Hydration studies of Mango Leaf ash blended with Ordinary Portland cement

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ABSTRACT
A variety of experimental procedures were used to investigate the hydration of Mango Leaf Ash (MLA) combined with Ordinary Portland Cement (OPC). MLA has replaced 20% of the OPC. Setting time and liquid phase analysis of Blended OPC were investigated. We determined free lime percentage and compressive strength at various time intervals. It has been discovered that the setting times of OPC are enhanced in the presence of MLA. Liquid phase analysis also reveals a reduction in calcium ion and hydroxide ion concentrations in blended OPC compared to control OPC. The behaviour of OPC and blended OPC may also be seen using scanning electron microscopy (SEM). Our mixed cement gains strength from the production of C-H-S. A 20% replacement of OPC with MLA increases its compressive strength, which is greater than the control OPC. After 28 days of hydration, the compressive strength of 20 wt% MLA blended cement mortar wasgreater than OPC. It has been described how pozzolanic action works. Based on these findings, it is obvious that cement consisting of 80% OPC + 20% MLA outperforms control OPC. It also lowers the production and cost of OPC and is beneficial to environmental protection.

Keywords: Mango Leaf Ash (MLA), Hydration, Pozzolanic, Blended Cement, SEM, Compressive strength.

1. INTRODUCTION

Cement is the most frequently used substance on the planet, second only to water. Construction activity may be improved by concentrating on sustainability as well as performance and functional capabilities. The primary goal of sustainable growth is to provide advantages for future generations without compromising the requirements of the current generation [1-3]. A binder is a necessary ingredient that joins two or more materials to form a cohesive mechanically or chemically through adhesion or cohesion. Portland cement is used in construction as a binder in concrete that keeps particles together [4]. Portland cement is classified into several varieties based on the raw materials utilized, the usage of additives, and the chemical composition modification. In reality, Ordinary Portland Cement (OPC) is the most common variety that is commercially accessible worldwide, while

Portland Pozzolana Cement (PPC) is becoming more popular in this decade due to its great performance [5]. Because of its increased compressive strength, concrete is being employed in a variety of applications as infrastructure develops. It also has certain drawbacks, such as a lack of toughness and the occurrence of cracks noticed during load application, and the crack scale varies depending on the size of the stress [6].
Concrete is a material composed of several different components that include a binding base and embedded aggregate particles or fragments. Concrete is made up of cement, aggregates, chemical admixtures, mineral admixtures, and water, and it includes all manmade materials in varying quantities. The amount of concrete used in our world is measured in billions of tonnes. Approximately, one million metric tonnes of CO_2 are created each year as a result of cement use and manufacture, posing environmental risks.The production of Portland cement is costly, with considerable energy consumption. The cement industry releases around 900 kg of $CO_2$for every 1,000 kg of cement, accounting for approximately 5% of total CO_2 emissions. When producing Portland cement in a big rotating kiln at an estimated temperature of 1,400°C, the amount of coal required to produce one tonne of cement ranges between 100 and 350 kg.Cement-making consumes a lot of energy and emits toxic gases into the environment, contaminating the atmosphere [7-12]. Partially replacing cement with locally accessible materials will minimize energy use and environmental effect.It is a smart technique to employ agricultural waste, an industrial by-product, and plant residue in the prescribed place of Portland cement to minimize raw material consumption, protect the environment, and improve cement quality [13]. Partially replacing cement with pozzolanic waste material in concrete production is a widespread practice. Some agricultural by-products and wastes are currently garnering a lot of attention due to their pozzolanic content for use as additives in commercial Portland cement. The hydration phase of the pozzolanic process typically improves the e performance of concrete. Several investigations on the use of Mango leaf ash (MLA) as a pozzolanic material in the production of concrete have been conducted across the world [14,15]. It was discovered that mango leaf ash is an excellent pozzolanic substance that combines with calcium hydroxide to generate calcium silicate hydrate.The pozzolanic activity of mango leaf ash rises when time and temperature are increased. It was determined that MLA may be utilized as a natural pozzolan to replace cement in the making of concrete. The measured value of maximum load and compressive strength of 20% blended concrete was greater than that of OPC [16,29]. The minimal technology required to convert mango leaf into ash, as well as its pozzolanic reaction, demand its use as a material for the fabrication of various architectural elements for economical housing provision, particularly in developing nations. As a result, the purpose of this research is to determine how mango leaf ash combined with cement influences the quality of concrete. The influence of the partial replacement of MLA on the mechanical and physical parameters of concretes such as consistency, setting time, compressive strength microstructure, and expansion will be investigated experimentally.
Mango dry leaves ash is a by-product of the burning of mango dry leaves. Mango output in the globe was 50.6 million tonnes, with India accounting for 39% of the total. It possesses a fibrous quality that allows for good bonding and so is appropriate for use as a stabilizer. Mango-dried leaves are gathered and charred [17].Mango is a well-known fruit that grows and is harvested yearly between the months of March and June. The mango tree produces a large number of leaves when it is ready to produce fresh fruit; older leaves that fall from the tree become garbage, littering and polluting the environment of the growing region. The volume of these wastes produced has motivated researchers to investigate their usage for blending.The binding characteristic of the pozzolanic substance reduces the permeability of embankments, increases soil strength, and improves embankment stability [18-20].

Mango leaf waste ash

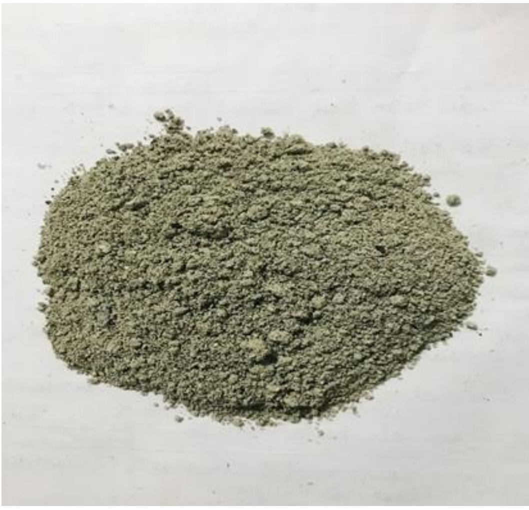
The mango leaf was obtained from the Village Sahab Nagar District Sitapur Uttar Pradesh. There are so many large gardens in this area. These gardens have a huge amount of mango trees. In the spring season, the dry leaves of these trees fell in huge amounts. Thefallen dried leaves of the mango trees were collected and then burned at a regulated temperature of roughly 700°C -800°C to produce ash. To avoid moisture absorption, theash was covered in a tight container.

2. MATERIALS AND METHODS

2.1. Materials

Dry mango leaves were burned in the open air for 2 hours before being cooked in a muffle furnace at 600^0C. For hydration experiments, Ultratech OPC 53 was utilized. Figure1 and 2 shows the image of the mango leaves and dried fallen mango leaves respectively and figure 3 shows the ash of the mango leaf. Table 1 shows the chemical compositions of MLA and OPC, whereas Table 2 shows the mineralogical compositions of OPC.

(1) (2)



(3)

Figure 1:(1) Mango leaf, (2) Dry Mango Leaves and (3) Mango Leaf Ash

Table 1: Chemical composition of OPC and MLA obtained by XRF analysis

Oxides	Average % by mass	
	OPC	MLA
Na_2O	0.48	0.01
MgO	3.02	1.543
Al_2O_3	6.47	15.96
SiO_2	20.05	45.80
P_2O_5	0.44	1.21
SO_3	0.35	0.13
Cl	0.04	0.79
K_2O	0.51	27.56
CaO	60.83	3.01
Fe_2O_3	2.79	1.03
ZnO	0.077	0.063
CuO		0.03
MnO	0.09	0.02
TiO_2	0.38	0.01

Table 2: Mineralogical composition of ordinary Portland cement

Phase	C_3S	C_2S	C_3A	C_4AF
Composition in (%)	47.7	25.2	12.0	8.5

Preparation of hydrated samples of OPC and MLA blended cement

We substitute various percentages of OPC with MLA, such as 10%, 15%, 20%, and 30%, Thus, we have four samples with varying quantities of OPC and MLA. Each sample has 300 gm of OPC and MLA mixed. Table 3 below includes information on water consistency (W/S).

Table 3: Replacement of OPC by MLA on different proportions.

S. N	% Replacement	OPC (in gm)	MLA (in gm)	Water (in ml)	W/S
1	10	270	30	110	0.36
2	15	255	45	122	0.40
3	20	240	60	130	0.43
4	30	210	90	138	0.46

2.2. METHODS

2.2.1. Water consistency and setting time measurement

Vicat apparatuswas used to determine the water consistency and setting time.The samples' initial and final setting times are recorded. We make a graph to indicate which sample takes the longest time to set. The sample with the longest setting time produces the best results.

2.2.2. Free lime determination

Free lime percentage of hydrated control OPC and blended OPC determine by Franke extraction method. According to the Franke extraction method, we take 1gm of hydrated sample and put it in the round bottom flask. Add 40 ml of an isopropyl alcohol and acetoacetic ester mixture of a ratio of 20:3. The mixture was refluxed for one hour using an air condenser to a silica tube. Cool it for half an hour. Now the solution is filtered quickly by G4 sintered glass crucible and washed with isopropyl alcohol. The filtrate was then titrated with 0.1N HCL using Bromophenol blue as an indicator. Colour changes from blue to yellow at the endpoint. Percentage of free lime calculated from flowing equation.

% FREE LIME = 0.2804 × V/W (1)

Here, V = Volume of 0.1 N HCL

W= Weight of sample.

2.2.3. Expansion Measurement

To determine the expansion of OPC and OPC mixed with 20% MLA during hydration, rods of size (280x25x25mm) were prepared and submerged in water after 24 hours and kept till the measurement was over. The expansions were measured with the help of the AIM377 length comparator.

2.2.4. Analysis of liquid phase for Ca++ ions and OH^- ions

We make a sample of 20% blended cement with 5 W/S ratios, which means 25 ml water in 5gm blended cement, to determine the concentration of Ca^{2+}. The solution was then filtered at various time intervals and titrated with 0.1N EDTA solution using Bromophenol Blue as an indicator.

To measure OH^- concentration, we prepare a sample of 20% mixed cement with a W/S ratio of 5, which is 25 ml water in 5gm of blended cement. The solution was then filtered at various time intervals and titrated with 0.1N HCL using Phenolphthalein as an indicator.

2.2.5.SEM studies

Scanning electron microscopy (SEM) of 28 days hydrated control OPC and blended OPC was taken from IIT, Kanpur, and the National Center of experimental mineralogy and petrology, university of Allahabad. Surface morphology of control and blended cement analyzed by SEM.

2.2.6. Compressive strength measurement

The compressive strength of cement indicates its strength. The cement paste was inserted into 50 mm3 steelmoulds. After one day, the cubes were de-moulded and kept in water at 27^0 C with a relative humidity of 100%. These cubes were then removed from the water before being tested. The compressive strengths were obtained using the Compression testing machine at 1, 3, 7,15,and 28 days. We create a bar graph to compare the strength of control OPC with blended OPC.

3. RESULTS AND DISCUSSION

3.1. Setting time

The results of initial and final setting times of control (OPC) and OPC blended with MLA (10%, 15%,20%, and 30%) are shown in Fig. 4. The results show that the addition of MLA first accelerates the setting time at 20% the initial and final setting time reaches maximum then after final setting timedecreases for 30%. The sample gives a high setting time and is considered the best sample. Therefore OPC+ 20% MLA gives us the best result [21].

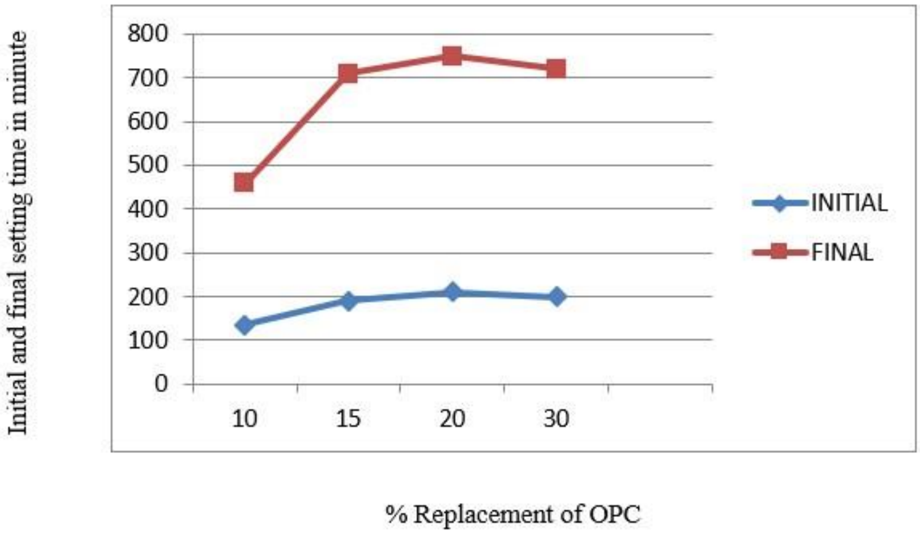


Figure4: Effect of MLA on the setting times

3.2.Free lime Percentage

The free lime percentage is measured from the Franke method. we calculate the free lime percentage of 1 day, 3 days, 7 days, 14 days, and 28 days hydrated sample of control OPC and 20% MLA blended OPC.

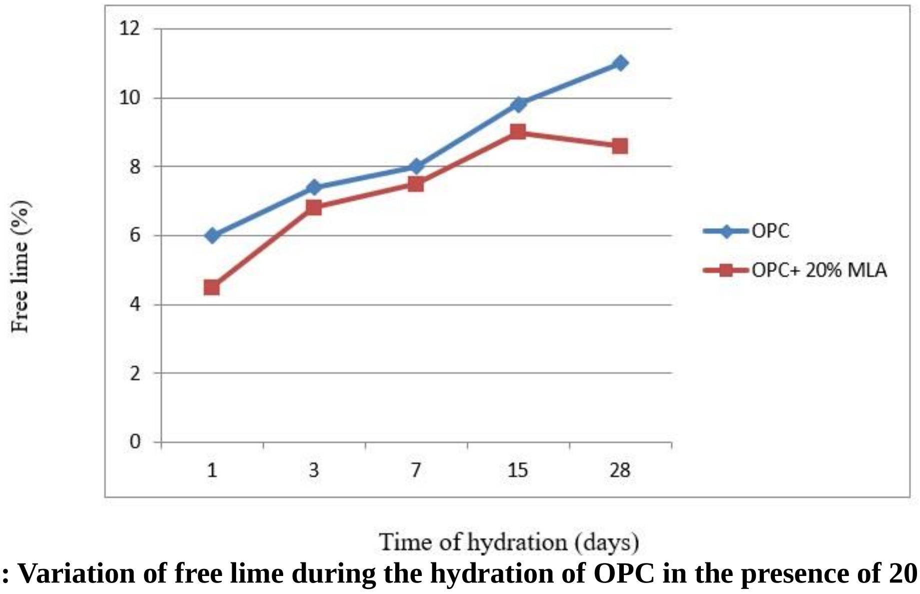


Figure5: Variation of free lime during the hydration of OPC in the presence of 20% MLA

Free lime levels (Fig. 5) were also observed to rise with time, indicating hydration. The values in mixed cement grew with time as well, but they are significantly lower than those in OPC. This is due to the interaction of Ca(OH)2 formed during hydration with MLA's amorphous silica.

3.3. Expansion Measurement

Expansion of control OPC and Blended OPC measured from the length comparator. We make a 28cm long bar of both types of cement and put them in water for the hydration reaction. We measured the length of the bar on different intervals of time like 2 days, 8 days, 16 days, 22 days, and 28 days. The expansion % of both control OPC and Blended OPC are plotted in the given graphFigure (6).

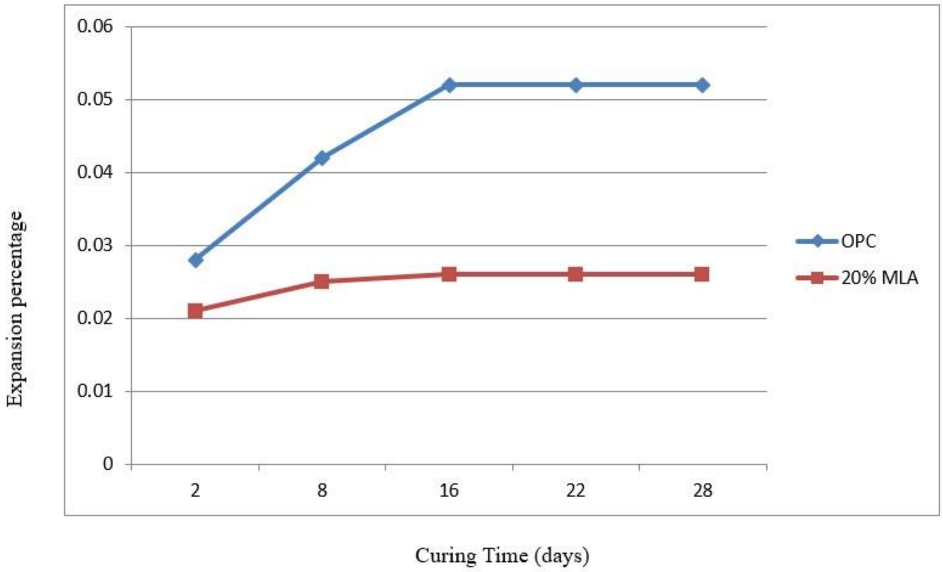


Figure 6: Expansion of cement at different intervals of time during the course of hydration

Expansion of control OPC is first increasedup to 16 days and then became constant up to 28 days. The same result was shown by Blended OPC. But the extent of expansion is very less in blended OPC. Expansion experiments have indicated that in the presence of MLA, the extent of expansion is reduced. The reduction in expansion is a characteristic of good cement. It helps to prevent cracking.

3.4. Analysis of liquid phase

Liquid phase analysis is a method to determine the concentration of Hydroxyl ions (OH^-) and Calcium ions (Ca^{2+}) at different intervals of time.Ca^{2+} ion concentrations in the liquid phase were studied at various hydration time intervals to better understand the process of hydration (Fig. 7). According to the graph, as soon as cement came into contact with water, Ca^{2+} ion concentrations in the liquid phase grew, at 25 min it became constant. After 35 minutes it increases rapidly and became constant after 45 minutes.In terms of Ca^{2+}ion concentrations, the solution becomes saturated or supersaturated.Following the highest value, the concentration drops due to the precipitation of various calcium hydration products. In the case of Blended cement, the curve is similar, with lower values. This implies that the Blended cement acts similarly to the control OPC. The lower value of Ca^{2+} ions concentrations in blended OPC is because of the pozzolanic reaction between MLA and OPC. The formation of C-H-S is the main reason for the decrease in Ca^{2+} ion concentrations.

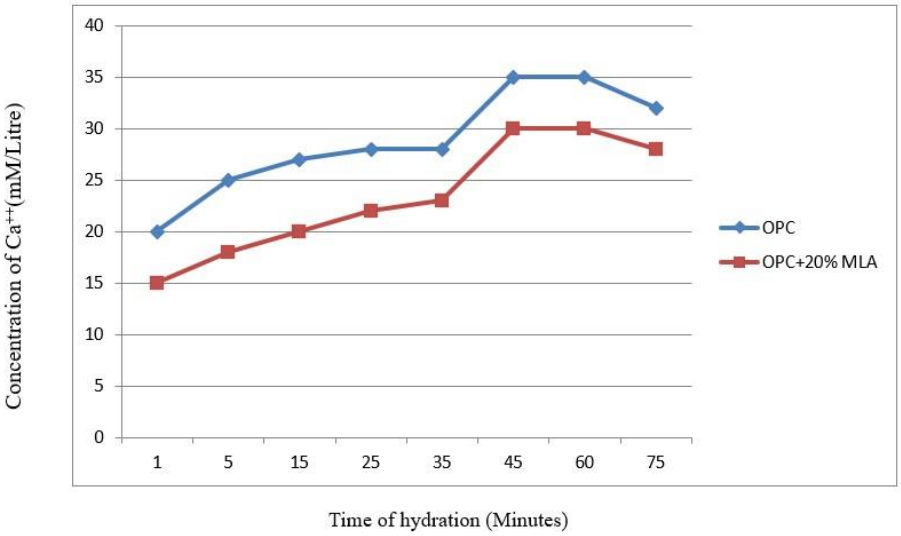


Figure 7: variations of Ca^{2+}Concentration during the hydration of cement in the liquid phase

A similar trend is shown(Fig .8) by OH^- ions,Concentration of OH^- first increases when it reacts with water. It increases up to 15 minutes and then became constant for up to 25 minutes. it further increases and reaches the maximum level at 45 minutes. after 60 minutes it further decreases.In Blended cement, the Concentration of OH^- is lower than the control OPC. The value is always lower in presence of MLA because less cement is present per unit area due to the 20% replacement of MLA and also some part of OH^- ions combined with MLA due to pozzolanic reaction between OPC and MLA [22-25].

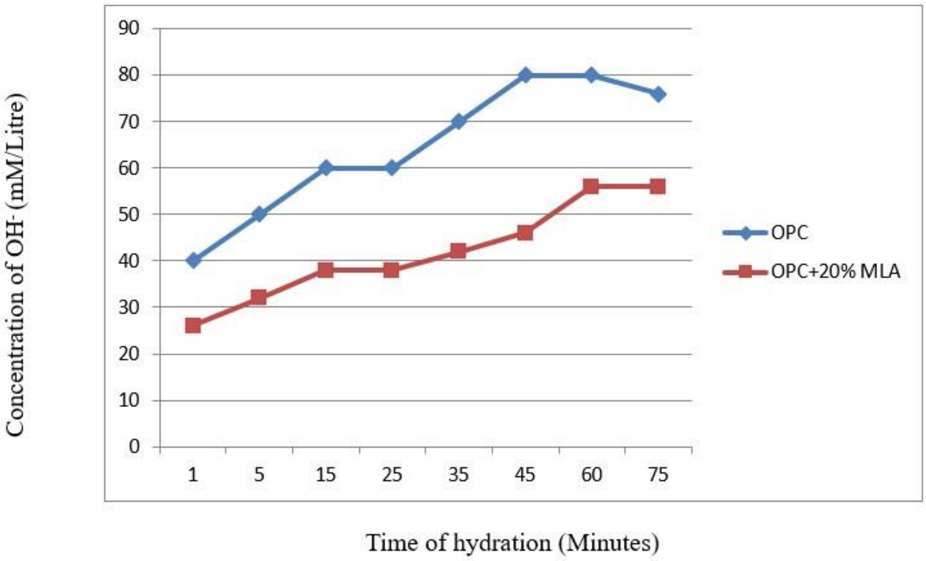


Figure 8: Variation of OH^- concentration during the hydration of cement in the liquid phase.

3.5.SEM ANALYSIS

Figure 9 depicts a scanning electron micrograph of a 28-day hydrated control OPC, whereas Figure 10 depicts an SEM of a 28-day hydrated blended OPC. Figure 9 shows an SEM image of the control OPC, which reveals that it is a less dense structure with substantial porosity. Hydrated crystals are extensively distributed. Yet, the SEM image of blended OPC in Figure 10 indicates that the structure is highly dense and has little porosity. Hydrated crystals are evenly distributed across the image. The pozzolanic response of MLA is the primary cause of this. This pozzolanic reaction produces an extra hydrated product C-H-S, which is seen in Figure 10 in a more organized and compact form. This formation of C-H-S is the main reason behind the strength of cement [26,27]

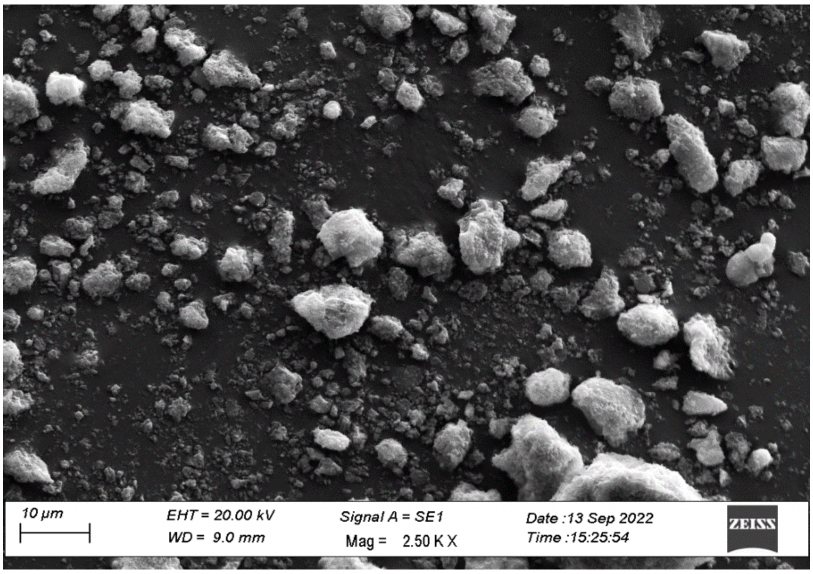


Figure 9: SEM photograph of OPC Hydrated for 28 days

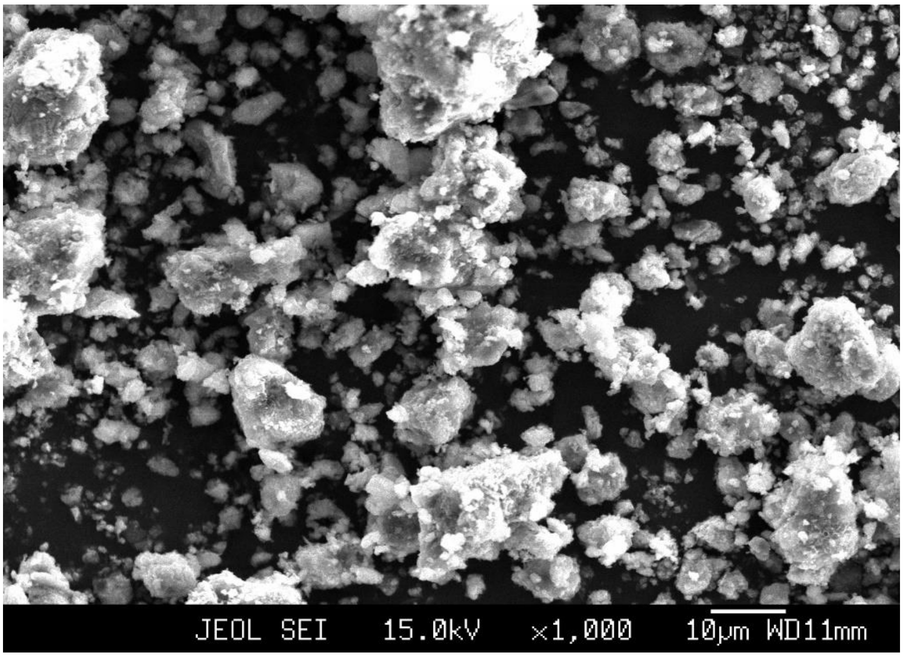


Figure 10: SEM photograph of OPC Hydrated in presence of 20% MLA for 28 days

3.6. COMPRESSIVE STRENGTH

The strength of blended cement determines by the help of compressive strength. Compressive strength is determined by a compressive strength testing machine. We make a mould (5cm×5cm×5cm). Put these Moulds in water for hydration after different intervals of time ex. 1 day, 3 days,7 days,15 days, and 28 days, we break mould with the help of a compressive strength machine.Figure 11 shows how the compressive strength of Blended cement increases [26]. Up to 7 days the strength of control OPC is greater than Blended OPC. But after 15 days when the hydration reaction proceeds the strength of

Blended OPC is greater than the control OPC. After 28 days of hydration, the strength of the control OPC is 90 KN whereas the strength of the Blended OPC reaches to 105 KN. Reduced compressive strength readings up to 7 days inMLA Blended cement may be related to lower pozzolanic reactivity early in hydration [27]. However, after 28 days of hydration, the compressive strength value is greater than that of the control, which may be attributable to an increased amount of calcium silicate hydrate(C-H-S) created as a result of the pozzolanic reaction [28].Structure developments in hydrating cement pastes result from the creation of various hydration products that are both crystalline and amorphous in character. As a result, the formation of C-H-S is responsible for the development of strength [29-31].

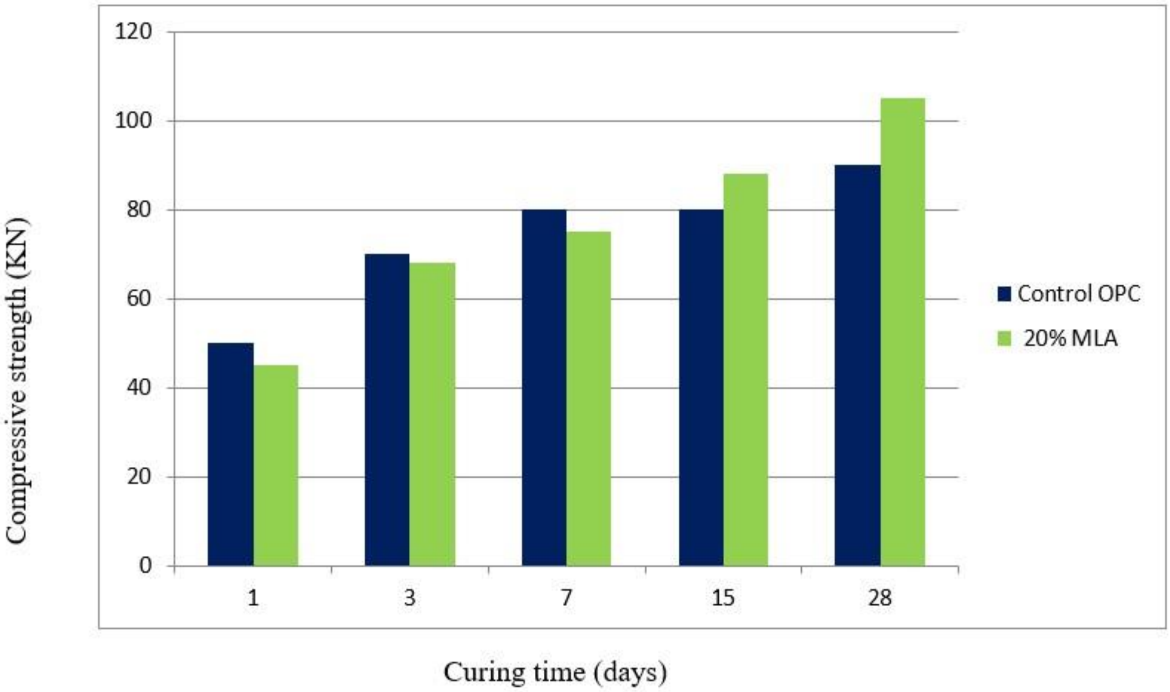


Figure 11: Variation of compressive strength with time

4. CONCLUSION

The findings indicate that MLA is a pozzolanic substance that combines with calcium hydroxide to create calcium silicate hydrate. MLA's pozzolanic activity increased with time. When 20% MLA was combined with OPC, the hydration characteristics were quite similar. The compressive strength values of blended OPC were found to be greater than ordinary OPC after 28 days of hydration. More studies under diverse settings are required before MLA can be suggested as a blending component.The production of C-H-S by the reaction of MLA causes an increase in compressive strength. According to liquid phase studies, the concentration of Ca^{2+} ions drop in blended OPC due to C-H-S production, which is more than in control OPC. SEM is also used to explore the development of C-H-S. The free lime percentage is also computed, demonstrating the reduction of free lime in blended OPC.All of the data show that MLA blended OPC (20% MLA + 80% OPC) is considerably superior to control OPC. We can also minimize the price of OPC with the aid of mixing. OPC production will also be reduced by 20%. This will aid in energy conservation as well as a considerable decrease in CO2 emissions. This will keep our planet from being affected by the greenhouse effect. As a result, we can state that MLA not only increases the quality of OPC but also helps to preserve our environment.

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