RESEARCH COMMUNICATIONS
(An International Open Access, Peer Reviewed, Multidisciplinary Online Journal)
https://research-communications.cmpcollege.ac.in
C. M. P. DEGREE COLLEGE
(A Constituent P.G. College, University of Allahabad)

Volume-3, Issue-2, July-December 2025, pp 1-9 ISSN: 2584-1270

DOI: doi.org/10.65719/RC.3.2.2025.001

# HYDRATION EFFECT OF EUCALYPTUS LEAVES (NILGIRI) ON THE STRENGTH OF WHITE CEMENT

**Shivani Pandey[1], Sachin Verma[1], Raushan Kumar[1], Kanhaya Lal[1], Anil Kumar Shukla[1], Sunanda Das[1] & Rakesh Kumar Ojha[2]**

[1]*Synthetic & Natural Products and Cement Chemistry Laboratory, Department of Chemistry, C.M.P. Degree College, University of Allahabad, Prayagraj, Uttar Pradesh, India*
[2]*Department of Economics, Bhatauli Mahavidyalaya, Bhatauli Unawal, DDU Ghorakhpur University, Uttar Pradesh, India*
***E-mail:*** *shivanipandey0529@gmail.com*

## Abstract

*Cement composites are becoming a necessary component of the building sector. The atmosphere is being harmed by emissions from the cement manufacturing process. Researchers are replacing cement with its supplements because of the need to reduce cement usage and their obligation to make concrete sustainable. When we mixed 0%, 7%, 10%, 12%, and 15% of Eucalyptus leaf ash, we found that 10% replacement in WPC gives an amazing result. Experimental results demonstrated that a partial replacement of WPC with 10% EULA not only maintained but also significantly improved the overall cement properties. We found that the 10% EULA blending with WPC achieves high setting time, compressive strength, workability, water absorption, and free lime analysis, which is incredible.*

***Keywords:*** *Eucalyptus leaf ash (EULA), Hydration mechanism, Setting time, Compressive strength, sustainable cement*

## 1. Introduction

India is characterized by its vast agricultural economy and extensive mountainous region, faces significant environmental challenges associate with the management of agricultural and forest waste specifically, the widespread growth of Eucalyptus species results in a large volume of fallen leaves that, it left to naturally decompose contribute to atmospheric pollution by releasing greenhouse gases like $CO_2$. Utilizing this biomass is crucial for environmental mitigation and sustainable resource management [1].

Currently, collected Eucalyptus leaves are frequently employed as solid fuel source in various local industries, including domestic cooking, pottery manufacturing, and brick kilns. The combustion process yields Eucalyptus leaf ash (EULA), which is then processed to enhance its reactivity the collected ash is typically subjected to control heating (calcinations) in furnace, often at temperature between 600-700°C and then it stored in air tight bag.

Given the high industrial demand for cement production and the necessity for cheaper, environmentally friendly alternatives, EULA is emerging as potent supplementary cementitious material (SCM). The ash exhibits strong pozzolanic characteristics, making it a desirable, cost-effective substitute for white Portland cement (WPC) [2-4].

India produced 7.8% more cement in February 2021 than it did in February 2020.10% replacement of the cementitious content in the mix with processed EULA yield cement with significant strength improvements [5,6]. This sustainable material achieves high compressive strength. Representing substantial reinforcement such enhanced strength composite are suitable for various construction application including park boundaries, flooring, and slopes, thereby providing durability and contributing to the circular economy by repurposing agricultural waste [7-9].

In Gonda district Eucalyptus tree grown in large scale. Eucalyptus is a widely spread material in the world like Australia, cheap and easily available. The silica content in this is much more comparisons to other element present in it. The pH of Eucalyptus ash is range between 7.56 -7.32, this is slightly alkaline in nature. So, it is better option for blending in White Portland cement. For this purpose, the hydration effect of different amounts of ash on the WPC pastes has been studied and found positive results.

## 2. Experimental

### 2.1. Material

#### 2.1.1. White Portland cement

Birla White cement used for this work was purchased from Mahaveer trading company, civil lines in Prayagraj, and Tables 1 shows the chemical composition of WPC.

**Table -1**: Chemical Constituent of WPC.

| Oxides | % in WPC |
|---|---|
| $SiO_2$ | 21.40 |
| $Al_2O_3$ | 2.74 |
| CaO | 68.58 |
| MgO | 0.33 |
| $K_2O$ | 0.24 |
| $Na_2O$ | 0.47 |
| $SO_3$ | 2.95 |

#### 2.1.2. Eucalyptus

Eucalyptus leaves obtained from Manikapur at Gonda district, Uttar Pradesh. In India this eucalyptus tree is commonly known as Nilgiri. After collection of these leaves dried at open place, and burnt at 600-700° C temperature then sieved it by 85 mesh size and ash store in tight polythene bag.


**Fig.1** Eucalyptus (a. tree, b. Leaves, c. Ash)

#### 2.1.3. (X-ray Fluorescence) XRF Analysis of EULA

XRF technique is used to determine the elemental composition of material. Table 2 illustrate the Waste material EULA X-ray fluorescence which denote high calcium oxide, and silica in this sample.

**Table-2:** Chemical constituents in EULA

| Oxides | Weight Concentration % in EULA |
|---|---|
| $CaO$ | 57.1 |
| $K_2O$ | 18.2 |
| $SiO_2$ | 13.0 |
| $MgO$ | 6.1 |
| $Al_2O_3$ | 4.0 |
| $Fe_2O_3$ | 3.2 |
| $P_2O_5$ | 2.1 |

**2.2. Preparation of Sample:** Table- 3 shows the chemical constituents of WPC and replacement of 0%, 7%, 10%, 12%, 15% of this Siliceous EULA with WPC, so we obtain 5 sample of different amount of EULA and WPC. All the sample contain 250 gram of WPC and EULA mixture. The water consistency (water /solid) is 0.4 for all different proportions of WPC and EULA Which is shown in table 3.

**Table-3:** Replacement of WPC by EULA in different proportion.

| S/N | % Replacement | Composition of WPC (in gm) | Composition of EULA (in gm) | Water (in ml) | W/S |
|---|---|---|---|---|---|
| **1** | 0 | 250 | 0 | 78 | 0.4 |
| **2** | 7 | 229 | 21 | 87 | 0.4 |
| **3** | 10 | 220 | 30 | 100 | 0.4 |
| **4** | 12 | 214 | 36 | 91 | 0.4 |
| **5** | 15 | 205 | 45 | 87 | 0.4 |

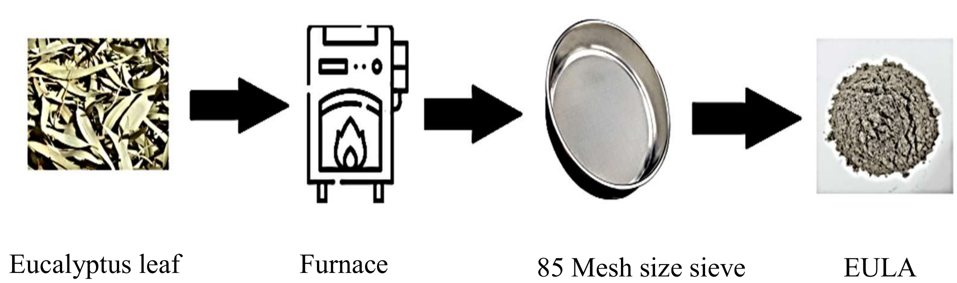


**Fig. 2** Preparation method of EULA

### 2.2.1. Setting time

We have done setting time with the help of Vicat apparatus. The initial setting time and final setting time is measured for the entire sample. The graph we plot in which the sample show highest setting time that sample shows best result [7-8].

### 2.2.2. Liquid Phase Analysis

In liquid phase analysis, we determine the concentrations of Hydroxyl ions ($OH^-$) and calcium ions ($Ca^{2+}$) at different time intervals. It is possible to quantify the content of calcium ions, $Ca^{2+}$, and hydroxide ions, $OH^-$, in a cementitious solution by means of titration methods. Calcium ion concentration is usually determined through 0.1 N EDTA titration. with an indicator such as bromophenol blue, which colour changes at the end point.

The volume of EDTA consumed allows for the calculation of $Ca^{2+}$ concentration. The hydroxide ion concentration is measured by acid-base titration. The sample was titrated with 0.1 N HCl, using phenolphthalein as an indicator because it loses its pink colour at the equivalence point. This, in turn, gives the volume of the acid used to provide the $OH^-$ concentration.

### 2.2.3. Free lime percentage

Free lime in cement is that percentage of calcium oxide, which remains uncombined into the clinker during hydration process. Free lime percentage of hydrated control WPC and blended WPC determine by Franke extraction method.

We take 1 gram of hydrated sample then put it on a round bottom flask after that pour 10 ml of isopropyl alcohol and acetoacetic ester in 20 ratios 3. This mixture refluxed by one hour using air condenser to a silica tube [9, 10, 11]. Now cool and titrate with 0.1 N HCl using bromophenol blue as an indicator. At the end, it turns from blue to yellow. Percentage of lime that is free as determined by flowing equation

$$\% \text{ free lime} = 0.2804 \times V/W$$

In this case, V = 0.1 N HCl Volume

W= Sample weight

### 2.2.4. Compressive Strength

Compressive strength is obtained by a compressive strength testing machine. We make mould (5cm×5cm×5cm), Put these Moulds in water for hydration after different intervals of time example- 1 day, 3 days, 7 days,15 days, and 28 days, we break mould with the help of a compressive strength testing machine [12].

### 2.2.5. Expansion

To determine the expansion of control WPC and 10%EULA combined WPC during hydration, rods of size of (280x25x25mm) were manufactured and immersed in water after 24 hours. The AIM377 length comparator was used to measure the expansion.

## 3. Results and Discussion

The results of this study are based on the examination of several key parameters such as compressive strength, setting time, liquid phase analysis, free lime percentage, and microstructural analysis using compressive strength, setting time and free lime. Five samples with different EULA content (0%, 7%, 10%, 12%, and 15% of this Siliceous EULA by weight).

### 3.1. Setting Time

The initial setting time and final setting times of composition (WPC-EULA) were measured using Vicat apparatus [13]. The results indicated a clear trend:

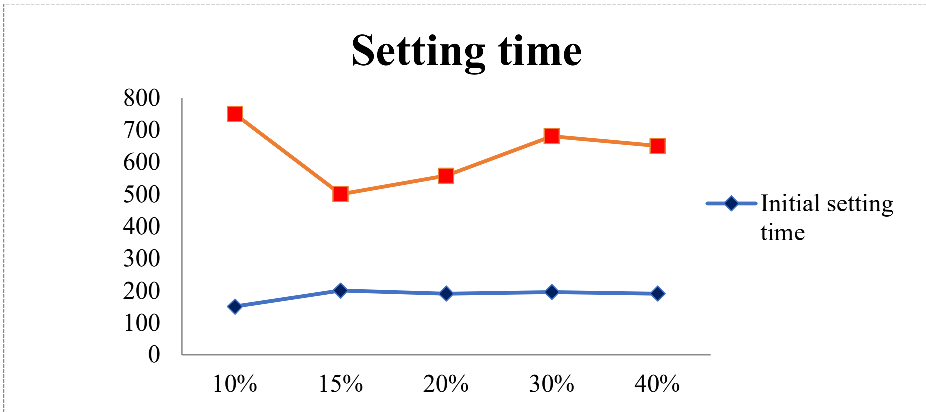


**Fig. 4** Initial and final Setting time of blended WPC

The setting time remained close to that of the control sample, with only a slight delay in the initial and final setting times. This suggests that the incorporation of EULA at these levels does not significantly affect the hydration process. As the proportion of EULA increased, the setting time was delayed further. The higher EULA content slowed down the hydration process, resulting in prolonged initial and final setting times. This effect is beneficial in some cases, especially in hot climates where rapid setting is undesirable [14].

The sample with 10% EULA exhibited the longest setting time, which may be advantageous for applications where extended workability is required.

### 3.2. Liquid Phase Analysis

Liquid phase analysis is a method to determine the concentration of Hydroxyl ions ($OH^-$) and Calcium ions ($Ca^{2+}$) at different intervals of time.

To determine $OH^-$ concentration, we make a sample of 40% blended cement of W/S =5 ratio, which means 25 ml water in 5gm Blended cement. Then we filtered the solution at different intervals of time and titrated them with 0.1N HCL by using Phenolphthalein as an indicator.

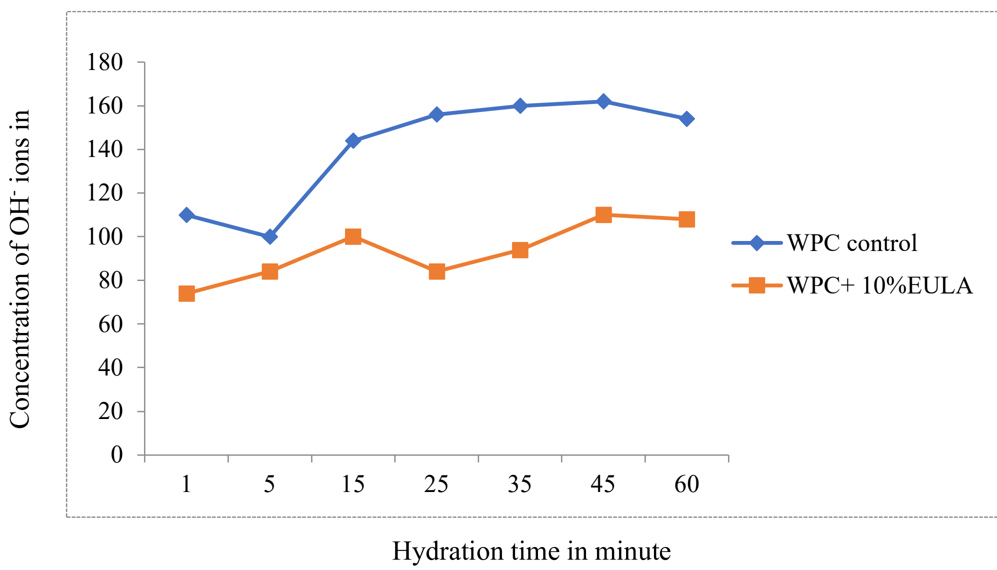


**Fig. 5** Liquid phase analysis of Hydroxyl ions

In **Figure 5,** the graph shows that the Concentration of $OH^-$ ion in blended WPC, first increases after 15 min its decreases. Then after 25 min its further increases and after 45 min it further decreases. In Blended cement, the Concentration of $OH^-$ ions is lower than the control WPC.

The value is always lower in presence of EULA because less cement is present per unit area due to the 10% replacement of EULA and also some part of $OH^-$ ions combined with EULA.

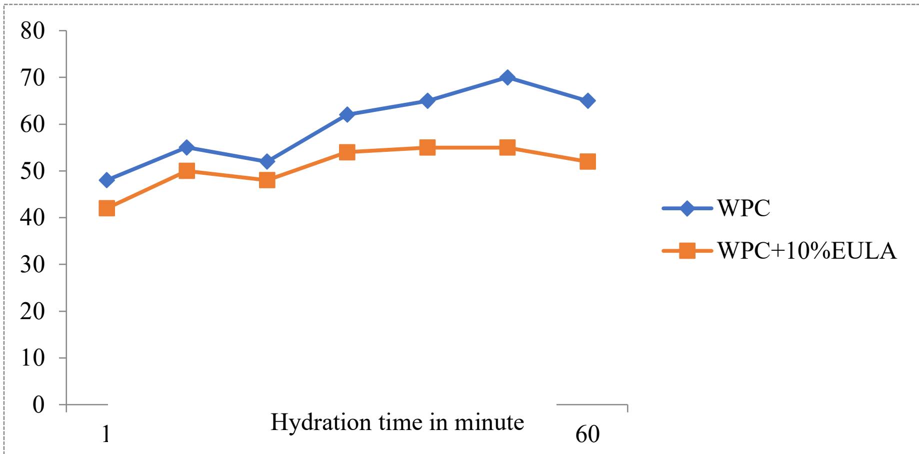


**Fig. 6** Liquid phase analysis of calcium ions.

Graph of Figure 6 shows Concentration of $Ca^{2+}$ ions in Blended WPC and control WPC. Concentration of $Ca^{2+}$ ions in Blended WPC, first increase after 5 min it decreases to the minimum level but after 15 min concentration increase again but after 25 min it increases very slowly up to 50 min than after it little bit decreases. A similar trend is shown in control WPC but Blended WPC has a lower value than control WPC, because on the blending of WPC the $Ca^{2+}$ ions of WPC are consumed in the reaction and form calcium silicate hydrate (C-S-H). The lower concentration of $Ca^{2+}$ ions also shows that blended WPC has lower cement content than control WPC.

### 3.3. Compressive Strength

Compressive strength is one of the most important properties of concrete and cementitious materials [15]. It provides insights into the strength measurement of the material [16,17]. The compressive strength of WPC blended with EULA was measured at different intervals, and the results showed an interesting trend.

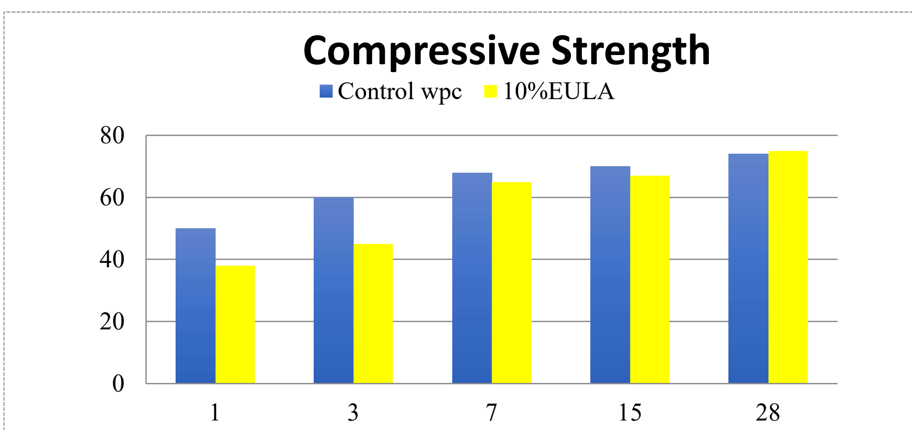


**Fig. 7** Compressive strength of Control WPC and EULA blended WPC

This graph in figure 7 clearly indicates that 10% EULA blended with WPC shows high compressive strength at 28 days. The compressive strength increases with increase curing time but below 28 days hydration value lower due to-

1. The presence of crystalline silica in this blended WPC which has little pozzolanic activity.
2. Blended WPC absorb more water but insufficient water is present in blended cement as a result hydration may be incomplete that's why value lowers.

### 3.4. Free Lime Percentage

The free lime percentage is measured from the Franke method [18]. We calculate the free lime percentage of 1 day, 3 days, 7 days, 14 days, and 28 days hydrated sample of control WPC and 10% blended WPC.

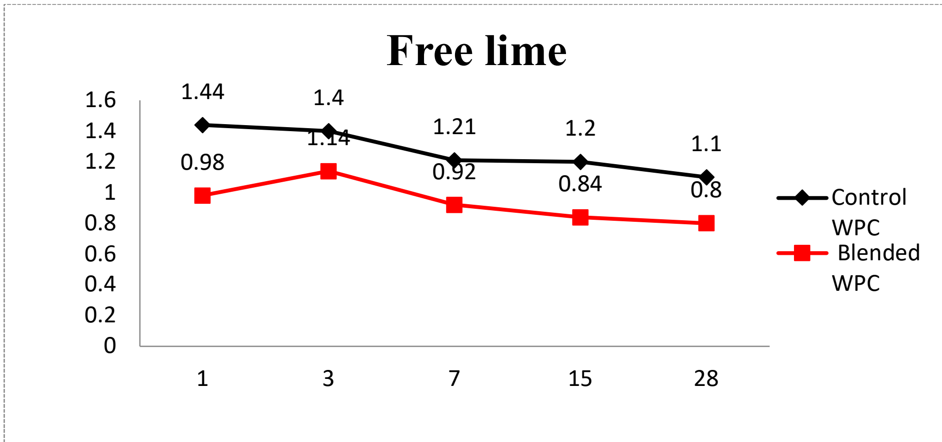


**Fig. 8** Free lime percentage at different intervals of time (Days)

The graph of Figure 8 shows that free lime % of control WPC first decreased but after 7 days it increases. Free lime % of blended WPC is lower than control WPC. This is due to the dilution effect and also because of the reaction between calcium hydroxide [19-22]. When hydration days increase the action of EULA also increases therefore Lime combined with EULA, therefore free lime % decreases. Hence, free lime % of blended WPC increases up to 3 days but after the pozzolanic reaction proceeds, free lime % starts decreasing up to 28 days.

### 3.5. Expansion

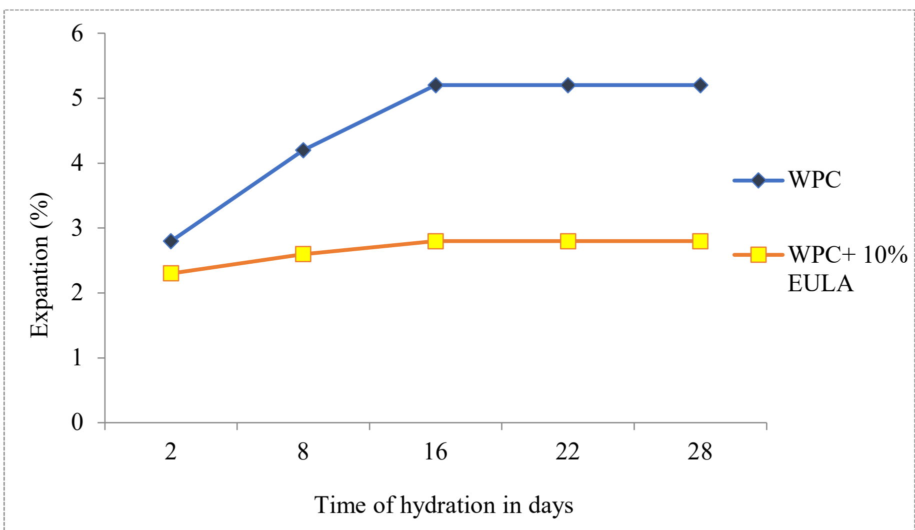


**Fig.9** Expansion of cement at different time intervals during hydration

Figure 9 shows expansion curves of control WPC and blended WPC separately. It confirms from graph at 7days of hydration the maximum expansion (11.4%) as compared to blended WPC which shows maximum expansion (9.7%) at 5 days. Thus, EULA blended WPC shows better result concerning Expansion.

## Conclusion

These result (setting time, liquid phase analysis, free lime percentage, compressive strength, and expansion) clearly shows that the EULA blends WPC have the potential to control the $CO_2$ emission, dumping garbage and for different architectural purpose. The free lime content decreases after hydration confirms reaction between EULA with WPC have high strength and to better approach for eco-friendly cement production. Blended cement has same color as WPC. The EULA blended white Portland cement to reduce the entropy of the universe. EULA blended WPC have greater workability and it also reduces the acid effect. It also minimizes the cost of production of cement. This blended cement is high strength and low cost for rural area.

### *Acknowledgement*

*I would like to show my special gratitude to Prof. N.B. Singh and my guide Prof A.K. Shukla whose guidance and support continuously increase my knowledge. And, thanks to my Principal and Convener of the Chemistry Department CMP Degree College Prayagraj.*

## References

1. Jinger, D., Kaushal, R., Kumar, R., Paramesh, V., Verma, A., Shukla, M., Chavan, S. B., Kakade, V., Dobhal, S., Uthappa, A. R., Roy, T., Singhal, V., Madegowda, M., Kumar, D., Khatri, P., Dinesh, D., Singh, G., Singh, A. K., Nath, A. J., . . . Kumawat, S. (2023). Degraded land rehabilitation through agroforestry in India: Achievements, current understanding, and future prospectives. *Frontiers in Ecology and Evolution*, *11*. https://doi.org/10.3389/fevo.2023.1088796
2. Sunarno, Y. (2025). The influence of fly ash characteristics as a supplementary cementitious material (SCM) on concrete's mechanical properties. *Materials Research Proceedings*, *48*, 587–596. https://doi.org/10.21741/9781644903414-64
3. Singh, N. B., Sarvahi, R., Singh, S. P., & Shukla, A. K. (1994). Hydration studies of rice husk ash blended white Portland cement. *Advances in Cement Research*, *6*(21), 13–18. https://doi.org/10.1680/adcr.1994.6.21.13
4. Mohamad, N., Muthusamy, K., Embong, R., Kusbiantoro, A., & Hashim, M. H. (2021). Environmental impact of cement production and Solutions: A review. *Materials Today: Proceedings*, *48*, 741-746. https://doi.org/10.1016/j.matpr.2021.02.212
5. Belaïd, F. (2022). How does concrete and cement industry transformation contribute to mitigating climate change challenges? *Resources, Conservation & Recycling Advances*, *15*, 200084. https://doi.org/10.1016/j.rcradv.2022.200084
6. Ayarkwa, J., Joe Opoku, D., Antwi-Afari, P., & Li, R. Y. M. (2022). Sustainable building processes' challenges and strategies: The relative important index approach. *Cleaner Engineering and Technology*, *7*, 100455. https://doi.org/10.1016/j.clet.2022.100455
7. Aslam, F., & Shahab, M. Z. (2024). Supplementary cementitious materials in blended cement concrete: Advancements in predicting compressive strength through machine learning. *Materials Today Communications*, *38*, 107725. https://doi.org/10.1016/j.mtcomm.2023.107725
8. Ahmad, J., Mohamed, K., Rahman, A. S. A., Mohd Ikmal, F. R., & Zulkifli, A. R. (2016). **Clay Stabilization Using OPC and Bottom Ash as Additives.** In *Regional Conference on Science, Technology and Social Sciences (RCSTSS 2014)* (pp. 27-33). Springer, Singapore. https://doi.org/10.1007/978-981-10-0534-3_3
9. Singh, N. B., Kalra, M., & Saxena, S. K. (2017). Nanoscience of Cement and Concrete. Materials Today:Proceedings, 4(4), 5478–5487. https://doi.org/10.1016/j.matpr.2017.06.003
10. Singh, N. B., Singh, N., Rai, S., & Singh, N. (2001). Hydration of rice husk ash blended portland cement.Indian Journal of Engineering and Materials Sciences, 8(4), 235–238

11. Kumar, R. Lal, K. Das,S. Shukla, A. K. (2023).Developing ultra-high-performance White Portland 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
12. **da Silva Filho, M. J., De Souza, M. L., Veras, V., & Cabral, A.** (2023). Durability analysis of partial replacement of ordinary Portland cement by white glass waste concrete. *Journal of Building Pathology and Rehabilitation, 8*(1). https://doi.org/10.1007/s41024-023-00284-4
13. **Etli, S., Yılmaz, T., & Hansu, O.** (2023). Effect of white-Portland cement containing micro and nano silica on the mechanical and freeze-thaw properties of self-compacting mortars. *Emerging Science and Technology Journal, 2023*, 101614. https://doi.org/10.1016/j.jestch.2023.101614
14. Sequeira, L., Forero, J., Bravo, M., & Evangelista, L. (2023). Durability of Concrete with Partial Replacement of Portland Cement by Incorporating Reactive Magnesium Oxide and Fly Ash. *Materials*, *16*(7), 2670. https://doi.org/10.3390/ma16072670
15. Kanagaraj, B., Lubloy, E., Anand, N., Hlavicka, V., & Kiran, T. (2023). Investigation of physical, chemical, mechanical, and microstructural properties of cement-less concrete – state-of-the-art review. *Construction and Building Materials*, *365*, 130020. https://doi.org/10.1016/j.conbuildmat.2022.130020
16. Elyasigorji, F., Farajiani, F., Hajipour Manjili, M., Lin, Q., Elyasigorji, S., Farhangi, V., & Tabatabai, H. (2023). Comprehensive Review of Direct and Indirect Pozzolanic Reactivity Testing Methods. *Buildings*, *13*(11), 2789. https://doi.org/10.3390/buildings13112789
17. Mañosa, J., Huete-Hernández, S., Alvarez-Coscojuela, A., Maldonado-Alameda, A., & Chimenos, J. M. (2024). Comparative study of limestone calcined clay cement produced with mechanically activated kaolin and calcined kaolin. *Journal of Building Engineering*, *97*, 110748. https://doi.org/10.1016/j.jobe.2024.110748
18. Fahim, N. S., Billah, A. K. M. M., & Dash, R. (2025, February). *Green ferrocement: Integrating pozzolanic waste for sustainable and cost–effective construction*. *Discover Civil Engineering, 2*(29). https://doi.org/10.1007/s44290-025-00188-x
19. Li, J., Ren, W., Zhang, A., Li, S., Tan, J., & Liu, H. (2022). Mechanical Properties and Microstructure Analysis of Cement Mortar Mixed with Iron Ore Tailings. *Buildings*, *13*(1), 149. https://doi.org/10.3390/buildings13010149
20. Khan, K., Ishfaq, M., Amin, M. N., Shahzada, K., Wahab, N., & Faraz, M. I. (2021). Evaluation of Mechanical and Microstructural Properties and Global Warming Potential of Green Concrete with Wheat Straw Ash and Silica Fume. *Materials*, *15*(9), 3177. https://doi.org/10.3390/ma15093177
21. Singh, N. B., Shukla, A. K., Singh, P., & Sarvahi, R. (1993). *Hydration of brick kiln ash blended white Portland cement*. *Silicates Industriels*, *58*(3–4).
22. Singh, N. B., Das, S. S., Singh, N. P., & Dwivedi, V. N. (2007). Hydration of bamboo leaf ash blended Portland cement. Indian Journal of Engineering and Materials Sciences, 14(1),69–76.