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Enhancing Studies on Microstructural and Mechanical Properties of Cement Mortar with Vermiculite Powder, Calcium Aluminate Cement, and GGBFS Substitution

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***Abstract*:**
This work delves into the exploration of novel materials to pave the way for more environmentally friendly and robust cement mortar formulations. The study centres on three key components: vermiculite powder (VP), calcium aluminate cement (CAC), and ground granulated blast furnace slag (GGBFS). These materials, when thoughtfully blended, contribute to the creation of sustainable cement mortar with enhanced performance characteristics. The research systematically investigates various mixtures of these materials, focusing on different ratios of vermiculite powder and CAC, along with the inclusion of GGBFS as a critical ingredient. Mortar mixes with a 1:3 ratio was prepared, and the compressive strength of each combination was rigorously examined and as a result found Ma mix exhibits a higher strength of approximately 15.02 MPa, while Mb, Mc & Md show slightly moderate strengths, around 12.0 Mpa, 12.24 Mpa and 13.54 MPa respectively, also the Vermiculite particles displayed a characteristic plate-like structure with a size range of approximately 10 to 50 micrometers, contributing to its unique properties in cement mortar. Meanwhile, the GGBFS particles appeared predominantly as irregularly shaped grains with an average size ranging from 5 to 20 micrometers. Notably, the vermiculite powder exhibited diverse compositions ranging from 0% to 50%, while CAC was varied between 10% and 50%, with GGBFS making up the remainder at 50%. The outcomes were compelling, with the optimal mortar dosage showcasing commendable compressive strength. Building upon these promising results, the study further extended its investigations to cement mortar formulations, yielding positive and significant advancements. The research culminated in a detailed assessment of compressive strength, where the newly developed cement mortar not only met but exceeded the performance of standard cement mortar compositions. This ground breaking research not only highlights the potential for sustainable construction practices but also underscores the significance of innovative material combinations in pushing the boundaries of cement mortar performance. The findings offer a tangible pathway toward eco-friendly construction while enhancing structural integrity, thus contributing to the development of more resilient and sustainable infrastructure systems.

Keywords: *Vermiculite Powder, Calcium Aluminate Cement, Ground Granulate Blast Furnace Slag, Sodium Hydroxide, Compressive Strength, Micro Structural Properties.*

I. Introduction

Cement mortar, the most common building ingredient, is primarily made up of natural aggregates and binder. In the

process of making cement mortar, ordinary Portland cement (OPC) is frequently employed as a binder material [1]. On the other hand, 5–8% of carbon dioxide emissions come from the cement sector [2]. Furthermore, the manufacture of one tonne of OPC is thought to emit approximately one tonne of carbon dioxide into the atmosphere, which has a negative effect on the environment [3]. Overuse of this non-renewable natural resource resulted from the widespread use of natural river sand as the fine aggregate in cement mortar. The ecosystem is negatively impacted by the overuse of naturally occurring river sand, as was previously observed [4]. Finding appropriate substitutes for OPC and natural sand in the manufacture of cement mortar is therefore crucial.
In this investigation the following materials were used:

Vermiculite powder:
Vermiculate is a hydrous phyllosilicate mineral that occurs naturally. Vermiculite is produced globally, reportedly 2.35 million tones per year, with the majority of reserves found in South Africa, the US, Australia, China, Russia, India, and Uganda. Vermiculite can expand up to thirty times its initial volume when heated to temperatures between 650 and 1000 C. As a result, vermiculite has very low density, high refractoriness, great absorption of sound, and low thermal conductivity when expanded. According to Koksal et al., vermiculite as shown in fig 1, dehydrates at a temperature of roughly 100 C because the water that has been physically absorbed loses weight. The loss of chemically absorbed water may be the cause of mass losses that occur between 500 and 900 degrees Celsius. Particulate matter (PM) and PM smaller than 10 micro- meters are the main pollutants in the vermiculite expansion process, according to reports from the US Environmental Protection Agency (EPA).

Fig 1: Vermiculite PowderCalcium aluminate cement:

After being invented in 1908 by J. Bied, calcium aluminate
cement (CAC), which comprises primarily of monocalcium aluminate (CA), has been utilized in the building industry from the late 19th and early 20th centuries. Although it was first created as an alternative to Portland cement to improve resistance to aggrieve ions (sulphates and chlorides), its early strength development (within 24 hours) led to its application to military facilities during World War I, which produced the various types of CAC. These days, CAC is used in a wide range of specific fields, such as refractory application as a fire-resistant material, industrial floor and wastewater application as a high resistance against chemical degradations, tunnel lining grout that sets and hardens quickly, and hydraulic dam spillway grout that is resistant to abrasion. Furthermore, the capacity to acquire strength quickly, even at temperatures below 0°C, allows for cold weather concreting. The application of CAC as shown in fig 2, combined with expanding agents as a repair material has garnered more attention recently.

Fig 2: Calcium aluminate cement (CAC)

Ground Granulated Blast Furnace Slag [GGBFS]: Ground Granulated Blast Furnace Slag is referred to as GGBFS as shown in fig 3. It is a byproduct of the iron and steel industries, made when steam or water is used to cool the molten iron slag in a blast furnace. GGBFS is ground into a fine powder that can be added to cement mortar as an additional cementitious material. Because GGBFS enhances cement mortar's strength, resilience, and resistance to chemical attacks, it is a widely used option in construction for high-performance, environmentally friendly cement mortar applications.

Fig 3: Ground Granulated Blast Furnace Slag GGBFS

II. Literature Survey

Koksal, Fuat, Turan Nazlı, Ahmet Benli, Osman Gencel, and Gokhan Kaplan. **"The effects of cement type and expanded vermiculite powder on the thermo- mechanical characteristics and durability of lightweight mortars at high temperature and RSM modelling."** *Case Studies in Construction Materials* 15 (2021): e00709. The investigation of the resistance of the mortars to be produced by replacing fine aggregate with expanded vermiculite powder (EVP) in certain proportions against high temperatures was performed in this study. In the mortar mixes, two different cement types namely, Portland cement (PC) and calcium aluminate cement (CAC) were used as a binder and fine aggregate (sand) was replaced with EVP.The microstructure, mechanical, thermal properties and durability of PC and CAC mortars produced in this way were determined under laboratory conditions after applying standard curing for 28 days and after being temperature exposure of 300 ◦C, 600 ◦C and 900 ◦C and the following conclusions have been drawn: • The compressive strength of PC blended mortars are higher than those of CAC blended specimens for control and all EVP incorporated specimens. • At 300 ◦C, combined use of CAC and EVP showed very high performance after high- temperature exposure by strength enhancements of 64.3%, 37.6%, 30.4% and 10.5% for the mixtures of CAC control and CAC blended mortars with 15%, 30% and 45%EVP contents respectively. At 600 ◦C, CAC blended specimens exhibited strength reductions of 20.8%, 15.2%, 25.0% and 22.4% for 0, 15%, 30% and 45% EVP addition. On the other hand, PC blended specimens revealed strength reduction at all temperature ranges and higher reduction than CAC specimens. Similarly, the highest strength of 20.70 MPa was obtained for the CAC Control specimen and the lowest value of 6.70 MPa was obtained for the mixture with 45%EVP content by 67.63% reduction in comparison with CAC Control.

Gunasekaran, Mr M., A. Priyalakshmi, C. Anudevi, H. Premachandar, and V. Balamuruagn. "Study on vermiculite incorporate in mortar." *Int. J. Innov. Res. Sci. Technol* 2 (2016): 36-42. Rubbed off Versatile and lightweight, vermiculite finds applications as calcium silicate boards, floor and roof screeds, insulating cement mortars, and loose fill insulation, among other applications. Research is done on using vermiculite in place of natural sand. Design mix with a water cement ratio of 0.5 and a mix percentage of 1:3. In these specimens, sand makes up 5%, 10%, 15%, 20%, 25%, and 30% of the total weight of sand, replacing some of the vermiculite. The samples receive an addition of Superplasticizer Conplast SP430 at a rate up to 1.5% of the cement weight. The mortar's characteristics, including its split tensile strength, water absorption capacity, and sorptivity after 28 days of curing, were ascertained.

K. S. Gokul Kishore and N. Pannirselvam developed a mortar employing vermiculite. It is discovered that adding more vermiculite to the resultant mixes boosts their water absorption while decreasing their compressive strength. When compared to mortar, it can be observed that water absorption increases as vermiculite level rises. Vermiculite mortar's compressive strength is equivalent to cement mortar's in a 1:2:1 ratio. When 33.33% of the fine total was replaced with vermiculite, the compressive strength was observed to be higher. When vermiculite is added to the mortar in the mix ratios of 1: 3 (C:VM), 1:0.5:2.5 (C:S:VM), 1:1:2 (C:S:VM), 1:1.5:1.5 (C:S:VM), and 1:2.5:0.5 (C:S:VM), the compressive strength of the mortar diminishes. In 1:3 (C:VM), the compressive strength was found to be the least compared to that of mortar. The addition of vermiculite to the mortar and the resulting decrease in compressive strength are inversely correlated with the concentration of hotness. In 1:3 (C:VM), the lowest temperature was recorded. As a result, vermiculite has better thermal insulation qualities. Cement mortar shrinks by 25 mm, while vermiculite without fine aggregate (1:3) and 1:2.5:0.5 show 48% and 16% of the shrinkage, respectively.

Mo, Kim Hung, Hong Jie Lee, Michael Yong Jing Liu, and Tung-Chai Ling. "Incorporation of expanded vermiculite lightweight aggregate in cement mortar**." Construction and Building Materials** 179 (2018): 302-306. This investigation presents an evaluation of the properties of cement mortars containing expanded vermiculite as partial sand replacement. When the expanded vermiculite was included at 30% and 60% replacement levels, the flow diameter was higher compared to the plain mortar without expanded vermiculite. The porous lightweight nature of the expanded vermiculite also contributed to the reduction in the unit weight and compressive strength of mortars, as well as increased water absorption. Although weight loss of the expanded vermiculite mortars subjected to elevated temperature was increased, the expanded vermiculite had positive effect in providing heat resistance and thermal stability to the mortars, observed by the reduction of compressive strength loss of mortars upon exposure to elevated temperatures.

Koksal, Fuat, Osman Gencel, and Mehmet Kaya. **"Combined effect of silica fume and expanded vermiculite on properties of lightweight mortars at ambient and elevated temperatures."** Construction and Building Materials 88 (2015): 175-187. In this study, properties of cement-based mortars produced with vermiculite and silica fume were investigated at ambient and elevated temperatures. Physical, mechanical, thermal and micro structure properties of mortars produced were determined. Mortars were produced at 4, 6 and 8 expanded vermiculite/ cement ratio (V/C) by volume. Silica fume was used at the ratios of 0%, 5%, 10% and 15% under each V/C ratio.

In total, 114 mortar specimens with 40 40 160 mm were investigated. Specimens were subjected to 300, 600 and 900 C for 6 h. It was observed that new formulations with silica fume increased both strength and durability at elevated temperatures of mortars with vermiculite. Unit weights of mortars at hardened state range between 1200 and 780 kg/m3. Water absorption values range between 24.2% and 40.6%. Strengths of mortars vary between 3.9 MPa and 16.4 MPa at ambient temperature. Thermal conductivity coefficient of mortars indicated a decrease depending on V/C ratio of mortar up to 0.257 W/m K which means 58.2% increment in thermal performance. Mortars produced using expanded vermiculite aggregate shows a good performance in terms of preservation of mechanical strength to elevated temperature. This means that expanded vermiculite turns out to be a good fire-resistant material.

Gencel, Osman, Aliakbar Gholampour, Hayrettin Tokay, and Togay Ozbakkaloglu. **"Replacement of natural sand with expanded vermiculite in fly ash- based geopolymer mortars."** Applied Sciences 11, no. 4 (2021): 1917. There has been a lot of focus on improving the thermal insulation of building components in order to lower the thermal energy loss of structures. Building thermal performance would be enhanced by substituting expanded vermiculite for natural river sand in the creation of building materials because of its porous structure. This study examines the characteristics of geopolymer mortars based on fly ash (FA) and made with expanded vermiculite. This study's primary goal was to create geopolymer mortar for use in building thermal insulation applications that has a lower thermal conductivity than traditional mortar. Twelve batches of geopolymers were made in order to assess their various characteristics.

Yang, Hee Jun, Ki Yong Ann, and Min Sun Jung. **"Development of strength for calcium aluminate cement mortars blended with GGBFS."** Advances in Materials Science and Engineering 2019 (2019). There has been a lot of focus on improving the thermal insulation of building components in order to lower the thermal energy loss of structures. Building thermal performance would be enhanced by substituting expanded vermiculite for natural river sand in the creation of building materials because of its porous structure. This study examines the characteristics of geopolymer mortars based on fly ash (FA) and made with expanded vermiculite. This study's primary goal was to create geopolymer mortar for use in building thermal insulation applications that has a lower thermal conductivity than traditional mortar. Twelve batches of geopolymers were made in order to assess their various characteristics. The development of strength in various mortars including granulated ground blast-furnace slag (GGBFS) and calcium aluminate cement (CAC) combination was examined in this study. The weight of binder substituted for GGBFS levels was0,20,40, and 60%; as a secondary phase, the CAC utilised in this investigation naturally comprised C2AS clinker. In addition to the mineral component, all specimens were cured for the first 24 hours at 35 ± 2°C to activate the hydraulic character of the phase. They were then stored at 25 ± 2°C in a 95% humidity environment. Following pouring, the fresh mortar's penetration resistance was measured, and the mortar's compressive strength was tracked for a full year. In order to assess the hydration kinetics during the early stages of life with respect to heat evolution, a 24-hour calorimetric investigation was conducted at an isothermal temperature of 35°C. Long-term hydration behaviour was determined by X-ray diffraction, corroborated by energy dispersive spectroscopy and scanning electron microscopy for microscopic inspection. To further measure the porosity, a pore structure analysis was conducted. Consequently, it was discovered that a rise in the mixture's GGBFS content led to an extended setup time and an increase in the total heat developed over the course of 24 hours in normalised calorimetry curves. Furthermore, the mortar's strength growth demonstrated a consistently rising value for a full year, accounting for 43.8–57.5 MPa for the mixture because, after the pastes were cured for 365 days, stratlingite formed, which was determined by chemical and microscopic inspection. With the exception of total incursion volume, GGBFS substitution had no effect on the cement matrix's pore size distribution.

Fan, Wei, Yan Zhuge, Xing Ma, Christopher WK Chow, Nima Gorjian, Jeong-A. Oh, and Weiwei Duan. **"Durability of fibre reinforced calcium aluminate cement (CAC)–ground granulated blast furnace slag (GGBFS) blended mortar after sulfuric acid attack."** Materials 13, no. 17 (2020): 3822. Wastewater facilities made of cement mortar are crucial to modern society, but they can be attacked by sulfuric acid in harsh environments. Because fibre reinforced mortar has a unique crack control and good anti-corrosion capacity, it has been accepted as a potential coating and lining material for structures made of degraded reinforced cement mortar. The purpose of this work is to assess the strain-hardening mortar's performance in a harsh sewer environment—sulfuric acid immersion—using a blend of ground granulated blast furnace slag (GGBFS) and polyethylene (PE) fiber-reinforced calcium aluminate cement (CAC). For a maximum of 112 days, specimens were subjected to a 3% sulfuric acid solution. Evaluations were conducted on the mechanical, visual, and physical aspects of the sulfuric acid attack, including compressive and direct tensile strength, sorptivity, and water absorption capacity. To better understand the deterioration mechanism, X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) were also used to evaluate micro-structure changes to the samples following sulfuric acid attack. The findings demonstrate that, in terms of visual observations, penetration depth, direct tensile strength, and compressive reduction, fiber-reinforced calcium aluminate cement (CAC)-based samples outperformed fiber-reinforced ordinary Portland cement (OPC)-based samples as well as mortar samples in sulfuric acid solution. The primary cause of the deteriorating process following exposure to acid assault was gypsum production in the cementitious matrix of both CAC- and OPC-based systems. Furthermore, it has been demonstrated that cementitious materials can be effectively screened against an acidic environment using laboratory sulfuric acid testing. The service life of wastewater pipes made of cement mortar may be designed using this technique.

Koksal, Fuat, Kübra Coşar, Murat Dener, Ahmet Benli, and Osman Gencel. **"Insulating and fire-resistance performance of calcium aluminate cement based lightweight mortars."** *Construction and Building Materials* 362 (2023): 129759. The study looked at how two different cement kinds and expanded vermiculite powder (EVP), used as fine aggregate, affected the lightweight mortars' ability to resist fire and provide insulation. In order to reduce the density and thermal conductivity of the mortars, river sand was completely replaced with EVP. Portland

cement (PC) and calcium aluminate cement (CAC) were the cements used. There were four distinct EVP/cement (PC or CAC) ratios found: 3, 4, 5, and 6. The temperatures at which the mortar specimens were subjected were 20, 300, 600, 900, and 1100 ◦C. After
28 days of conventional curing, tests for thermal conductivity, mechanical qualities, dry unit weight, and ultrasonic pulse velocity were conducted to determine how high temperatures affected the mortar specimens. Using a scanning electron microscope, the effects of high temperatures on microstructural degradation were examined. In terms of compressive strength, mixtures having an EVP/CAC ratio of 4 often performed the best when exposed to high temperatures. At both 20 ◦C and 1100 ◦C, the mortar with the lowest thermal conductivity had an EVP/CAC ratio of 6. The results of the experiment indicate that expanded vermiculite and CAC can be used to create lightweight composite coating materials that are cement-based and resistant to fire. Expanded vermiculite can also be used as a lightweight aggregate in plaster applications for building insulation.

Benli, Ahmet, Mehmet Karatas, and Hasan Anil Toprak. **"Mechanical characteristics of self- compacting mortars with raw and expanded vermiculite as partial cement replacement at elevated temperatures."** *Construction and Building Materials* 239 (2020): 117895. This study examined the impact of expanded and raw vermiculite (EVM) on the mechanical properties and durability of self- compacting mortars (SCMs) at room temperature and above. In this case, nine SCM series were created by replacing RVM and EVM with mineral additions at weight-based rates of 0%, 5%, 10%, 15%, and 20%, including the control mix. To test strength qualities, 81 beams with dimensions of 40 x 40 x 160 mm were cast and water cured for 3, 28, and 90 days. The durability characteristics of SCMs, including porosity, water absorption, sorptivity, and density, were measured by casting 54 cubes measuring 50 x 50 x 50 mm and let them to cure in water for 28 and 90 days. The mini-v- funnel flow test and slump diameter were evaluated to quantify the new features of SCMs. The viscosity test was used to ascertain the rheology of SCMs. After 28 days of curing, the hardened SCMs specimens were subjected to 300, 600, and 900 C, respectively. The experimental results showed that for all water curing ages at room temperature, a notable decrease in the compressive and flexural strength of SCMs specimens was observed as the concentration of RVM and EVM increased. In comparison to its flexural strength after 28 days, the RVM20's flexural strength showed a very slight drop after 90 days. The findings demonstrated that compared to RVM specimens, EVM specimens shown greater high temperature tolerance.

Koksal, Fuat, Emrah Mutluay, and Osman Gencel. **"Characteristics of isolation mortars produced with expanded vermiculite and waste expanded polystyrene."** Construction and Building Materials 236 (2020): 117789. One of the most crucial parts of cement-based composites is mortar. The characteristics of mortars are significantly impacted by aggregates as well. When making mortar, natural and crushed fine aggregates are typically employed for a variety of purposes, including energy conservation in structures and buildings. When used as aggregates in mortar, vermiculite and leftover polystyrene offer a chance to lower the thermal conductivity coefficient and unit weight, both of which are crucial for thermal isolation. Mortars were made using five vermiculite + polystyrene/cement ratios, 3, 4, 5, 6, and 7, by volume. In addition to their combination at 25%, 50%, and 75%, 100% vermiculite and 100% polystyrene by volume were also examined in each ratio. To study the physical, mechanical, and thermal qualities, a total of twenty-five mortars measuring four by sixteen centimetres were made. Because of their extremely high porosity of up to 67.2%, it has been noted that the use of vermiculite and polystyrene in mortar allows for the fabrication of mortars with unit weights between 393 and 946 kg/m3. In terms of thermal conductivity, which drops by up to 0.09 W/mK, this is also highly significant. The range of the compressive strength is
0.57 to 5.89 MPa. When necessary, mortars containing polystyrene and vermiculite are good insulators.

Karatas, Mehmet, Ahmet Benli, and Hasan Anil Toprak. **"Effect of incorporation of raw vermiculite as partial sand replacement on the properties of self-compacting mortars at elevated temperature."** Construction and Building Materials 221 (2019): 163-176. The new features of SCMs were assessed using the slump flow diameter, V-funnel flow, and viscosity tests. After curing for 28 days, the SCMs specimens were heated to 300 C, 600 C, and 900 C. Before conducting experiments, they were chilled to ambient temperature. The findings showed that when RVM rates increase, all SCMs mixes' compressive and flexural strengths drop at water curing for all ages. Across all temperature ranges, the loss of compressive and flexural strengths for SCMs incorporating RVM remained extremely low when compared to the strength loss of control samples. For many applications, mini-slump flow values are practical and suitable in terms of consistency. RVM- containing SCMs can be utilized to create lightweight cement mortar with superior qualities such as low density and heat insulation.

III Objectives of the Work

Following objectives are identified:

- To study feasibility of vermiculite powder, calcium aluminate cement and GGBFS
- To study the physical properties of vermiculite powder, calcium aluminate cement and GGBFS
- To study the mechanical properties of vermiculite powder, calcium aluminate cement and GGBFS
- To study the behaviour of individual material on different mixes.
- To study the micro structural evaluation foroptimum mixes

IV Material and Methodology

Cement mortar is the mix of cement and fine aggregate, coarse aggregate and water, superplasticizer, and mineral aggregates. In this study replacement of cement with vermiculite powder, calcium aluminate cement and ground granulated blast furnace slag as shown in fig 4 &5.

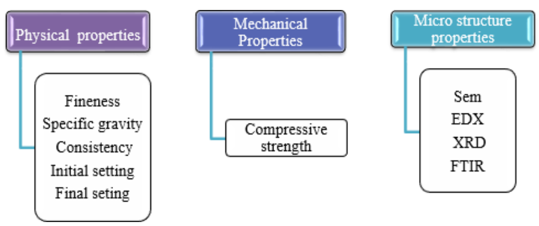

Fig 4: Methodology of proposed work

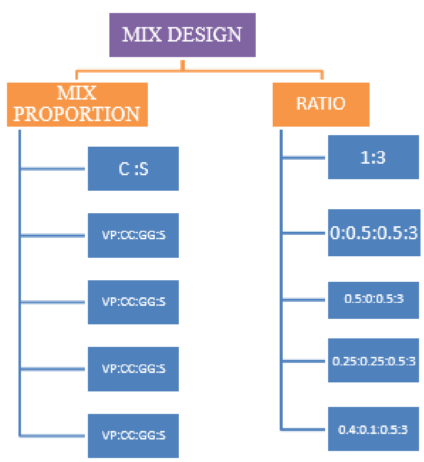

Fig 5: Mix ratios of proposed work

A total of 4 mixes were prepared and tested in this study. Table 1 contains all of the mix details. All design calculations for the 1:3 ratio mortar was done with vermiculite powder 0%, 50% ,25% and 40% ratios and Calcium aluminate cement with 0%, 50%, 25% and 10% ratios and GGBFS with 50%. After all of the samples with weights have been measured, place them in a tray and mix them with the mixing percentage of water and the Sodium Hydroxide(4m). and the cube was cast. Mix proportion of cement mortar specimens and other properties are displayed in table 1-8.

Table 1: Mix proportion of cement mortar specimens

Mix Designation	Mcc	Ma	Mb	Mc	Md
Binder (kg/m^3)	520	520	520	520	520
CAC (kg/m^3)	0	0	260	130	52
VP (kg/m^3)	0	260	0	130	208
GGBFS (kg/m^3)	0	260	260	260	260
Sand (kg/m^3)	1560	1560	1560	1560	1560
Water or NaOH (kg/m^3)	388	388	388	388	388

Table 2: Physical Properties of vermiculite Powder

S.no	Properties	Test results
1	pH value	7.1
2	Specific Gravity	2.63
3	Particle Size	1mm -7mm
4	Bulk Density	8-120kg/m^3

Table 3: Chemical Compositions of Vermiculite powder

S.no	Oxide (%)	ermiculite Powder
1	SiO_2	38.76
2	Al_2O_3	15.8
3	Fe_2O_3	12.06
4	CaO	2.32
5	MgO	17.69
6	SO_3	0.38
7	K_2O	5.5
8	Na_2O	0.3

Table 4: Physical Properties of Calcium AluminateCement

S.no	Properties	Test results
1	Specific Gravity	3.2
2	Particle Size	5,5150cm^2/gm
3	Density	3.0gm/cm^3

Table 5: Chemical Compositions ofCalcium Aluminate Cement

S.no	Oxide (%)	Calcium Aluminate Cement
1	SiO_2	5.02
2	Al_2O_3	52.03
3	Fe_2O_3	0.86
4	CaO	38.83
5	MgO	0.42
6	SO_3	0.09
7	K_2O	0.68
8	Na_2O	0.17

Table 6: Physical Properties ofGGBFS

S.no	Properties	Test results
1	Specific Gravity	2.95
2	Fineness	3.4
3	Standard Consistency	33
4	Initial Setting Time	45

Table 7: Chemical Compositions of GGBFS

S.no	Oxide (%)	GGBFS
1	SiO_2	29.7
2	Al_2O_3	13.1
3	Fe_2O_3	0.64
4	CaO	47.18
5	MgO	4.55
6	SO_3	2.3
7	K_2O	0.53
8	Na_2O	0.22

Table 8: Physical Properties of FineAggregate

S.no	Properties	Test results
1	Specific Gravity	2.53
2	Bulk Density (kg/m^3)	1506
3	Sieve Analysis	Zone-II

Curing Conditions:

In this investigation the following curingconditions were used:

Water curing: We have done water curing, but the samples are not showing stiffness. The sample particles were getting separated when we touched the surface of the mould. So, we conclude that water curing is not suitable for the materials like; VP, CAC and GGBFS. We adopted for Oven curing as shown in fig 6.

Fig 6: Water Curing

Oven curing: This type curing giving strength and stiffness. Oven curing cannot be adopted for cast in situ applications. So, we are planned to check for Ambient curing as shown in fig 7.

Fig 7: Oven Curing

Ambient curing: When the cubes were ambiently cured. The strength was very good. Compare to oven curing, the strength was almost similar. So, we preferredfor Ambient curing as shown in fig 8.

Fig 8: Ambient Curing

Consistency: A consistency test as shown in fig 9 for cement is typically conducted to determine the amount of water required to achieve a standard consistency in cement paste. This test helps assess the workability of the

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cement and is essential for quality control in construction. The procedure is usually based on ASTM or other standard methods.

Fig 9: Consistency TestInitial setting time:

It is conducted to determine the time it takes for a cement paste to start losing its plasticity and begin to set. Here's how the test is typically performed as shown in table 9:

Preparation: A neat cement is prepared by mixing a specific amount of cement with water. The mixture is stirred thoroughly until it reaches a uniform consistency.

Vicat Apparatus: It is commonly used for this test. It consists of a vicat needle and a mold to hold cement paste.

Filling the mold: The cement paste is placed in the mold and the surface is smoothed out.

Table 9: Properties of VP, CAC, GGBFS

S.no	Tests	Results
1	Consistency	62.50%
2	Initial Setting Time	45 min
3	Final Setting Time	2 hours

- Gradation curve:
  Sieve analysis of fine aggregate is tested so that give table was values of the test based onthat values we draw the gradation curve as shown in fig 10.

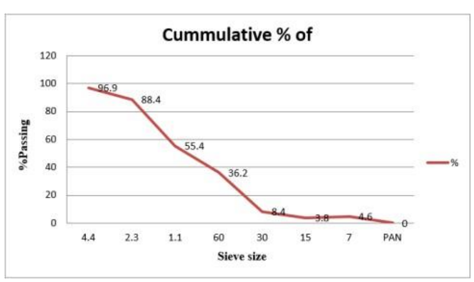


Fig 10: Gradation curve of Fine aggregates

Table 10: Fineness modulus of fine aggregate

S.no	Sieve(mm)	Wt retained (gm)	Cumulative Wt retained	% Wt retained	Cumulative % of passing
1	4.47	36	36	3.6	96.4
2	2.36	91	127	12.7	87.3
3	1.18	340	467	46.7	53.3
4	600	190	657	65.7	34.3
5	300	240	897	89.7	10.3
6	150	57	954	95.4	4.6
7	75	38	992	99.2	0.8
8	pan	8	1000	100	0

Table 11: Physical properties of fineaggregate

S.no	Properties	Test results
1	Specific Gravity	2.53
2	Bulk Density ($kg/_{m3}$)	1506
3	Sieve Analysis	Zone-II

B. Mechanical Properties

- **Compressive strength test:**

Casting of cubes done and the mould removes after 24 hours then put in the curing tank. After the allotted curing period, remove the specimen from the water, and wipe off any extra moisture from the surface. To the closest 0.2m, round the specimen's size as shown in table 12. Wash the roller bearing edge of the testing device. Place the test piece in the instrument ensuring the load is distributed uniformly across the opposing sides within the cube. Slide the specimen through the tool's base plate. Turn the portable element by hand so it gets to the top surface within the specimen as shown in fig 13. Carefully raise the strain avoiding disturbance at all times at a rate of 140 kg/cm^2/minute until the specimen extinctions. Make a note of any remarkable features regarding the failure type and record the maximum load as shown in fig12 &13.

Fig 11: Compression testing machine

C. Micro Structural Analysis

SEM: Scanning Electron Microscopy: As mentioned earlier, SEM stands for Scanning Electron Microscopy. It is an imaging technique that uses a scanning electron microscope to create high- resolution images of the surface of a sample, revealing its topography and composition at the micro- and nanoscale as shown in fig 12.

Analysis on MA:

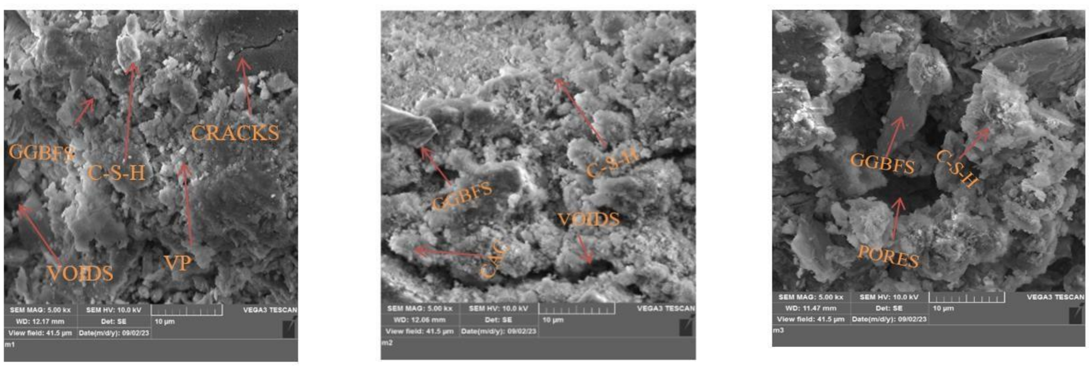
The SEM images revealed distinct particle sizes and morphologies within the sample. The Vermiculite particles displayed a characteristic plate-like structure with a size range of approximately 10 to 50 micrometers, contributing to its unique properties in cement mortar as shown in fig 12(a).

Analysis on MB: The dominant presence of CAC and GGBFS suggests the likelihood of identifying characteristic phases associated with these materials, such as calcium aluminate hydrates and amorphous silicate phases as shown in fig 12 (b).

Analysis on MC: The SEM images revealed a diverse range of particle sizes and distinct characteristics within the sample. The CAC particles exhibited a granular structure with an average particle size ranging from approximately 1 to 10 micrometers, consistent with the properties of calcium aluminate cement as shown in fig 12 (c).

Crystal Structure Determination: XRD is used to determine the crystal structure of a material. By analyzing the angles and intensities of the X-ray diffraction peaks in the pattern, scientists can derive information about the spacing between atoms and their arrangement in a crystal lattice.

V. Results And Discussions



(a) (b) (c)

Fig 12: (a) Analysis on MA (b) Analysis on MB (c)Analysis on MC

Days	Ma	Mb	Mc	Md
	CAC=0%	CAC=50%	CAC=25%	CAC=10%
	VP=50%	VP=0%	VP=25%	VP=40%
	GGBFS=50%	GGBFS=50%	GGBFS=50%	GGBFS=50%
7 Days	10.51	8.52	9.92	12.02
	12.71	9.45	11.58	10.18
	11.89	9.58	10.01	10.32
14 Days	13.42	10.21	11.48	12.42
	12.51	9.86	11.04	11.39
	14.07	10.94	12.12	13.76
28 Days	14.68	12.5	12.08	12.21
	14.94	11.91	12.01	13.52
	15.01	11.25	12.25	14.69

Table 12: Individual test results of compressive strength (mpa)

EDX:

Energy-Dispersive X-ray Spectroscopy (EDX or EDS): In the context of materials analysis and spectroscopy, EDX refers to Energy-Dispersive X-ray Spectroscopy or EDS. It's a technique used in conjunction with scanning electron microscopy (SEM) to analyze the elemental composition of materia
ls. It works by measuring the energy of X-rays emitted from a sample when it's bombarded with electrons. This information can be used to determine the elementspresent in the sample and their relative abundances.

XRD: XRD stands for X-ray diffraction, which is a widely used technique in materials science, chemistry, and physics to determine the atomic and molecular structure of a crystal. It relies on the principle of X- ray diffraction, where X-rays are directed at a crystalline sample, and the X-rays are scattered by the atoms in the crystal. The resulting diffraction pattern provides information about the arrangement of atoms within the crystal lattice as shown in figs 14-19.

Key points about X-ray diffraction (XRD) include:

Table 13: Average compressive strength test results atMa , Mb , Mc and Md

Sample name	7 Days (mpa)	14 Days (mpa)	28 Days (mpa)
Ma	11.69	13.08	15.02
Mb	9.02	10.94	12.0
Mc	10.43	11.48	12.24
Md	10.54	12.89	13.54

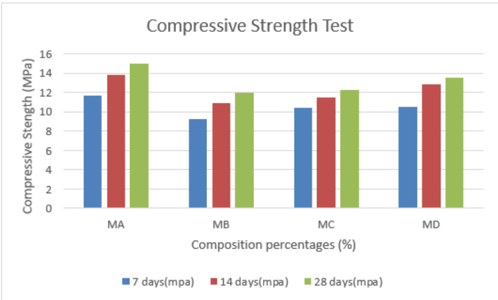


Fig 13: Graph showing Compressive Strength Ma,Mb, Mc, Md at different compositions

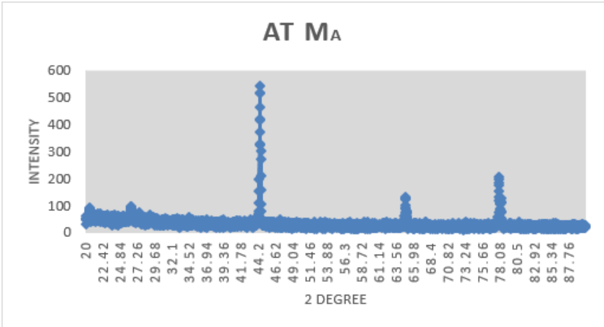


Fig 14: XRD pattern for MA

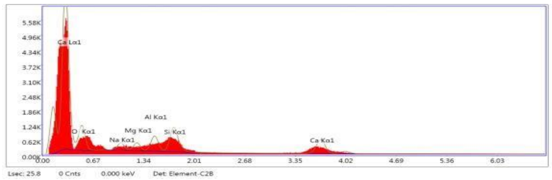


Fig 15: EDAX showing weight percentage of peakelements at MA

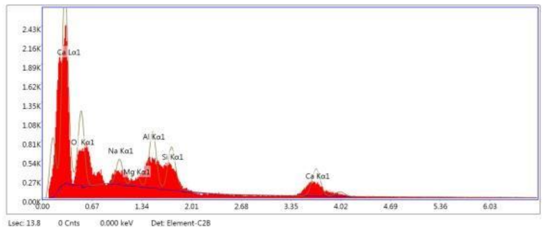


Fig 16: EDS showing weight percentage of peak elementsat MB

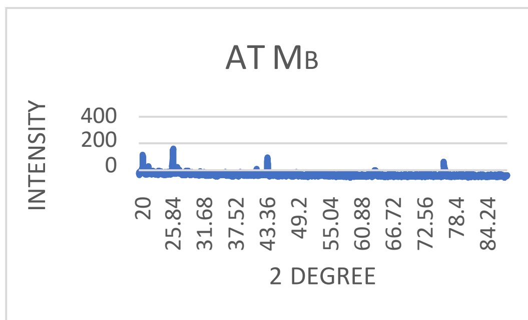


Fig 17: XRD pattern for MB

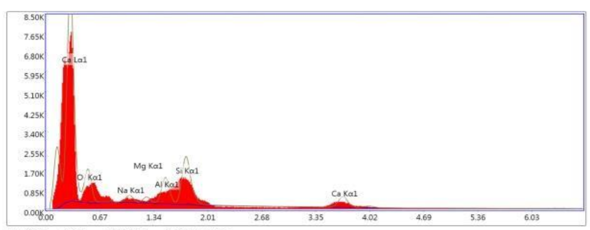


Fig 18: EDS showing weight percentage of peakelements at Mc

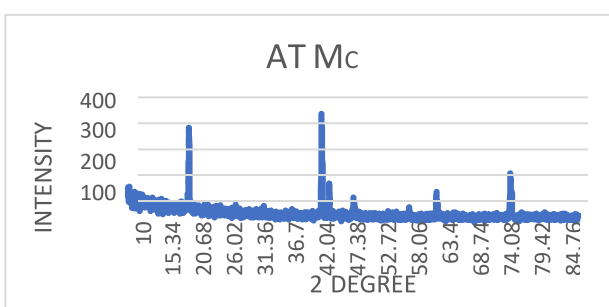


Fig 19: XRD pattern for MC

VI. Conclusion

The experimental data clearly illustrates the significant impact of varying cement mortar compositions on compressive strength. Compositions with different percentages of Calcium Aluminate Cement (CAC), Vermiculite (VP), and Ground Granulated Blast Furnace Slag (GGBFS) demonstrate diverse strength development patterns over the curing periods. In general, all cement mortar compositions exhibited a consistent increase in compressive strength as the curing period extended from 7 days to 28 days. This behavior aligns with standard cement mortar curing expectations, indicating that the cement mortar mixtures are maturing and gaining strength over time. The presence or absence of specific components, such as CAC, VP, and GGBFS, had a noticeable impact on the compressive strength. For instance, compositions with higher CAC content exhibited comparatively lower initial strengths but showcased continuous strength development. Conversely, VP and GGBFS contributed to different properties, and their combination with CAC led to unique strength profiles. At the 28-day mark, the strengths further improve, with Ma reaching 15.02 MPa, Mb at 12.0 MPa, Mc at 12.24 MPa, and Md at 13.54 MPa. These results suggest that the cement mortar samples continue to develop strength over time, with Ma exhibiting the highest compressive strength at the 28-day mark. These trends are consistent with standard cement mortar curing behavior and are indicative of the material's progress in gaining structural integrity and durability due to addition of vermiculite. Vermiculite particles displayed a characteristic plate-like structure with a size range of approximately 10 to 50 micrometers, contributing to its unique properties in cement mortar. Meanwhile, the GGBFS particles appeared predominantly as irregularly shaped grains with an average size ranging from 5 to 20 micrometers. Vermiculite, known for its insulation properties, demonstrated its potential as a component in cement mortar mixtures. The presence of Vermiculite affected both early and late-stage strength development, making it an interesting candidate for further exploration in cement mortar applications. Finally, we obtained 15mpa as optimum strength, So it is considered as S-Motar (13-
20 mpa). The research project underscores the importance of exploring alternative and sustainable materials in cement mortar mixtures. The inclusion of GGBFS, a byproduct of iron production, in some compositions aligns with the pursuit of environmentally friendly construction practices. In conclusion, this study contributes valuable insights into the influence of composition on cement mortar strength development and highlights the potential for creating sustainable and tailored cement mortar mixtures. The results encourage further research and application of these materials in the construction industry to enhance structural performance while reducing environmental impact.

Applications: This type of mortar can only be used on load bearing exterior walls, interior walls, and parapet walls. It is best suitable for sub- structure such as: masonry foundations, retaining walls, severs
, manholes , etc.

VII. Future Scope

Future work in this research area presents several exciting avenues for exploration and development. Firstly, a more comprehensive understanding of the long- term durability and resistance properties of the cement mortar mixtures is essential. Extensive testing for factors like freeze-thaw resistance, chloride ion penetration, and sulfate attack will provide insights into the materials' performance in adverse environmental conditions. Additionally, the optimization of the compositions to achieve a balance between early-age strength and long- term durability is a crucial aspect that warrants further investigation. Fine-tuning the ratios of Calcium Aluminate Cement (CAC), Vermiculite (VP), and Ground Granulated Blast Furnace Slag (GGBFS) could lead to cement mortar mixtures tailored for specific applications, such as structural, insulating, or even self- healing cement mortar. Exploring the feasibility of scaling up the production of these cement mortar mixtures on an industrial level is another significant avenue. This involves assessing the economic viability, availability of raw materials, and compatibility with existing construction practices to promote the adoption of sustainable and high-performance cement mortar in the construction industry. Furthermore, an in-depth microstructural analysis, including techniques such as SEM, XRD, and microscopy, can provide deeper insights into the interaction between components at a nanoscale level, offering a more comprehensive understanding of the cement mortar's behavior and properties. Lastly, real-world structural testing is crucial to validate the performance of these cement mortar mixtures in actual construction projects. This can include load-bearing tests, structural integrity assessments, and the evaluation of long-term behavior under various environmental conditions. In summary, future work in this research area should focus on enhancing the durability and performance of the cement mortar mixtures, optimizing their compositions, scaling up production, conducting advanced microstructural analyses, and validating their practical applicability in real-world construction scenarios. These endeavors will contribute to the advancement of sustainable and high-performance cement mortar solutions in the construction industry.

References

[1] ACI Committee 523, Guide for cast-in-place Low Density Cement mortar, American Cement mortar Institution, Detroit, Michigan, 1967, 8 pages
[2] “Vermiculite, Roof Deck and Insulating Cement mortar,” Cement mortar Construction, March 1961, Pages 6-67.
[3] H. Jatymowicz, J. Siejko, G. Zapotoczna-Sytek, “Technologia autoklawizowanego betonu komórkowego”, Wydawnictwo Arkady, Warszawa, 1975
[4] G. Zapotoczna-Sytek, M. Soboń, V International Conference of Autoclaved Aerated Cement mortar, Bydgoszcz, 2011, p. 27
[5] G. Zapotoczna-Sytek, “Autoklawizowany beton komórkowy w krajach europejskich”, Konferencja Dni Betonu, Wisła, 200
[6] Plain and Reinforced Cement mortar-Code of Practice (Fourth Revision), Bureau of Indian Standards, NewDelhi.
[7] Specification for Sand for Masonry Mortars (First Revision), Bureau of Indian Standards, NewDelhi.
[8] Code of Practice for Preparation and Use of Masonry Mortars (First Revision), Bureau of Indian Standards, New Delhi.
[9] Method for the Determination of Thermal Conductivity of Thermal Insulation Materials (Two Slab, Guarded Hot-Plate Method) (First Revision), Bureau of Indian Standards, New Delhi.
[10] Specification for Ordinary Portland Cement 53 Grade- Specification (First Revision), Bureau of Indian Standards, New Delhi.
[11] Non-Destructive Testing of Cement mortar - Part 1, Ultrasonic Pulse Velocity, Bureau of Indian Standards, New Delhi.
[12] Standard Specification for Expanded or Exfoliated Vermiculite Thermal Insulating Cement, ASTM International, West Conshohocken.