (W/C – 0.4)

There is a general trend toward a decline in RCPT values accompanying an increase in GGBS concentration; this pattern indicates increased resistance to chloride penetration. This pattern is proper regardless of the amount of water in the binder or time spent curing the compound. A higher percentage of GGBS in the concrete mixture increases durability and reduces chloride penetration. When comparing the RCPT values within each GGBS content, smaller water-to-binder ratios often result in lower RCPT values, which indicates superior resistance to chloride penetration. This can be seen by comparing the RCPT values. In most cases, the RCPT values go down while the curing duration increases, indicating an increase in the durability of the concrete over time. Decreased RCPT value and increased chloride penetration resistance can be attributed to longer curing times.

3.3 Water Sorptivity

3.3.1 Fly Ash

The proportion of water to binder is 0.3, as shown in Figure 9(a). At a water-to-binder ratio of 0.3, the combination of 30% fly ash consistently produces low sorption values throughout all three sorption durations (Sor-28, Sor-56, and Sor-90). This is the case regardless of which of the other fly ash percentages is being used.

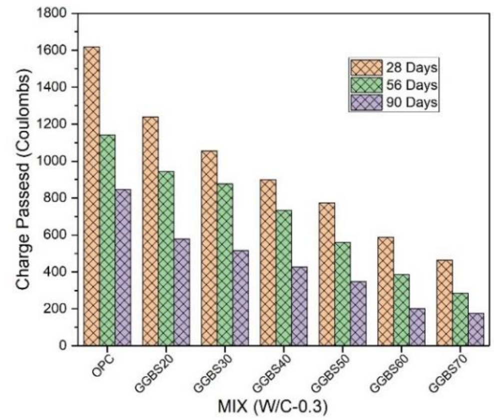

Figure 8a GGBS vs. OPC - RCPT of MIX (W/C – 0.3)

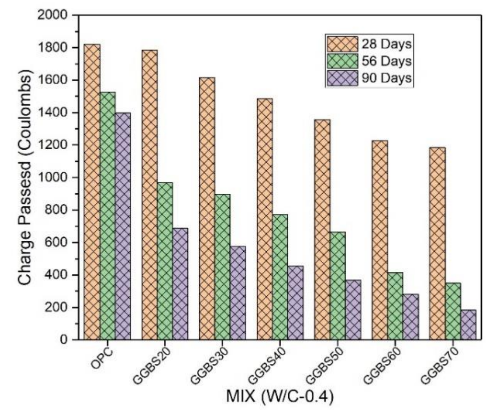

Figure 8b GGBS vs. OPC - RCPT of MIX (W/C – 0.4)

Considering this water-to-binder ratio, 30% fly ash would be a solid option for the optimal combination. As a pozzolanic substance, fly ash has the potential to enhance the performance of concrete by lowering the material's permeability. It can fill up the cracks and cavities within the concrete matrix, decreasing the number of paths via which water can be absorbed. In this instance, the percentage of fly ash in the concrete, which is 30%, achieves the best possible compromise between lowering the permeability of the concrete and preserving its other desirable features. It is expected that the mixture produced by mixing a lower water-to-binder ratio (0.3) with 30% fly ash will have a denser microstructure and a lower permeability because of this combination. This denser structure impedes water flow and lowers the sorption values over a range of sorption durations (Sor-28, Sor-56, and Sor-90), indicating a decreased water absorption rate. From Figure 9(b): water-to-binder ratio: 0.4, The data demonstrates that the sorption values are stable throughout a wide range of fly ash percentages when maintained at 0.4.

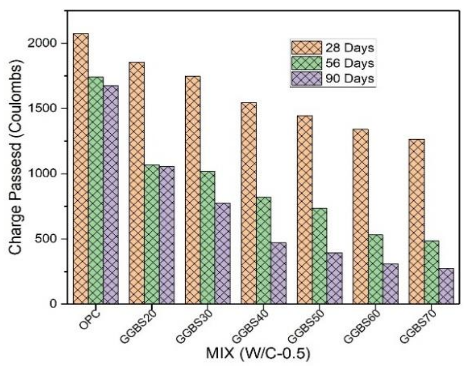

Figure 8c GGBS vs OPC - RCPT of MIX (W/C – 0.5)

However, compared to different percentages of fly ash at the same water-to-binder ratio, the combination of sixty percent fly ash tends to have consistently lower sorption values. As a result, the combination of sixty percent fly ash has the potential to be regarded as the most effective combination for this water-to-binder ratio. When there is a higher percentage of fly ash, there is greater availability of reactive materials, making the pozzolanic reaction stronger. Because of this reaction, additional hydration products are formed, which help to densify the material and bring the porosity down. From Figure 9(c), The water-to-binder ratio is 0.5. The 30% fly ash combination consistently demonstrates lower sorption values across all three sorption durations for a water-to-binder ratio of 0.5. This is the case regardless of the sorption time. This combination is a contender for the most excellent variety considering this water-to-binder ratio. The addition of thirty percent fly ash to the mix achieves a happy medium between lowering the concrete's permeability and preserving its other vital features, such as its strength and workability. It guarantees that the concrete will benefit from the qualities of fly ash without compromising any other essential characteristics. There is a significant quantity of reactive materials provided by the 30% fly ash content, which helps to develop a powerful pozzolanic reaction. This reaction results in the development of new cementitious compounds, which contribute to the densification of the material, a reduction in the amount of porosity, and an improvement in the material's resistance to water absorption.

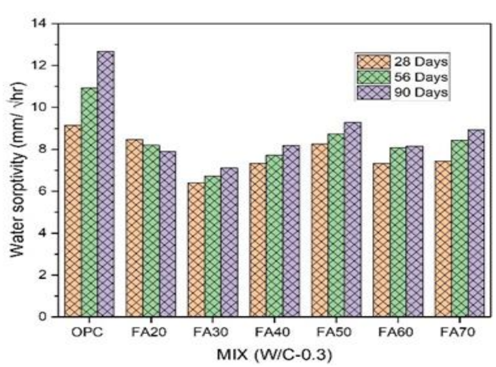

Figure 9a Fly ash vs. OPC - Water Sorptivity of MIX (W/C – 0.3)

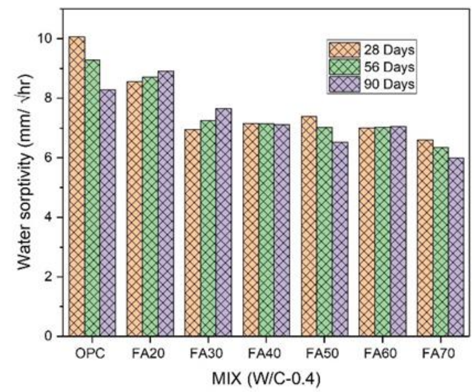

Figure 9b Fly ash vs. OPC - Water Sorptivity of MIX (W/C – 0.4)

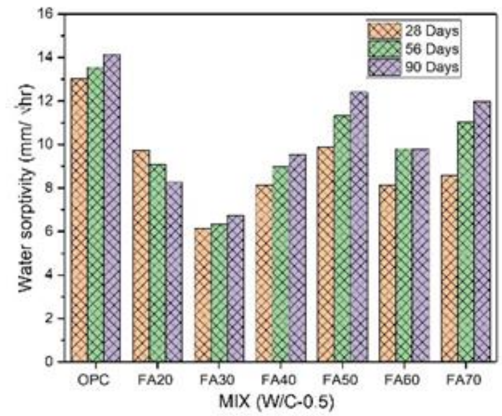

Figure 9c Fly ash vs. OPC - Water Sorptivity of MIX (W/C – 0.5)

3.3.2 GGBS

From Figure 10 (a) Water-to-binder ratio: 0.3, the combination of 30% GGBS consistently exhibits the lowest sorption values throughout all three sorption durations (Sor-28, Sor-56, and Sor-90). This shows that the concrete mixture with 30% GGBS and a w/b ratio of 0.3 has a higher water absorption resistance than other combinations at this ratio. Therefore, 30% GGBS at a w/b ratio of 0.3 can be regarded as the optimal mix for this ratio. The 30% GGBS concentration provides many reactive components to participate in a vigorous pozzolanic reaction. This reaction creates new cementitious compounds, which fill the gaps and lower the pore diameters inside the concrete matrix. As a result, the concrete becomes denser, with lower interconnected porosity, restricting the paths for water absorption. From Figure 10 (b) Water-to-binder ratio: 0.4, the combination of 40% GGBS consistently displays lower sorption values throughout all three sorption durations. This suggests that the concrete mixture with 40% GGBS and a w/b ratio of 0.4 demonstrates increased resistance to water absorption compared to other combinations at this ratio. Therefore, 40% GGBS at a w/b ratio of 0.4 can be regarded as the optimal mix for this ratio. The presence of GGBS in the concrete mixture enhances the packing of particles, resulting in a denser matrix.

The improved particle packing decreases the available vacuum space for water to permeate, minimizing water absorption. The 40% GGBS concentration enhances the particle packing while retaining workability and other desired qualities of the concrete. From Figure 10 (c) Water-to-binder ratio: 0.5, the combination of 50% GGBS consistently provides the lowest sorption values throughout all three sorption durations.

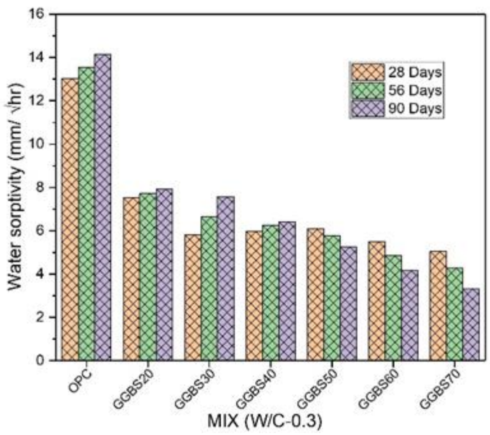

Figure 10a GGBS vs. OPC - Water Sorptivity of MIX (W/C – 0.3)

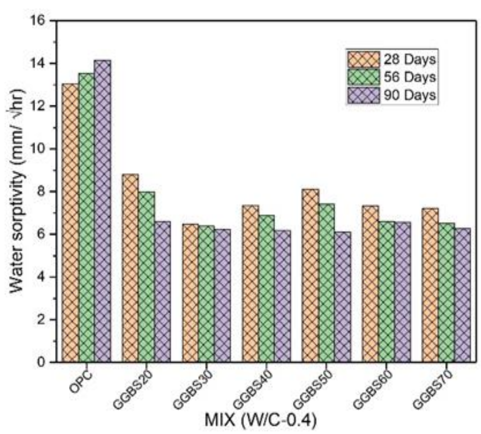

Figure 9b GGBS vs. OPC - Water Sorptivity of MIX (W/C – 0.4)

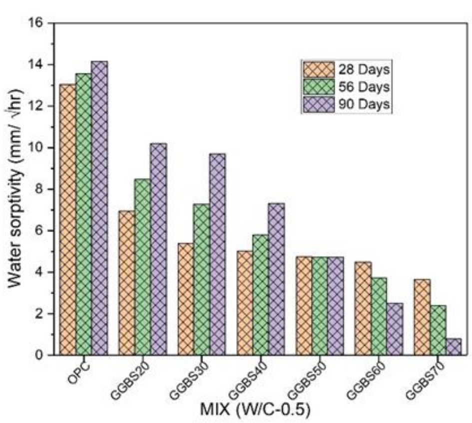

Figure 10c GGBS vs. OPC - Water Sorptivity of MIX (W/C – 0.5)

This implies that the concrete mixture with 50% GGBS and a w/b ratio of 0.5 has a higher water absorption resistance than other combinations at this ratio. Therefore, the combination of 50% GGBS at a w/b ratio of 0.5 can be regarded as the optimal mix for this ratio. The presence of GGBS in the concrete mixture promotes particle packing, resulting in a denser and more compact matrix. The improved particle packing decreases the available vacuum space for water to permeate, minimizing water absorption. The 50% GGBS component enhances particle packing, boosting the concrete's resistance to water absorption.

4.0 CONCLUSION

The following conclusions were drawn based the tests conducted.

The fly ash and GGBS decrease the permeability of concrete, increasing the material's resistance to chloride ion penetration, sulfate assault, and alkali-silica reaction. These materials are fillers because of their smaller particle size and pozzolanic qualities. As a result, the amount of water required to produce the mixture is decreased, and its cohesiveness is improved. These materials are often more affordable than cement, allowing them to help offset some of the total construction expenses.

While assessing the RCPT values, it is essential to note that the specific optimal fly ash percentage may vary depending on various factors such as project requirements, environmental conditions, and desired durability levels. The data in the table support that adding fly ash to concrete can enhance its resistance to chloride penetration, leading to lower RCPT values and improved durability.

Further, there is a need to note that the specific optimum GGBS content and water-to-binder ratio may vary depending on various factors, such as project requirements, environmental conditions, and desired durability levels.

Therefore, further analysis and consultation with concrete with other aspects shall recommend determining the most suitable GGBS content and water-to-binder ratio for specific applications.

In summary, the above figures provide insights into the effect of GGBS content and water-to-binder ratio on the resistance of concrete to chloride penetration, as measured by RCPT values.

The data suggest that increasing GGBS content and reducing the water-to-binder balance generally improved durability and enhanced resistance to chloride penetration. The sorpitivity of the concrete is improved upon adding the GGBS and fly ash.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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