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Research Article

Sustainable Strength: Investigating The Properties And Durability Of Concrete With Blended Cement

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ABSTRACT

Hydration of ternary OPC-FA-SF concretes has been concentrated on utilizing number of procedures. Intensity of hydration studies were made with the assistance of Cap AIR calorimeter, and it was found that fly debris hindered the hydration of OPC and decreased the complete intensity development. Nonetheless, fly debris and silica rage together superior the intensity advancement, however the qualities were lower than that of OPC. Differential filtering calorimetric investigations of concretes hydrated for 28 days were made, and it was tracked down that Ca(OH)(2) created during the hydration of OPC responded with fly debris and silica seethe. SEM pictures of hydrated concretes were recorded. The outcomes have shown that silica rage speeds up the hydration and limits the lacks of fly debris mixed concrete. Instrument of hydration has been proposed.

Keywords: OPC, FA, SF, SEM

1. Introduction

Portland cement, aggregates, and water are the primary components of concrete, which is an artificial material that plays a crucial role in construction. Concrete is a crucial building material that can be cast and shaped into any shape. It is made from materials that are typically available locally and are used in construction. Moreover, it has a high compressive strength and a high modulus of adaptability. This adds to commonness for concrete. After water, it is the most consumable material on the planet (Rana et al., 2015; Rashad, 2013; Mineral Thing Association (MPA), 2012). It is guage that huge use will reach upto 4.8 million tons by 2030 (WBCSD, 2015; Jewell and Kimball, 2015; Habert, 2014). As a matter of fact, the improvement of a nation is straightforwardly connected with the utilization of concrete and cement. Cement production has increased dramatically over the past three decades (Aliabdo et al., 2016; Imbabi et al., 2013; McCaffery, 2002). According to the 2018 USGS Mineral Commodities Summary, India produces the second most cement, making up 6.8% of all cement produced worldwide. It is guessed that this cutoff will augment by 205 (WBCSD-IEA 2018).
There has been a constant change in the developments in 21st century which in like manner impacted on the improvement business either concerning plan or improvement of various plans. Concerning cash, way of life, and recreation, these logical and designed modern changes bring about friendly changes for individuals living in industrialized countries. Substantial interest is likewise expected to ascend by 12 to 23% by 2050 in emerging countries (IEA, 2018). At any rate, from one side of the planet to the next there are major natural issues related with the arrangement of customary portland concrete, which causes environment hurt (Kang et al.,2019; WBCSD-IEA 2018; Hong et al., 2015; Provis and Bernal, 2014; Barcelo et al., 2014; Mehta, 2002; Davidovits, 1994). The breakdown of the fundamental part, calcium carbonate ($CaCO_3$), into calcium oxide (CaO) and carbon dioxide (CO_2) is one of the cycles related with substantial creation and the transmission of CO_2 that is responsible for the environment's CO_2 levels.
Another source of emissions is the use of coal to generate the necessary heat to consume the concrete's normal fixings at temperatures between 1400 and 1500 degrees Celsius (IEA, 2016). Subsequently, gathering of one ton of Portland concrete contribute around 7% radiations of in general carbon dioxide (Fan and Miller,2018; Dave et al., 2017; Olivier et al., 2017; Ludwig and Zhang, 2015; Baikerikar, 2014; Benhelal et al., 2013; Keun-Hyeok, 2013). The significant street numbers 7% of present day energy use and 7% of generally speaking floods of CO_2 (IEA, 2018) and around 1.6 heaps of common assets are consumed by it (2015, Jagadesh et al.) Thusly, the development of one kilogram of Portland concrete ordinarily brings about the emanation of one kilogram of carbon dioxide and the ingestion of roughly 1.5 kWh of energy (Huynh et al., 2018; Dunuweera and

Rajapakse, 2018; Le Quéré et al., 2017; Hwang et al., 2016; Mill operator et al., 2016; Aliabdo et al., 2016; Barcelo et al.). This rate As shown by Factory administrator et al. (2017), there are different approaches for restricting power usage and CO2 releases during the substantial creation process. The significant creation endeavor has been revolved around in four key course of study to limit the floods of hurtful gases which are as per the going with (Hanein et al., 2018):

(1) Substitute feedstock and igniter,

(2) Replacement of concrete by utilizing horticultural and current results known as significant cementitious materials (SCM),

(3) Carbon dioxide segregation and catch

(4) The chance of an elective that uses less carbon clasp.

Every strategy has advantages and disadvantages. To make blended or composite cement, subbing significant cementitious materials (SCMs) for substantial clinker is the principal push toward cutting down petroleum product results. Results from various present day and provincial cycles as frequently as conceivable yield SCMs like metakaolin (MK), ground granulated influence radiator slag (GGBFS), rice husk trash (RHA), silicon rage (SF), sugarcane bagasse flotsam and jetsam (SCBA), fly garbage (FA), animal bone powder (BP), calcined soil (CC), lime powder (LP), and egg shell powder (ESP). To accomplish the better normal and explicit benefits, the SCMs in critical creation ought to be utilized cautiously. The SCMs might be used by a turn of events or replacement of customary portland concrete (Nazerigivi and Najigivi,2019; Lim et al., 2019; Fan and Industrial facility director, 2018; Ferraro et al., 2017; Dave et al., 2017; Marinković et al., 2017; Evi, 2017; Hemalatha and Ramaswamy, 2017; Kotwica et al., 2017; Plant chairman et al., 2016; Makhloufi et al., 2014; Gusano et al., 2015a; Arezoumandi and Volz,2013; Damtoft et al., 2008). The advancement business' shortfall of standardization upsets the market's affirmation of progressing enhancements in elective substantial covers for general improvement applications. Nonetheless, carbon dioxide emanations can be decreased by "new" restricting material without requiring novel plant plan changes (WBCSD, 2009a).

1.1 Research Objectives

The following were the objectives of this investigation in light of the preceding considerations:

- to make blended Portland cement from waste materials like FA, SF, MK, and animal bone powder and make it work best.
- to investigate how blended cement hydrates under various conditions.
- To plan concrete from the mixed concrete and to study morphological, mechanical and strength properties. Experiments were carried out in order to accomplish the goals, and the results were presented in this thesis and published in a number of research journals.

2. Material and Experimental Methods

2.1 Materials

The readiness of concrete and the investigation of hydration have both been completed utilizing customary Portland concrete (OPC) acquired from Birla concrete. The flow of atom size of OPC is address in Fig.2.1. Fly flotsam and jetsam (FA) was obtained from NTPC Dadri and Jharli, India. Silica rage (SF), metakaolin (MK), creature bone powder (BP), and Dow Corning SHP - 50 (Silicone hydrophobic powder) were different materials utilized in this review. The FA, MK, and SF XZ

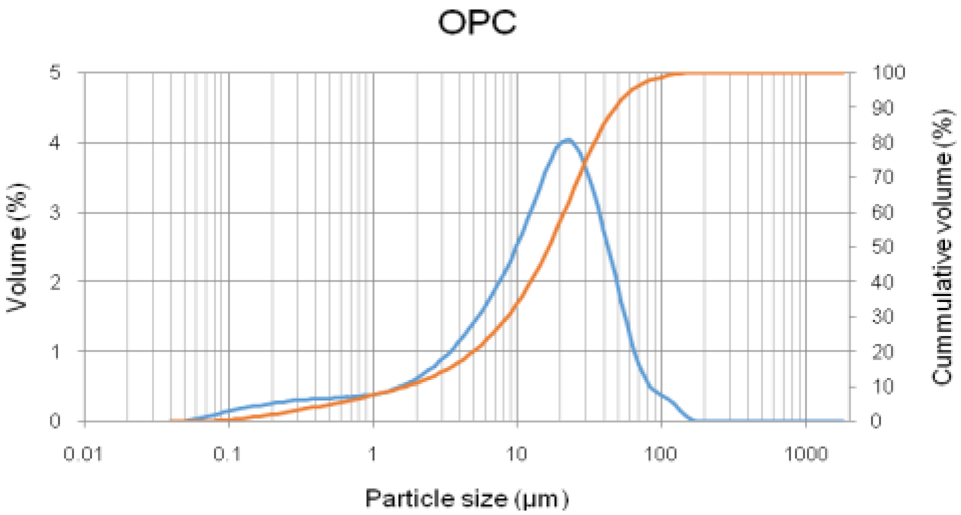


Fig. 2.1: Dispersion of molecule size of OPC

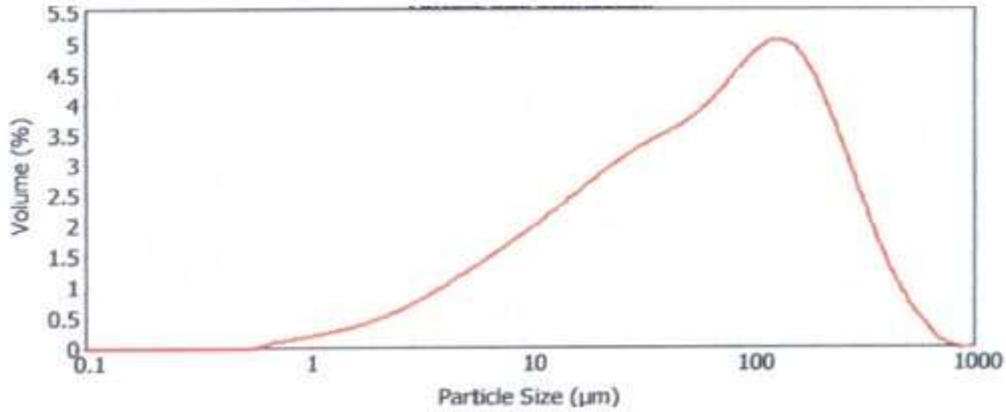


Fig. 2.2: Particle size distribution of FA (NTPC, Jharli)

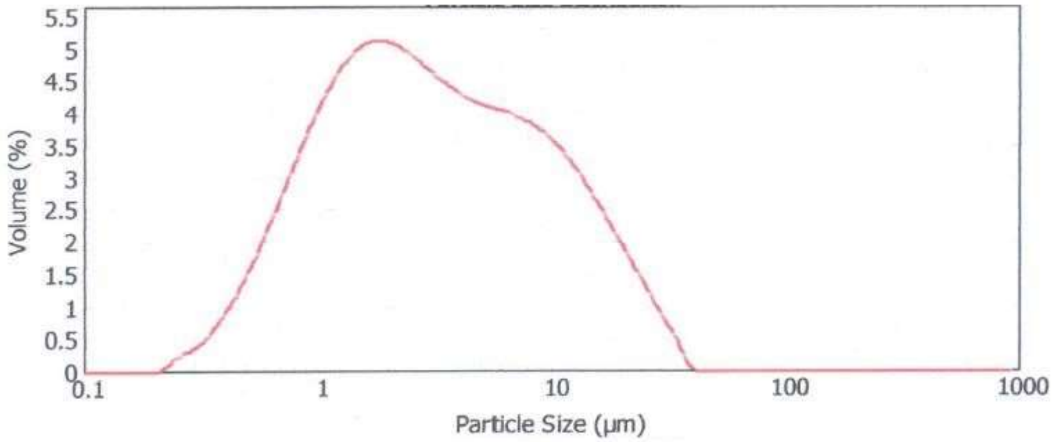


Fig. 2.3: Distribution of particle size of Metakaolin

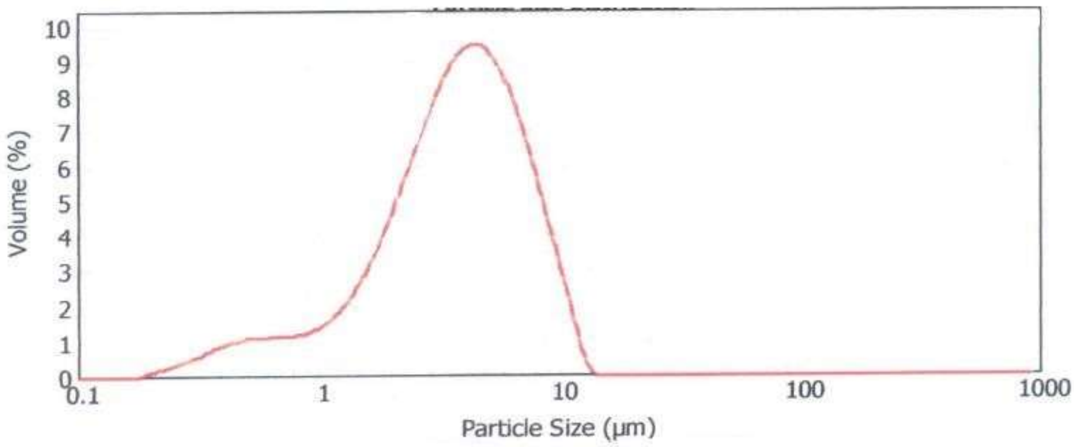


Fig. 2.4: Distribution of particle size of Silica Fume

2.2 Methods

Number of exploratory techniques have been completed for the review. The definite strategies have been depicted in this section.

2.2.1 Detail of samples

2.2.1.1 Hydrated samples preparation

A 20-gram cement sample was taken from a number of polythene bags. To keep the water-to-solid (w/s) ratio at 0.5, 10 milliliters of distilled water were added to each bag. By pressing for five minutes between fingers, uniform mixing was achieved. To keep away from carbonation of test, the air was eliminated from the sacks prior to fixing. The fixed packs were kept at room temperature (27±2 o C) for 1, 3, 7, 14 and 28 d. The course of hydration was finished at specific time periods (1, 3, 7, 14 and 28 d) by using isopropyl alcohol and ether. The examples were then dried in a stove at 105 degrees Celsius and put away in a desiccator.

2.2.1.2 Cement mortar preparation
On a non-porous plate, a 1:1 mixture of OPC and sand was homogenized for one minute in a dry state. After that, water was added, the mixture was thoroughly mixed, and it was put into a 70.6 mm3 cube mold (IS: 4031 part 6, 1988). What's more, different rates of SF (going from 0 to 20 wt %) and 20 wt percent FA were blended into customary Portland concrete.

2.2.1.3 Concrete preparation
The substantial blend of M30 grade was made according to IS 10262. A mixture of 20% FA, 5% SF, and 0.3 percent SHP-50 made up the OPC. The M55-grade concrete mix was produced in accordance with IS 10262. FA, MK, and ABP were mixed with the OPC in varying proportions.

2.2.2 Blaine Air Permeability method for specific surface area
A specific surface was used to calculate the cement's fineness. The "Blaine Air Permeability" apparatus was utilized to measure specific surface area (IS: 4031, part 2, 1999) The main problem is figuring out in what way extended it receipts for a certain amount of air to flow through a consolidated cement bed with a certain porosity and dimension. A manometer, permeability cell, disc, and plunger make up the equipment. Punctured plate was kept on the edge at the lower part of the penetrability cell and on this metal circle, put a channel paper circle. Weighing and filling of the cement quantity (W) were done. Another filter paper disc was used to cover the leveled cement, and the plunger was used to compress the cement so that the plunger collar and the top of the cell meet. The manometer of the apparatus was then connected to the permeability cell, which was filled to the brim with dibutyl, a low-density, non-hygroscopic liquid. One arm of the manometer was consistently cleared until the fluid arrived at the best grade and afterward it was locked firmly. The clock began as the lower part of the meniscus of the manometer fluid arrived at the subsequent imprint and halted as the lower part of the meniscus of fluid arrived at the third imprint. Noticed the time stretch. Eq. provides the specific surface S (cm2/g). 2.1: S = (2.1) k is the device continuous; e is the porosity of the cement bed; t is the number of measured time intervals; s is the cement's specific gravity; and v is the air's viscosity at the test temperature. The particular not entirely settled by Pycnometer utilizing lamp oil.

2.2.3 Determination of Standard water Consistency
According to IS: 4031 part 4, 1998), cement paste of standard consistency must have a specified resistance for the Vicat plunger to penetrate the Vicat mold for 5 to 7 mm from its bottom (Fig. 2.7). A glue was arranged utilizing a gauged measure of concrete and water, remembering that the time expected for blending ought to be between 3 to 5 min and the method involved with checking is finished before any indication of setting happened. Place the paste under the Vicat apparatus's rod-bearing plunger after filling the mold with paste. The unclogger was brought tenderly down to come into contact with the top layer of the shape and delivered quickly to enter into the glue. For each kind of cement, different amounts of water were mixed into paste until the above-mentioned penetration was reached.

2.2.4 Setting time
Concrete glue was made by blending concrete and 0.85 P water, where P = standard consistency as viewed as before, remembering that the time expected for blending ought to be between 3 to 5 min and the most common way of checking was finished before any indication of setting happened. Recorded this time. The Vicat's shape was filled by glue and the form was set under the bar bearing needle of Vicat device. Brought down the needle gradually till it interacted with the completed level of the shape and delivered quickly, so it enters in the glue. At first, the whole needle penetrated the concrete shape. The cycle was rehashed after each two min till the needle couldn't infiltrate the concrete shape for around 5±0.5 mm estimated from the base. this time, notated. The early location period, as defined by IS: 4031 part 5, 1988, is the period of time between the time that water was added and the point at which the needle could not penetrate the cement paste by approximately 50.5 millimeters from the bottom of the mold. In the Vicat device, the needle with an annular connection was utilized to decide the last setting time. At the point when the needle was tenderly let out of the concrete glue, it had an impression, however the connection didn't, demonstrating that the concrete had at long last set. This time was the last setting time.

2.2.5 Slump measurement

The substantial not entirely settled according to IS: 1199, 1959in rut cone. A hard, non-absorbent surface was used to keep the slump cone apparatus in place. Three equally spaced layers of Fresh Concrete were used to start the process. Utilizing a 16 mm-breadth metal bar with a slug nose, restrained each layer multiple times. After thoroughly satisfying the pinecone, extra significant was taken out and significant superficial was leveled out. Without influencing the substantial cone, the rut form was raised upward vertical. The substantial cone broke down. The slump value, or subsidence, of the concrete cone was measured to the nearest 10 mm.

3.Hydration of Fly Ash Blended Cement in presence of Silica Fume

The study of climate change is currently the most pressing issue. The emission of carbon dioxide (CO_2) by industries is the primary cause of climate change and global warming. Cement production is associated with significant environmental issues and climate damage. Assembling of OPC produces around 7% CO_2. According to IEA (2018), Olivier et al. (2017), Ludwig & Zhang (2015), and Jagadesh et al. (2015), the cement manufacturing is one of the largest customers of vigor, the second largest emitter of carbon dioxide, and it also uses approximately 1.6 tons of natural resources. The most significant measure for reducing CO_2 emissions from OPC manufacturing is the use of blended or composite cement. Additional cementitious materials (SCMs) like calcined clay (CC), fly ash (FA), rice husk ash (RHA), sugarcane bagasse ash (GGBS), lime powder, metakaolin (MK), silica fume (SF), and so on can partially replace OPC. (Marinkovi et al., 2017; Kotwica et al., 2017; Evi, 2017; Ferraro et al., 2017; Hemalatha and Ramaswamy, 2017; Dave et al., 2017; and Miller et al., 2016; Fan and Miller, 2018) Portland concrete can be to some degree supplanted by FA. FA has filler impact as well as it responds artificially with hydration items to frame additional calcium silicate gel (C-S-H) (Pacewska and Wilinska, 2013; Morsy et al., 2014). It provided additional nucleation sites for hydration and raised the packing density of the mortar as a result of the filler effect. FA's initial pozzolanic activity is low due to its small surface area, and it remains chemically inactive for up to seven days. However, as hydration progresses, the biochemical response amid FA and portlandite (C-H) begins, resulting in the formation of additional C–S–H gel (Zhao et al., 2016; Bjegovic et al., 2012; Chindaprasirt et al., 2005). The fundamental issue related with FA expansion in mortar and cement is low early strength improvement. Concrete containing FA and the early strength of the mortar are being improved, but this is still a challenge. These obstacles might be overcome by SF because of its high reactive nature. Rendering to Chen et al. (2016) and Liu et al. (2014), the cement's hydration is significantly slowed down and the SF's initial reactivity is hindered when SF and FA are mixed simultaneously in OPC. There is defer in speeding up impact by SF. However, SF is thought to be more reactive than fly ash due to its higher SiO_2 content and larger surface area. In order to speed up the development of strength at an early age, SF provides a subsequent quantity of calcium silicate gel. The application of silica fume is thought to have the potential to lessen the negative effects of FA in Portland cement. In this review, the impact of SF on the hydration of FA mixed OPC was examined and results were dissected to grasp the system.

3.1 Experimental details

3.1.1 Material

This study utilized OPC from Birla cement, FA from NTPC, Dadri, and SF from Elkem, Mumbai. The biochemical arrangement of all of the materials (OPC, FA, and SF) used in this study. A blend of 80 mass percent OPC and 20 mass percent FA was made, and 5, 10, 15, and 20 mass percent SF were added as a replacement. The subtleties of tests are given in Table 3.1.

Table 3.1: Sample details

Sample No.	Samples
1	OPC
2	OPC20FA
3	OPC20FA5SF
4	OPC20FA10SF
5	OPC20FA15SF
6	OPC20FA20SF

3.1.2 Methods

Impact of various amount of SF (5, 10, 15, 20%) on 80 mass% OPC + 20 masses% FA mixed concrete was concentrated by utilizing the accompanying strategies.

- Arrangement of hydrated examples of OPC and mixed concrete
- Conventional water Consistency
- Predicting dates
- Intensity of hydration estimation
- Non-evaporable water content
- Water permeation by penetrability device
- Mortar's compressive strength
- DSC studies
- SEM research

3.2 Results and Discussion

Figure 3.1 display the variation in reference mix, binary blend, and ternary blend normal aquatic constancy. The water consistency of OPC and 20 mass % FA mixed concrete was 26.5% and 26% separately. It was noted that the importance of consistency increased when SF was added. This increment was because of high surface. area of SF

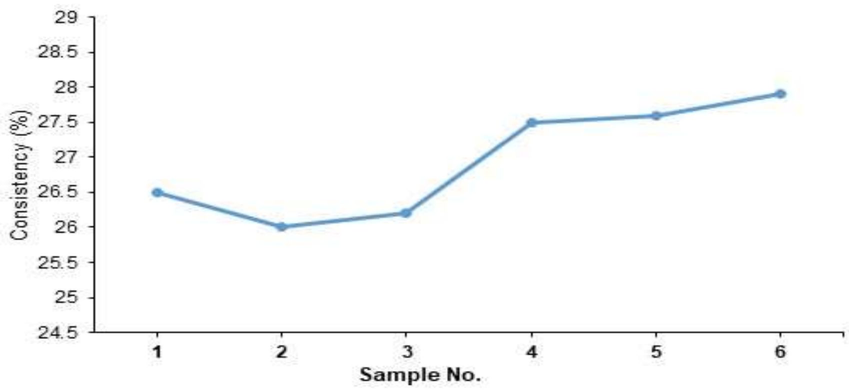


Fig.3.1: Variation of water consistency

Figure 3.2 display the setting times for the reference mix, binary blend, and ternary blend. Due to the dilution effect (low reactivity, reduced alkalinity of the pore water, and lower Portland cement content), it was discovered that FA-blended OPC required longer setting times than the reference mix. Setting times were observed to decrease when SF was included in FA-mixed cement. This could be because the rate of hydration is sped up when SF is present. Higher how much SF, higher the hydration and lower the benefits of setting times.

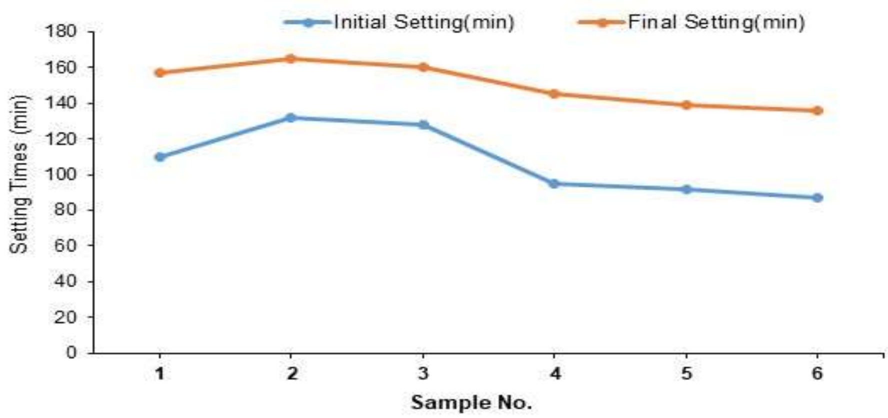


Fig.3.2: Variation of setting times

The hydration reaction began when the adhesive was varied with aquatic, resulting in the creation of C-S-H, C-H, and other hydration compounds. C-H shaped as free lime was assessed and given in Fig.3.3. It was found that the expansion of SF decreased the amount of free lime in the blend and this decrease expanded with how much SF. Poszolanic reactivity may be heightened when SF is present, which could account for this.

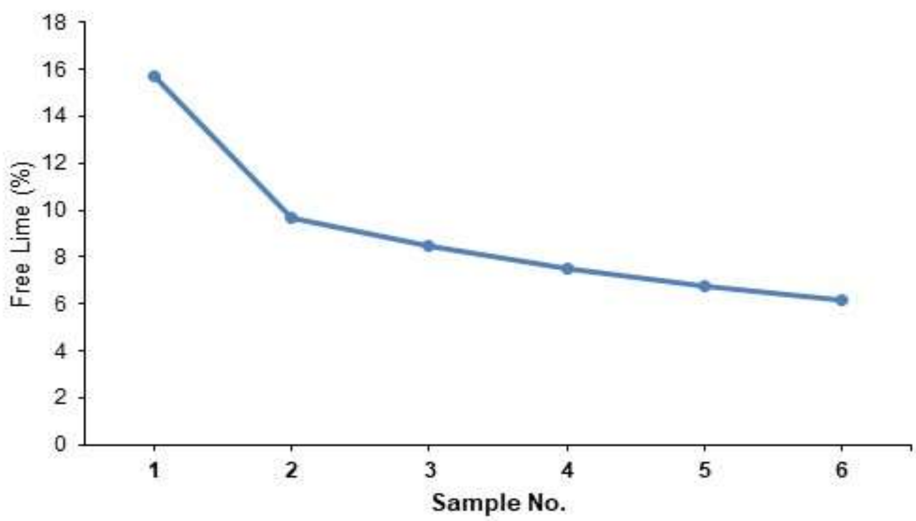


Fig. 3.3: Free lime in 28 days hydrated samples

The level of non-evaporable water in the body is a decent experimental sign of how hydrated an individual is. The extent of concrete that has totally responded with water to the aggregate sum of concrete in the example is known as the level of hydration. Figure 3.4 depict the non-vaporous water content of various mixes that were kept hydrated for 28 days. Non vaporific water gratified lessened with extension of FA and SF. The impact of weakening causes this.

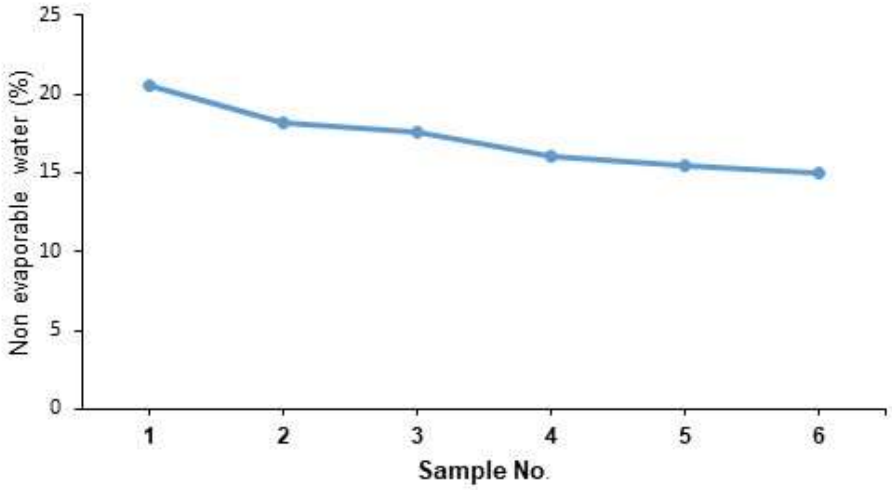


Fig. 3.4: Non-evaporable water content in 28 days hydrated cement

In Fig., heat stream as a component of period throughout concrete hydration in the nonappearance and attendance of FA and SF has been estimated and plotted. 3.5. The power stream twist has five areas.

1) The main phase of fast intensity development was brought about by concrete wetting, the disintegration of soluble bases and hemihydrates, the hydration of C3A, and the response with gypsum. After a brief peak of a few minutes, there was a two-hour induction period with a slow rate of reaction.

2) During the acceptance stage, hydration item cores shaped and arrived at basic size.

3) After the subsequent stage, the pace of intensity advancement arrived at its most noteworthy point and hydration advanced rapidly with time, especially in the alite stage.

4) and 5) In deceleration stage a huge amount of hydration items covered the external essence of unhydrated concrete and response turned out to be slow and dissemination controlled. In comparison to regular Portland cement, fly ash delayed the peak of hydration and reduced the rate of heat evolution when cement was replaced by 20% mass % FA. The FA removed the Ca2+ ion that was released into the solution when the water was mixed. The nucleation and crystallization of C-H and C-S-H was slowed by the decreased concentration of the Ca2+ ion, which also slowed the process of hydration. At the point when added 5 mass% SF, the intensity of hydration was upgraded somewhat yet more modest than Opc's.

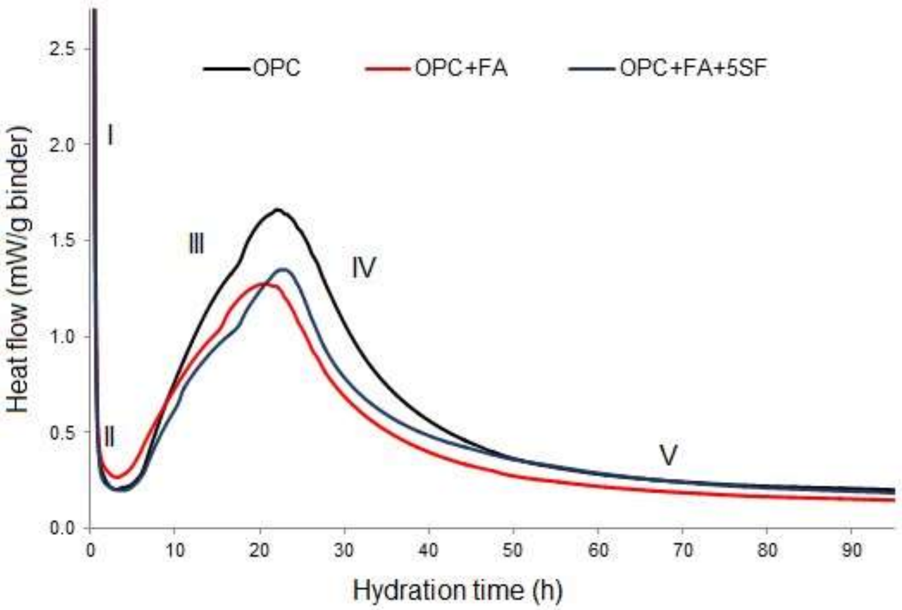


Fig. 3.5: Heat evolution profile

Figure 3.6 depicts the entire heat produced. With time, the whole intensity expanded and it was followed to follow arrangement: All of the heat OPC > All of the heat OPC20FA5SF > All of the heat OPC20FA The dissolution of various phases during the hydration process produced a variety of ions in the solution. These ions attempted to combine by moving at random. This quirk rely upon unambiguous superficial part of adhesive, pH, fever and zeta potential. When enough dissimilar ions joined together and reached the critical limit, crystal growth and the formation of critical size nuclei began. Subsequently, the reaction got a move on over the long run. There was a weakening impact, and less particles entered the arrangement on the grounds that the blend contained 20% mass FA. As a consequence, both the rate of heat development and total heat evolved decreased. At the point when 5 mass% SF was added into OPC20FA, hydration was respectably upgraded due to more surface area of silica smolder when contrasted with others. Because of silica smolder, the nucleation destinations expanded which came about into higher hydration. The dilution effect could not be balanced even with this amount of SF.

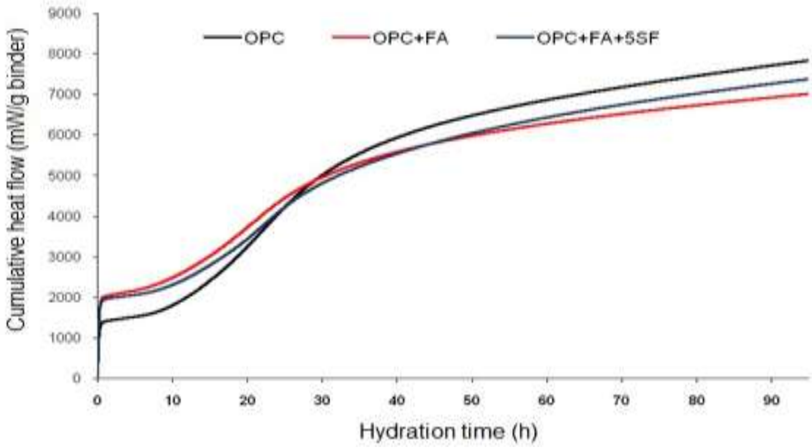


Fig. 3.6: Total heat evolved as a purpose of period

Figure 3.7 depicts the DSC curves of OPC (anhydrous), OPC, OPC 20FA, and OPC 20FA 10SF after being hydrated for 28 days. Expansive tops underneath 450K showed the expulsion of adsorbed water atoms. Except for anhydrous OPC, where there was virtually no C-H, peak temperatures around 720 K indicated the decomposition of C-H formed during hydration. The pinnacle force during hydration process was in the accompanying succession. OPCCH > OPC20FACH > OPC20FA10SFCH One of the hydration products produced by Portland cement's hydration was the release of calcium hydroxide. This is easily leached from hardened mass because it dissolves in water. A pozzolanic reaction that partially consumed calcium hydroxide took place when fly ash was added to cement. According to the curves, the amount of portlandite (C-H) in cement was reduced by adding fly ash. The peak was further reduced when 10 mass percent SF was added. This confirmed that the presence of SF enhanced the pozzolanic response and supported the findings of the free lime determination.

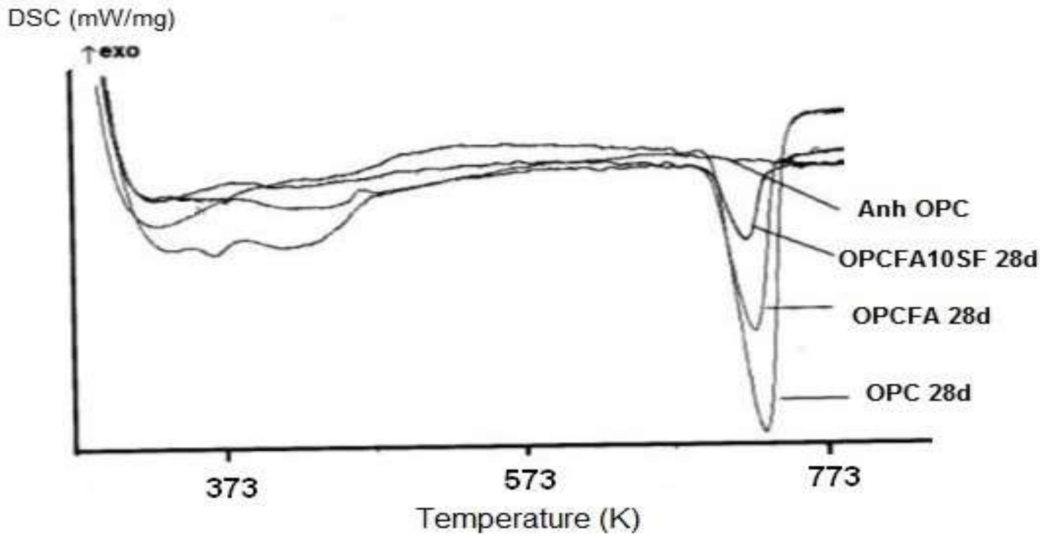


Fig.3.7: DSC curves

Compressive strength of concrete mortars hydrated at various ages (3, 7 and 28 d) is addressed in Fig.3.8. At three days after hydration, the compressive strength showed a slight decrease (6%) when OPC was replaced with 20 mass percent FA. Up to 7 days after hydration, the reference specimen performed better than the FA blended mix. This is consistent with previous measurements that demonstrated that FA has no effect on cement's early strength progression. This was because FA's dilution and low pozzolanic reactivity occurred during this time. However, enhanced pozzolanic reaction led to an surge in compressive asset in later times. With expansion of SF, compressive strength improved in any event, during early times of hydration. Expansion of SF have physical as well as synthetic impacts. Because of its smaller size, SF easily filled the cement's pores, giving it a better filler effect than fly ash-mixed cement and increasing its compressive strength. Other than pressing activity, both FA and SF act as communities for nucleation all through hydration. The greater specificity of SF's surface area results in improved overall hydration efficiency.

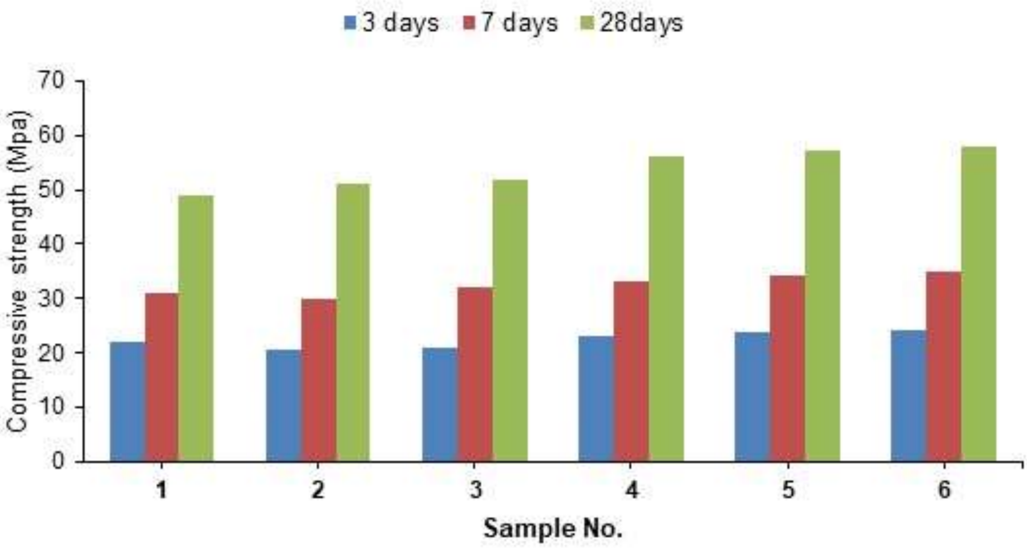


Fig.3.8: Comp. Str. of cement hydrated for 3, 7 and 28 d

Percolation of water provides insight into mortar durability. Figure 3.9 display the water percolation values. It has been noticed that fly debris mixed concrete containing silica exhaust had a lower worth of water permeation. In the presence of SF, a smaller pore size may be the cause of the value decrease.

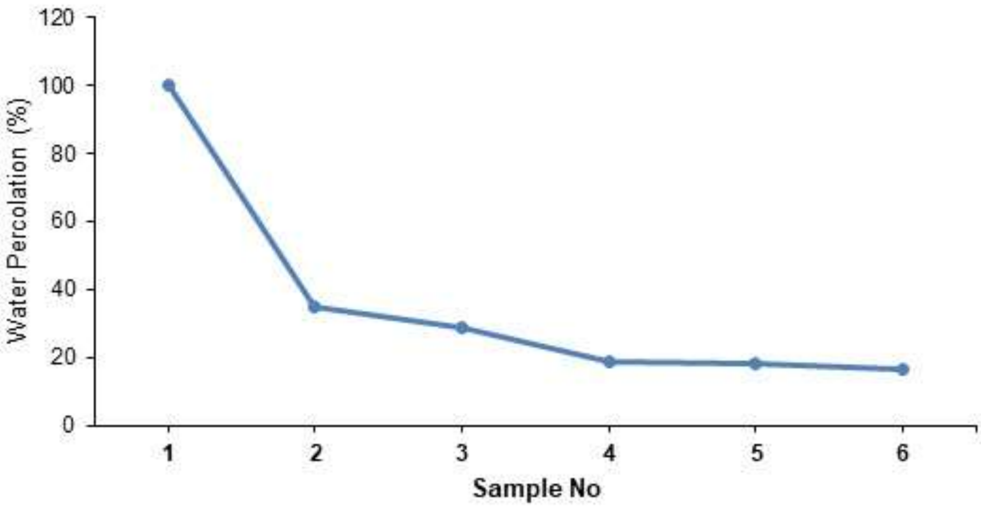
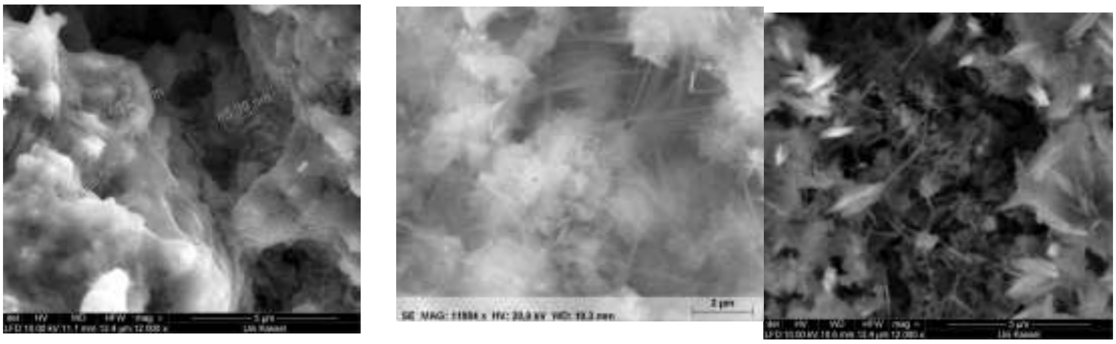


Fig. 3.9: Water percolation of samples

Figure 3.10 shows SEM images of OPC, OPC20FA, and OPC20FA10SF, which were hydrous for 28 days. SEM images show products of hydration with tiny dimensions. When silica fume is present, the morphology is dense. In both FA and FA SF presence, hydration products in the shape of needles can be seen. Figure 3.11 addresses EDX spectra of 28 days hydrated example OPC20FA10SF and the outcome showed no insights about the presence of ettringite.



OPC20FA10SF-28d
Fig.3.10: SEM flicks of hydrous samples.

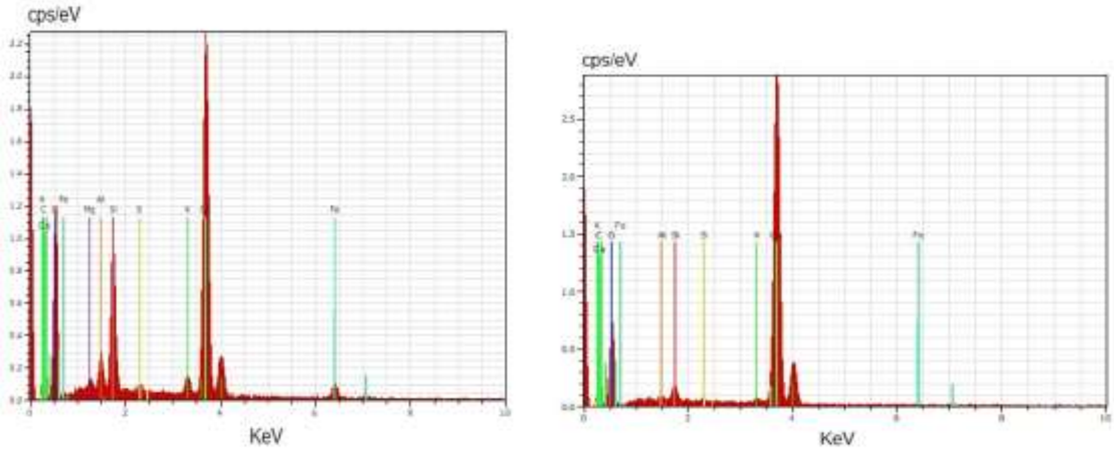


Fig.3.11: EDX of hydrated samples

4. Conclusions

The outcomes showed that the hydration of OPC20FA is advanced within the sight of SF. In presence of SF, OPC20FA's compressive strength was similar to OPC alone. At three days, the compressive forte of OPC20FA was better than that of OPC when there was a greater amount of SF present. The general discoveries demonstrated that expansion of SF can limited the lacks of FA mixed concrete.

Reference

1. Abbass, W., Iqbal Khan, M. and Mourad, S. (2018)'Evaluation of mechanical properties of steel fiber reinforced concrete with different strengths of concrete,' Construction and Building Materials, 168, pp. 556-569.
2. Abdelalim, A.M.K., Ghorab, H.Y., Abdelaziz, G.E. and Elsayed, M.S. (2010)
3. 'Dealuminated kaolin as a cement replacement material,' Cement Wapon Beton, 76(3), pp.132-140.
4. Abdelgader, H. S. and El-Baden, A.S. (2015) 'Effect of silica fume on two stage concrete strength,' IOP Conf. Series: Materials Science and Engineering, 96, 012043. doi:10.1088/1757-899X/96/1/012043.
5. Acharya, P.K. and Patro, S.K (2016) 'Use of ferrochrome ash (FCA) and lime dust in concrete preparation', Journal of Cleaner Production, 131, pp. 237-246.
6. Adesaya, D.A. and Raheem, A.A. (2009) 'A study of the workability and compressive characteristics of corn cob ash blended cement concrete,' Construction and Building Materials, 23(1), pp.311-317.
7. Aguirre-Guerrero, A.M., Mejia-de-Gutierrez, R. and Ribeiro Montes-Correia, M.J. (2016)
8. 'Corrosion performance of blended concretes exposed to different aggressive environment', Construction and Building Materials, 121, pp. 704–716.
9. Aitcin, P.C. (2000) 'Cements of yesterday and today. Concrete of tomorrow', Cement and Concrete Research, 30(9), pp. 1349-1359.
10. Aitcin, P.C. and Mehta, P.K. (1990) 'Effect of coarse aggregate characteristics on mechanical properties of high strength concrete', Materials Journal, 87(2), pp. 103-107.
11. Ajileye, F.V. (2012) 'Investigations on Microsilica (Silica Fume) As Partial Cement Replacement in Concrete', Global Journal of Researches in Engineering Civil and Structural Engineering, 12, pp. 16-23.
12. Alani, A.H., Johari, M.A.M., Aldahdooh, M.A.A. and Bummori, N.M. (2019)

13. 'Development of engineering and transport properties of green high strength concrete utilizing ternary blended binders,' European Journal of Environmental and Civil Engineering, 23. https://doi.org/10.1080/19648189.2019.1573381.
14. Alexander, M.G. and Magee, B.J. (1999) 'Durability performance of concrete containing condensed silica fume,' Cement and Concrete Research, 29(6), pp.917–922.
15. Ali, S.A. and Abdullah, S. (2014) 'Experimental study on partial replacement of cement by fly ash and GGBS', International Journal for Scientific Research and Development, 2, pp. 304-308.
16. Aliabdo, A.A., Abd, A.E.M., Elmoaty and Aboshama, A.Y. (2016) 'Utilization of waste glass powder in the production of cement and concrete', Construction and Building Materials, 124, pp. 866–877.
17. Aliabdo, A.A., Elmoaty, A.E.M.A. and Auda, E.M. (2014) 'Re-use of waste marble dust in the production of cement and concrete', Construction and Building Materials, 50, pp.28–41.
18. Alnahhal, M.F., Alengaram, U.J., Jumaat, M.Z., Alsubari, B., Alqedra, M.A. and Mo, K.H. (2018) 'Effect of aggressive chemicals on durability and microstructure properties of concrete containing crushed new concrete aggregate and non – traditional supplementary cementitious materials,' Construction and Building Materials, 163, pp. 482-495.
19. Antiohos, S.K., Papadakis, V.G. and Tsimas S.(2014) 'Rice Husk ash effectiveness in cement and concrete as a function of reactive silica and fineness', Cement and Concrete Research, 61-62, pp.20-27.
20. Aprianti, S.E. (2017) 'A huge number of artificial waste material can be supplementary cementitious material (SCM) for concrete production: a review part II', Journal of Cleaner Production, 142, pp. 4178-4194.