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Improving Concrete Properties Through the Blending of White Portland Cement, Mustard Husk Ash and Gypsum to Enhance Sustainability and Performance

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ABSTRACT
The effect of mustard husk ash (MHA) on white Portland cement (WPC) has been studied in this paper. The partial replacement of WPC by MHA and gypsum (GS) is investigated by different experimental techniques. Here, 12% of WPC has been replaced by MHA. We also added 3% GS. Which acts as a retarder for setting time. We examined setting times for different compositions of WPC and MHA. In some compositions, 3% GS is added. We also determine the Ca^{2+} ion concentration and compressive strength of blended and control WPC. Compressive strength shows that after 28 days of hydration, the strength of blended WPC is greater than control WPC. The formation of calcium-silicate-hydrate gel (C-S-H) by the pozzolanic reaction is the main reason behind this increasing strength. The formation of C-S-H gel is also shown by the Ca^{2+} ion concentration graph. The decrease in Ca^{2+} ion concentration shows that Ca^{2+} ions get consumed in reaction to form C-S-H. From these experiments, it is clear that 12MHA3GS blended WPC is better than control WPC.

KEYWORDS- White Portland cement (WPC); Mustard husk ash (MHA); Gypsum (GS); Setting time; Compressive strength

1. INTRODUCTION

India is one of the fastest-growing nations in the world. Construction activities are triggered by ever-growing human needs and urbanization. Being a developing country, India is developing every sector, whether it be infrastructure, with projects like highways, office complexes, hospitals, or residential buildings. Growth in construction activities is seen due to the increasing population and economic development that needs a better transport system, modern work culture, health facilities, and shelter. In India's journey of development, the building and construction industry is simultaneously playing an important role in this transformation, adding much-needed fillip to the country's economic growth along with a better quality of life for its people. Due to the uniform distribution of its constituent elements across the globe and its ease of use, concrete has dominated the construction industry over the years. Since cement has a hydraulic quality that has been valued for ages, it has been a primary component of concrete. But because it contributes to the atmospheric emission of carbon dioxide, the manufacture of cement has come under heavy fire and scrutiny. Cement, a widely used human-made material, has experienced significant growth in usage, parallel to the global population increase [1]. Unfortunately, though, the manufacture of cement, including WPC, is among the leading causes of green house gas emissions such as carbon dioxide. The whole manufacturing process requires limestone or calcium carbonate to be heated up inside extremely hot furnaces called kilns which subsequently release high quantities of CO_2. This gets worse due to the energy-intensive nature of the processes mostly run by fossil fuel. Such gases contribute a great deal to climatic change by bringing about global warming, rising sea levels, and extreme weather patterns [2-3]. Each year, the cement industry generates over 4 billion tonnes of carbon emissions, accounting for 5% of total emissions [4-7]. WPC manufacturing is highly electricity-intensive due to the several complicated and energy-consuming procedures. For example, the primary stages involve grinding raw materials, heating them in kilns to temperatures above 1,400°C, and further milling of clinker, which requires massive amounts of electricity consumption. These processes are of prime importance in the development of the essential chemical and physical characteristics of cement but take a high quantity of energy at the same time [8-9]. Currently, the production of eco-cements-a type of cements gaining favour in green and sustainable construction is characterized by very high dependence on the utilization of recycled and reused SCMs, wastes, and industrial by-products. These supplementary cementitious materials, comprising fly ash, slag, and agricultural residues such as rice husk ash, serve as partial replacements for conventional cement ingredients, hence decreasing the overall energy use and consumption of raw materials. In recent times, industrial by-products like fly ash, silica fumes, slag, nano silica, and Metakaolin have become common replacements for some cement components [10-12]. However, agricultural waste, such as mustard husk, also holds potential as a cement substitute.

Gypsum is a set-retarding agent mainly composed of calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) that finds broad applications in the cement industry. It plays an important part in the setting time of cement in its role of delaying the reaction of

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tricalcium aluminate with water. The issues that govern this include the content of C_3A in the clinker, which accelerates the setting; hence it requires more gypsum for its effective retardation. Moreover, the finer cements, having a greater surface area, also require increased gypsum to manage rapid reactions. Additional amounts of alkalies in the clinker increase the rate of setting; hence, the requirement for gypsum to obtain workability and control in setting [13-15]. Gypsum also promotes cement strength at the proper concentration level. A different study looked at how adding gypsum affected the growth of compressive strength [16]. It became evident that, in the presence of gypsum, fine crystals of ettringite formed and played a major role in strength development. These crystals help in filling the larger pores within the cement structure and effectively refining the pore size of the cement. While this greatly enhanced the overall density of the cement matrix, it substantially contributed to the growth in compressive strength, as the reduction of large pores minimized the number of possible weak points in the material. However, adding too much gypsum (greater than 5%) resulted in a loss in strength because of expansion [17-18]. Here we use 3% GS as a WPC replacement because the initial setting time of MHA blended WPC is very short. To enhance the setting time, we use GS as a retarder.
India is a country with immense and varied agricultural acreage; almost all types of grains, fruits, and vegetables are grown in different parts of the country. Mustard holds a pride of place in both Indian agriculture and cuisines. It finds great extension because of its important part in the local diet. In addition to producing mustard oil, which is a very major cooking oil in Indian kitchens, mustard seeds are also one of the common spices lending flavour and burning sensation to several dishes. People of India love to have spicy and delicious foods, so mustard is in high demand. One of the reasons for this could be the multiple usage of mustard during cooking, starting from tempering a dish to making pickles and sauces. This does not only indicate its demand in the high consumption pattern but also its importance in Indian cuisine. The high demand for mustard reflects its integral role in enhancing the taste and quality of Indian cuisine. According to Economic Times data in the 2022-23 period, India produced a staggering 11.5 million tonnes of mustard. We make mustard husk ash from the waste that is left after extracting mustard oil. For disposal, people burn this waste material therefore large amounts of toxic gases are released. When these gases are absorbed by the human body, these air contaminants induce several respiratory illnesses [19-20].
Consequently, a substantial amount of mustard husk is generated as waste in India. When combined with White Portland cement (WPC), mustard husk ash (MHA) presents an eco-friendly alternative to traditional white Portland cement (WPC) By replacing a portion of WPC with 12% MHA and 3% GS. This study explores how it affects chemical and mechanical properties, including setting time, Calcium ion concentration, and compressive strength. The findings indicate that MHA enhances compressive strength by facilitating the formation of extra calcium silicate hydrate (C-S-H). The following chapter gives an in-depth analysis that highlights the potentials of MHA-blended White Portland Cement as an environmentally responsible alternative to conventional cement. In the process of incorporating MHA into such a type of cement mix, this blended cement reduces dependency on conventional raw materials and aids effectively in value addition of agricultural waste. The MHA chemical composition imparts pozzolanic activity, which enhances the strength, durability of cement, and contributes to reduced carbon footprint. It contributes toward sustainable construction practices with reduced waste, energy use, and greenhouse gas emissions.

2. EXPERIMENTAL

The white Portland cement is blended with mustard husk ash and gypsum. The mustard plants are collected from villages of Prayagraj, Uttar Pradesh, India. These plants became waste after getting mustard seeds from them. We collect this waste and burn to make MHA.

Table 1 XRF analysis of WPC, MHA, and GS

	SiO_2	CaO	SO_3	K_2O	MgO	P_2O_5	Al_2O_3	Fe_2O_3	MnO
WPC	**21.40**	**68.85**	**2.95**	**0.24**	**0.33**	**-**	**2.74**	**0.19**	**-**
MHA	**45.34**	**20.50**	**6.80**	**12.10**	**4.12**	**5.34**	**6.5**	**0.15**	**0.03**
GS	**0.95**	**33.01**	**44.43**	**-**	**0.86**	**-**	**0.25**	**0.08**	**-**

2.1 Sample preparation

For the determination of setting time of WPC, two series of specimens were prepared by using different proportions of WPC, MHA, and GS. In the first series of samples, only WPC and MHA were used in different proportions. The aim of preparing the first set was to study the influence of MHA on the setting time of cement. The other series of samples had GS combined with WPC and MHA; these were used for measuring the effectiveness of the GS as a retarder within the mixture. It will help in achieving the suitable blend for extended setting time and the best performance. The first two samples do not contain GS. They contain WPC and 5% MHA (WPC5MHA), and the other sample contains WPC and 10% MHA (WPC10MHA). Three samples contain 3% GS. These samples are WPC7MHA3GS, WPC12MHA3GS, and

WPC17MHA3GS. All these samples contain 7%, 12%, and 17% MHA, respectively. The total weight of a mixing sample is 300 grams (mixing 5% MHA with 95% WPC means 15 grams MHA mixed with 285 grams WPC).

Table 2 Composition of WPC, MHA, and GS

S.No.	Composition	WPC (gm)	MHA (gm)	GS (gm)	Water(ml)
1.	WPC	300	-	-	94
2.	WPC5MHA	285	15	-	110
3.	WPC10MHA	270	30	-	135
4.	WPC7MHA3GS	270	21	9	140
5.	WPC12MHA3GS	255	36	9	150
6.	WPC17MHA3GS	240	51	9	163

2.2 Setting Time

The initial and final setting times of cement are the two major parameters that control the workability and suitability of the concrete in different construction applications. In this work, setting times are determined for each sample of WPC, including blended samples with MHA and GS, by the Vicat apparatus. These needs to be determined precisely so that it can be recognized which sample needs a longer time to set. Which mixture has the highest setting time is particularly important because of its effects on scheduling and efficiency in construction projects. Mixing longer setting times allows for more prolonged workability, affording more time to mix, transport, and place the cement without possible hardening before these processes are done. By measuring setting times for every sample, we will be able to make a comparison and choose the best blend that can give us the appropriate balance between setting time and mechanical strength. This will ensure that the chosen cement mixture can satisfy both the practical and performance requirements necessary for successful outcomes in construction.

2.3 Calcium ion Concentration

In the present investigation, a titration method was applied to determine the concentration of Ca^{2+} ions in WPC, MHA, and GS blended WPC. A 0.1 N EDTA solution was used. The procedure of titration will help to know the Ca^{2+} ions concentration in control WPC and blended WPC. The indicator used to determine the endpoint of the titration was bromophenol blue, whose colour changes during the reaction. It can be observed that at the beginning of the titration, the solution assumes a wine-red colour. On adding EDTA, progressive complexation of the Ca^{2+} ions occurred. The endpoint was reached when all the calcium ions were bound by EDTA, as evidenced by the colour of the solution changing from wine red to purple.

2.4 Compressive Strength

Compressive strength of WPC and its blended mixtures was measured at the ages of 1 day, 3 days, 7 days, 15 days, and 28 days for assessment of strength development over time. These were done in a Compression Testing Machine (CTM), which is the quick, reliable, standard testing machine for determining the capacity of cement to bear load under compaction. Moulds were prepared and cured in water for each test to ensure proper hydration of the cement samples. The moulds were taken out at each interval from the water and then placed in the CTM machine, where pressure was continuously increased until fracture occurred. Compressive strength was then calculated based on the maximum load the sample could resist before breaking. Aside from these time intervals, compressive strength tests are carried out, through these tests, a view on how the strength of the cement has developed. Normally, the highest value that is usually given is at 28 days. From this data, the effectiveness in the use of WPC blends with supplementary materials such as MHA and GS for the improvement of durability or performance in the long term will be evaluated.

3. RESULT AND DISCUSSION

3.1 Setting Time

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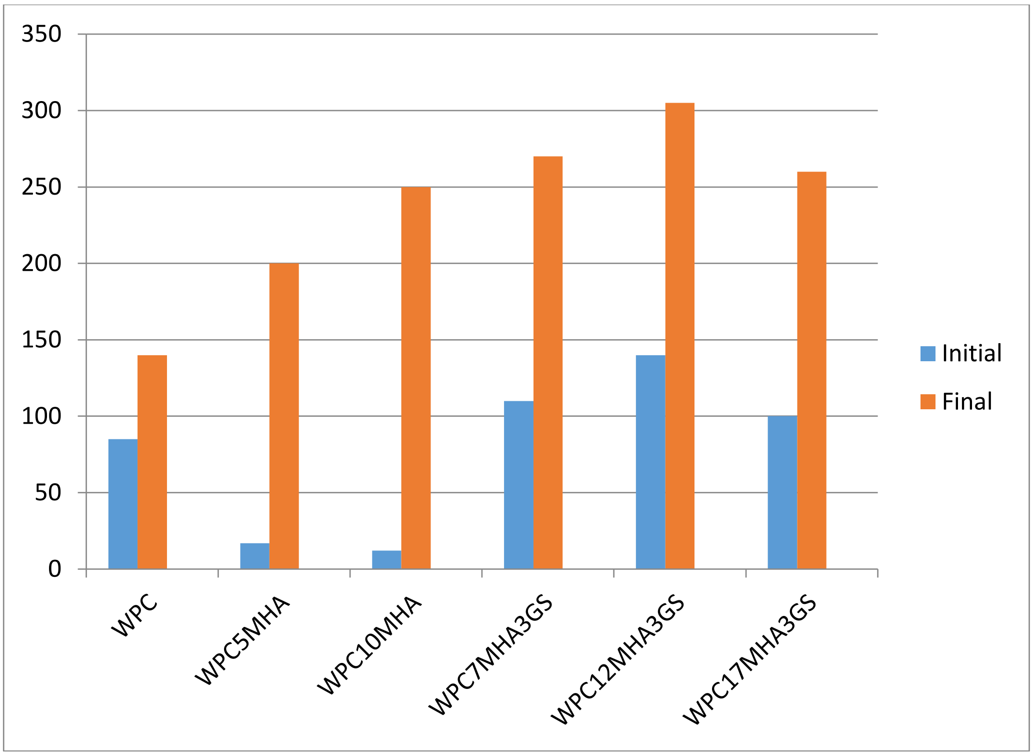

Fig.1 Setting time of WPC and Blended WPC

From the above figure, the initial setting time obtained is 85 minutes and the final setting time obtained is 140 minutes for the WPC. If White Portland Cement is blended with MHA then the initial setting time is hugely reduced. For example, WPC with the addition of 5% MHA (WPC5MHA) had an extremely short initial setting time of 17 minutes, and it was further reduced to 12 minutes with WPC containing 10% MHA (WPC10MHA). The results clearly show that with an increase in the proportion of MHA in WPC, there is a drastic reduction in the initial setting time. Due to this, the cement sets too fast and therefore cannot be used practically in a lot of construction applications. A retarder would be required to delay the setting process and give a sufficient amount of workable time to handle and place the cement. In this case, GS is used as a retarder [21-23]. It offsets the quick setting brought by MHA through an increase in time of initial and final setting of the cement mixture. Incorporating GS improves the overall performance of the blended cement through proper control over setting time with the improved pozzolanic activity of MHA [24]. We add 3% GS to mixtures. Tricalcium aluminate (C_3A) is the most reactive of all the major compounds in cement, reacting exothermally with water to form the initial set of hard gel CAH, or calcium aluminate hydrate. Normally this setting would be very rapid, too fast for practical application because it would prematurely set the concrete. The presence of gypsum postpones this process. The reaction of gypsum with CAH produces ettringite, coating the surfaces of both the CAH and the C_3A. The ettringite layer formed obstructs further rapid reaction of the C_3A with water to produce more gel by acting as some kind of barrier-effective control of the set of the cement. Consequently, addition of gypsum to the mix creates such conditions where in setting process becomes less uncontrollable and more manipulative, which enables cement to set hardening at an appropriately measurable pace for construction purposes [25]. WPC7MHA3GS has more initial and final setting times than Control OPC. But WPC12MHA3GS has the highest initial and final setting times. The increase in MHA amount in WPC17MHA3GS is the main reason for the shorter setting time than WPC12MHA3GS. Longer setting times are considered advantageous in most cases because the mixes allow more time for handling, placing, and finishing, thereby reducing any likely wastages arising from the premature hardening of the materials. The longer it takes for concrete to set, the larger the leeway afforded to workers during construction, since workers have ample time to adjust and work on the cement before it sets.

3.2 Calcium ion Concentration

The concentration of Ca^{2+} ions in MHA blended White Portland Cement is higher when compared with the control one, because both MHA and WPC are rich in calcium oxide (CaO). MHA itself contains good amount of reactive CaO, which is directly adding to the overall calcium ion concentration when this material is blended with WPC [26]. In addition, even though it constitutes only 3%, the GS also contains high levels of CaO. With WPC combined with both MHA and GS, the combined CaO content significantly increases. Therefore, the concentration of Ca^{2+} ions is high in blended cement, which is shown in Fig. 2. From Fig. 2, we also conclude that the concentration of Ca^{2+} ions first increase and reaches a maximum at 35 minutes, but after 35 minutes, when the reaction proceeds, the concentration of Ca^{2+} ions start decreasing. The reduction of Ca^{2+} ion concentration acts as an indicator for the consumption of these ions due to the hydration reaction and form C-S-H gel during the progress of the pozzolanic reaction. In the presence of active materials such as MHA and GS, Ca^{2+} ions from the cement combine with the silica (SiO_2) in the pozzolanic materials to form C-S-H [27-28]. However, in the pozzolanic reaction, more Ca^{2+} ions are consumed as the reaction progresses, hence by implication reducing its concentration within the mixture. This reduction is an assurance of the progressive chemical reactions that improve the mechanical properties of blended cements. It proves that the pozzolanic materials are actually working and reacting with the cements and enhancing the properties of cements [29-30].

$Ca(OH)_2 + SiO_2 \rightarrow$ C-S-H (Calcium silicate hydrate) [31]

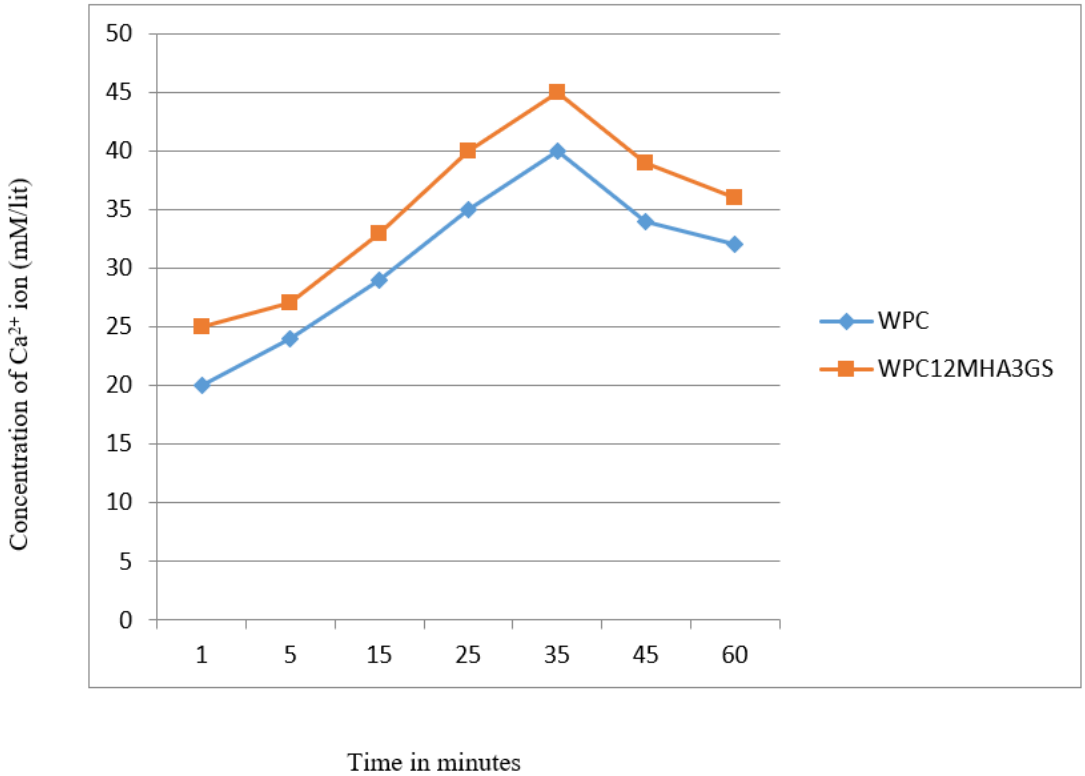

Fig.2 Concentration of Ca^{2+} ion in control WPC and 12MHA3GS blended WPC

3.3 Compressive Strength

Compressive strength test was carried out using Compression Testing Machine, CTM. Moulds of size 50 mm³ for control WPC, MHA blended WPC and WPC blended with both MHA and GS were prepared. Afterwards, the moulds were submerged in water to allow hydration reactions to take place. The strengths of samples were determined by breaking the moulds after various time intervals to test for compressive strength. According to fig.3 the compressive strength of control WPC is only stronger than that of WPC5MHA. Whereas WPC10MHA showed higher compressive strength than control WPC on 15 days of hydration, i.e., (30N/mm^2). WPC7MHA3GS shows more compressive strength than control WPC after 3 days of hydration, but it has less compressive strength than WPC12MHA3GS and WPC17MHA3GS. WPC12MHA3GS has the highest compressive strength (42 N/mm^2) among all after 28 days of hydration. WPC12MHA3GS shows 2N/mm^2 more strength than WPC17MHA3GS, and it shows 10N/mm^2 more strength than control WPC on 28 days of hydration. Hence, we can say that WPC12MHA3GS gives 31.25% more strength than the control WPC. As expected, when hydration days increase the compressive strength increases. Such an increase in compressive strength is due to the development of the key strengthening compound of cement, namely calcium-silicate-hydrate gel (C-S-H) [32-33]. According to, this C-S-H gel is a product of the pozzolanic reaction between White Portland Cement (WPC) and MHA. Indeed, MHA reacts with calcium hydroxide $Ca(OH)_2$, liberated upon hydration of WPC, to give additional C-S-H gel. The formation of C-S-H significantly enhances the mechanical properties and compressive strength of blended cements with time [34-38]. Those mixtures containing GS give more compressive strength than others, which means adding 3% GS not only increases its setting time but also gives some additional strength.

$Ca_2SiO_5 + H_2O \rightarrow CaO\text{-}SiO_2\text{-}H_2O$ **[$C_2S + H \rightarrow$ C-S-H]**

$Ca_3SiO_5 + H_2O \rightarrow CaO\text{-}SiO_2\text{-}H_2O + Ca(OH)_2$ **[$C_3S + H \rightarrow$ C-S-H +CH]** [39-40]

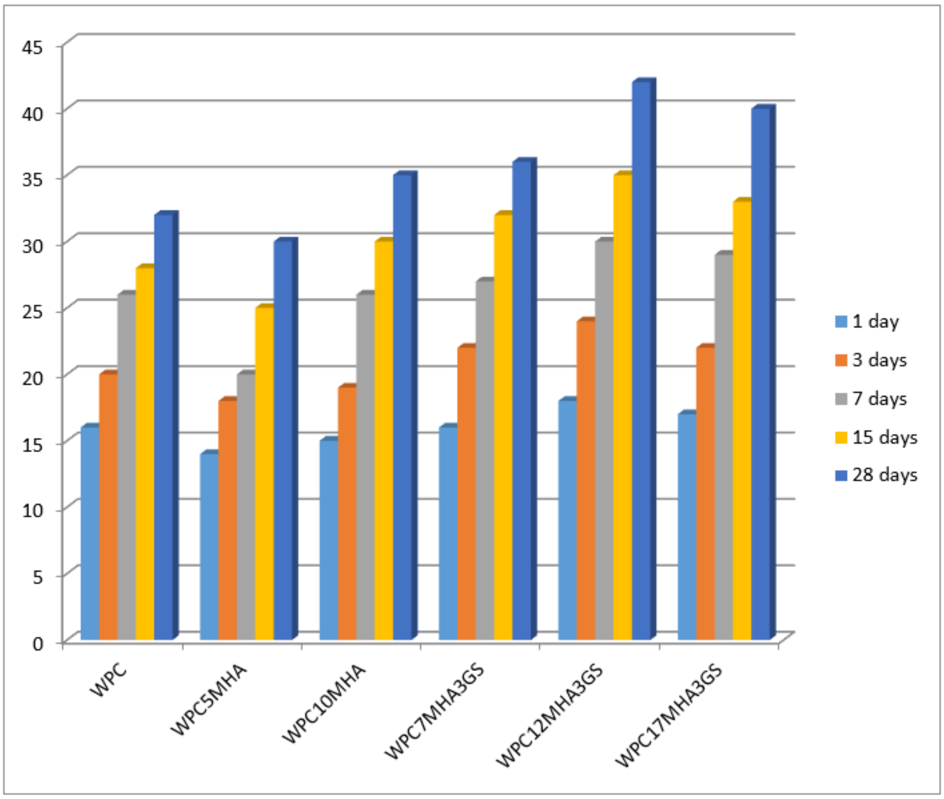

Fig.3 Compressive strength of WPC and blended WPC.

4. CONCLUSION

In this paper, the physical and chemical behaviour of WPC, MHA, and MHA with GS-blended WPC was assessed. From the analysis and discussion, it is quite evident that the blending of WPC with MHA develops outstanding pozzolanic activities. The properties of the materials like strength and durability improved by the pozzolanic reaction. This means MHA acts as a good supplementary material, and therefore the blended WPC becomes more efficient and sustainable in construction applications. We determined the initial and final setting times of WPC and its blends with MHA and GS. Our tests showed that MHA-blended WPC has a very short initial setting time, which will be hard to handle for most construction projects relying on longer working times. For improvement, we blended WPC with MHA and GS, as GS acts as a retarder. This increased the setting time substantially compared with MHA-blended WPC. The combination of pozzolanic activity that MHA exerts and GS's retarding properties can give an optimal mix, benefiting workability and strength in cement. This in turn makes the WPC blend of MHA and GS a more versatile and efficient material for various applications in construction, with better control over setting times while ensuring enhanced durability and strength over time. WPC12MHA3GS has a maximum initial and final setting time. The hydration reaction responsible for forming the C-S-H gel is closely monitored through the concentration of Ca^{2+} ions, depicted in Fig. 2. Given that WPC, MHA, and GS are rich in calcium oxide(CaO) they are expected to release Ca^{2+} ions upon the hydration reaction. In Fig 2, the graph of the blended mixture WPC12MHA3GS shows a higher concentration of Ca^{2+} ions than the control WPC. This may means that in the blend of WPC with MHA and GS, more calcium ions are contributed. The decreasing of the Ca^{2+} ion concentration graph after 35 minutes suggests that when the hydration reaction proceeds, Ca^{2+} ions get consumed in the reaction and form calcium-silicate-hydrate gel (C-S-H). Which increases the strength of blended cement. The compressive strength tests were conducted, which reflects that the strength of blended cement increases with the increase in the hydration period. Thus, the mixtures hydrated for 28 days achieve their maximum compressive strength. The strength gain is due to a C-S-H gel developed by the pozzolanic reaction between WPC and MHA. The pozzolanic activity of MHA also contributes to consumption of calcium hydroxide with the formation of additional C-S-H, which is the main product contributing to the strength of cement. This improved generation of C-S-H over time is considered to be responsible for significant improvements in the mechanical properties of the blended cement. WPC12MHA3GS gives maximum strength, i.e., ($42 N/mm^2$). The addition of GS also enhances the strength of blended cement. It is also shown in Fig.3. All mixtures that contain GS give more strength than others that do not contain GS.

The major contribution to pollution is liable by WPC production, releasing huge amounts of harmful gases such as CO_2 and NO_2 into the atmosphere. Both of these harmful gases cause global warming and air pollution to a great extent. These environmental impacts can be minimized only by decreasing the production of WPC through the incorporation of blending sustainable alternatives. The blending of WPC with the addition of pozzolanic materials such as MHA or GS improves not only the properties of the cement itself but also diminishes dependence on pure WPC. This way, blending will contribute to lowering harmful gas emissions by requiring less WPC in construction and saving energy to preserve the environment. Industrial wastes, such as fly ash (FA), are now widely used as blending materials in cement production due to their pozzolanic nature. However, since FA is a waste derived from coal combustion, its availability is controlled by the coal reserve, which is depletable, hence limited. Eventually, the depletion of coal will result in a shortage of FA as a sustainable blending material. Agro-based waste materials have promising potential as an alternative to FA. MHA derived from wastes of mustard is one type of material that is capable of replacing FA effectively. MHA is highly active pozzolan. Hence, it offers an excellent replacement in the blending of cement. Its usage saves not only natural resources but also aids in the recycling of agricultural waste. Hence, it is proving to be sustainable and eco-friendly for the construction industry as a whole. In the process, by utilizing agro-based waste materials like MHA, our dependency will gradually shift away from coal-derived products, thus helping to contribute toward long-term sustainability. Using MHA as a blending material in WPC enhanced the physical and chemical properties of WPC. By utilising MHA as a blending material, we not only help us to consume waste material but also protect our environment from pollution. By using MHA, we also reduce the price of WPC, so we can make low-cost, high-strength cement.

REFERENCES

1. Li, Z.(2011) Advanced Concrete Technology; John Wiley & Sons, Inc.: Hoboken, NJ, USA.
2. Lee, H.; Hanif, A.; Usman, M.; Sim, J.; Oh, H.(2018) Performance evaluation of concrete incorporating glass powder and glass sludge wastes as supplementary cementing material. J. Clean. Prod., 170, 683–693.
3. Stajanca, M., & Estokova, A. (2012). Environmental Impacts of Cement Production. *Technical University of Kosice, Civil Engineering Faculty, Institute of Architectural Engineering*, 296–302.
4. Olivier, J.G.J.; Peters, J.A.H.W.; Janssens-Maenhout, (2012) G. Trends in Global CO2 Emissions. 2012 Report; EU Publications: The Hague, the Netherlands.
5. Yang, H.J.; Usman, M.; Hanif, (2021) A. Suitability of Liquid Crystal Display (LCD) Glass Waste as Supplementary Cementing Material (SCM): Assessment based on strength, porosity, and durability. J. Build. Eng.,42, 102793.
6. Rashad, A. M., & Zeedan, S. R. (2011). The effect of activator concentration on the residual strength of alkali-activated fly ash pastes subjected to thermal load. Construction and Building Materials, 25, 3098–3107**.**
7. Park, S.-S., & Kang, H.-Y. (2008). Characterization of fly ashpastes synthesized at different activator conditions. Korean Journal of Chemical Engineering, 25(1), 78–83.
8. Becchio, C, Corgnati, S.P, Kindinis,A, Pagliolico,S.(2009) Improving environmental sustainability of concrete products: investigation on MWC thermal and mechanical properties, Energy Build. 41 (11) 1127–1134.
9. Afkhami, B., Akbarian, B., Beheshti A., N., Kakaee, A., & Shabani, B. (2015). Energy consumption assessment in a cement production plant. *Sustainable Energy Technologies and Assessments*, *10*, 84-89. https://doi.org/10.1016/j.seta.2015.03.003
10. Hanif, A.; Diao, S.; Lu, Z.; Fan, T.; Li, Z.(2016) Green lightweight cementitious composite incorporating aerogels and fly ash cenospheres— Mechanical and thermal insulating properties. Constr. Build. Mater., 116, 422–430.
11. Kim, Y.; Hanif, A.; Usman, M.; Munir, M.J.; Kazmi, S.M.S.; Kim, S.(2018) Slag waste incorporation in high early strength concrete as cement replacement: Environmental impact and influence on hydration; durability attributes. J. Clean. Prod., 172, 3056–3065.
12. Adjei, S., & Elkatatny, S. (2020). A highlight on the application of industrial and agro wastes in cement-based materials. *Journal of Petroleum Science and Engineering*, *195*, 107911. https://doi.org/10.1016/j.petrol.2020.107911
13. Taylor, H. F. W. (1997). Cement chemistry. *Cement Chemistry*.182–183, 218–221.https://doi.org/10.1680/cc.25929
14. Locher FG, Richartz W, Sprung S. (1980) Setting of cement—Effect of adding calcium sulfate. ZKG intern.;6:271–7
15. Theisen K. (1983) Relationship between gypsum dehydration and strength development in Portland Cement. ZKG intern.;10:571–7.
16. Holderbank, (1975) Gypsum during cement grinding, Seminar on Grinding,14–25.
17. A. Mustaqim, (2014). Pengaruh Penggunaan Semen PCC (Portland Composite Cement) Pada Fas 0,4 Terhadap Laju Peningkatan Mutu Beton," *Scaffolding*, vol. 3, no. 1
18. Park, H.; Jeong, Y.; Jun, Y.; Jeong, J.; Oh, J. (2016) Strength Enhancement and Pore-Size Refinement in Clinker Free Cao-Activated GGBFS Systems through Substitution with Gypsum. Cem. Concr. Compos., 68, 57–65.
19. Gao, S.; Hegg, D.A.; Hobbs, P.V.; Kirchstetter, T.W.; Magi, B.; Sadilek, M.(2003) Water-soluble organic components in aerosols associated with savanna fires in southern Africa: Identification, evolution, and distribution. J. Geophys. Res. D Atmos., 108.
20. Zhang, H.; Wang, S.; Hao, J.; Wang, X.; Wang, S.; Chai, F.; Li, M. (2016) Air pollution and control action in Beijing. J. Clean. Prod.112, 1519–1527.
21. Chandara, C., Azizli, K. A. M., Ahmad, Z. A., & Sakai, E. (2009). Use of waste gypsum to replace natural gypsum as set retarders in portland cement. *Waste Management*, *29*(5), 1675-1679. https://doi.org/10.1016/j.wasman.2008.11.014

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22. Caillahua, M. C., & Moura, F. J. (2018). Technical feasibility for use of FGD gypsum as an additive setting time retarder for Portland cement. *Journal of Materials Research and Technology*, *7*(2), 190-197. https://doi.org/10.1016/j.jmrt.2017.08.005
23. Bhanumathidas, N., & Kalidas, N. (2004). Dual role of gypsum: Set retarder and strength accelerator. *The Indian Concrete Journal*, *78*, 1-4.
24. Papageorgiou, A., Tzouvalas, G., & Tsimas, S. (2005). Use of inorganic setting retarders in the cement industry. *Cement and Concrete Composites*, *27*(2), 183–189. https://doi.org/10.1016/j.cemconcomp.2004.02.005
25. Herliati, Sagitha, A., Dyah Puspita, A., Puput Dwi, R., & Salasa, A. (2021). Optimization of Gypsum Composition Against Setting Time and Compressive Strength in Clinker for PCC (Portland Composite Cement). *IOP Conference Series: Materials Science and Engineering*, *1053*(1), 012116. https://doi.org/10.1088/1757-899x/1053/1/012116
26. Faris, M. (2021). *Modern Approaches on Material Science Production Of Silica From Mustard Husk Ash*. 525–529. https://doi.org/10.32474/MAMS.2021.04.000188
27. Singh N.B, Bhattacharjee K.N, Shukla A.K, (1995) " Hydration of Portland Blended cement " Cement and Concrete research, 25(5)
28. Li.Q, Coleman N.J, (2014) " Hydration kinetics, ion-release and antimicrobial properties of whit Portland cement blended with zirconium oxide nanoparticles" Dental Materials jornal**,** 33(6): 805–810
29. Ngun BK, Mohamad H, Sakai E, Ahmad ZA.(2010) Effect of rice husk ash and silica fume in the ternary system on the properties of blended cement paste and concrete. *J Ceram Process Res*.11(3):311-315.
30. A.M. Neville, Properties of Concrete, fourth and final ed., Longman, Harlow, Essex, 1997 reprint
31. Singh NB, Das SS, Singh NP, Dwivedi VN.(2007) Hydration of bamboo leaf ash blended Portland cement. *Indian J Eng Mater Sci*.;14(1):69-76.
32. Kumar, R. Lal, K. Das,S. Shukla, A. K. (2023).Developing ultra-high-performance WhitePortland cement with a low environmental effect using silica-rich white sand. BioGecko A Journal for New Zealand Herpetology, 12.2:311-322. *http://biogecko.co.nz/admin/uploads/BIOgecko%201.pdf*
33. Lal, K., Kumar, R., Yadav, B., Shrivastava, S. K., Kumar, A., Singh, S. Y., & Das, S. (2023). incorporating white silica sand to improve mechanical and microstructural properties of ordinary portland cement. Mater. Sci. Technol., *22*(12). 224-232. https://doi.org/10.10543/f0299.2023.41846
34. Sathe S, Zain Kangda M, Dandin S. (2023) An experimental study on rice husk ash concrete.*MaterTodayProc*.;77(December):724-728. doi: 10.1016/j.matpr.2022.11.366
35. Williams FN, Anum I, Isa RB, Aliyu M. (2014) Properties of Sorghum Husk Ash Blended Cement Laterized Concrete. *Int J Res Manag Sci Technol*.;2(2):73-79.
36. Abdelzaher M, A, (2022) " Performance and hydration characteristic of dark white evolution (DWE) cement composites blended with clay brick powder "Egyptian Journal of Chemistry, 65(8) ,419-42
37. Nochaiya, T., Wongkeo, W., & Chaipanich, A. (2010). Utilization of fly ash with silica fume and properties of Portland cement – fly ash – silica fume concrete. *Fuel*, *89*(3), 768–774. https://doi.org/10.1016/j.fuel.2009.10.003
38. Lal, K., Kumar, R., Verma, S., Pandey, S., Shukla, A. K., & Das, S. (2023). concrete for a greener future : examining the utilization of silica fume and neem leaf ash to improve environmental sustainability in construction. Mater. Sci. Technol., *22*(11). 124-130 https://doi.org/10.10543/f0299.2023.41775
39. Harrisson, A. M. (2019). Constitution and specification of Portland cement. In Lea's Chemistry of Cement and Concrete (5),87-155.
40. Baltakys, K., Jauberthie, R., Siauciunas, R., & Kaminskas, R. (2007). Influence of modification of SiO_2 on the formation of calcium silicate hydrate. *Materials Science-Poland*, *25*(3), 633-640.