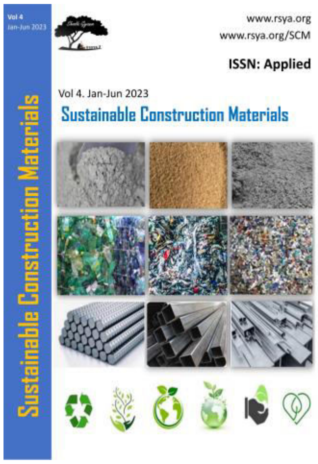

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Effect of Calcined Clay and PVC Waste Powder on Concrete Properties

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Abstract: This study's objective is to provide the findings of an experimental inquiry in which different amounts of polyvinyl chloride waste powder (PWP) were utilised to partially replace cement. In the process of creating test specimens, PVC waste powder (PWP) was changed in the proportions of 0%, 5%, and 15% by weight of cement while the 10% calcined clay was kept constant. The slump test was carried out to examine new concrete. Concrete's mechanical properties, such as compressive strength, split-tensile strength, and flexural strength, were investigated using curing times of 7, 14, 28, and 56 days. According to the findings of this study, M40 grade concrete can contain up to 5% PWP and 10% calcined clay without degrading its fresh or mechanical properties. It has been discovered to be favourable to obtain greater strength concrete by using PWP up to 5% as a partial replacement for cement with fixed calcined clay concentration of 10%.

Keywords: PVC Waste, Concrete, Mortar, Compressive Strength

Introduction

Concrete is the most popular and frequently utilised substance when it comes to construction materials. Its consumption is second only to that of water worldwide. Together, wood, steel, and aluminium only make up 50% of its global usage. By 2025, the global manufacturing of ready-mix concrete will bring in over $600 billion. Cement, the main adhesive in concrete, is produced from lime, clay, and shale. When cement is made, a significant amount of carbon dioxide is released into the atmosphere, causing pollution. Many scientists have been trying to find strategies to reduce the risk. Environmental effects of cement manufacture include the depletion of natural resources, increased energy use, and greenhouse gas emissions. However, the growing concerns about trash and how it should be handled keep researchers busy. To lessen the amount of cement required in concrete, researchers have been experimenting with a variety of wastes. Research on substitute materials and wastes that can partially replace cement in the production of concrete is badly needed. In some situations, PVC waste powder (PWP) could substitute cement in part. However, disposing of PWP has grown to be a significant problem in both industrialised and developing countries, including India. Due to increased industrialization, there are now more plastic waste being produced, which presents disposal problems. Researchers from all around the world have been experimenting with a variety of options to generate unique and affordable building materials and improved construction techniques in order to handle difficult requirements, such as the processing of plastic wastes. [1][2][3]. Over the next 30 years, it is predicted that India's annual production of plastic waste will increase to 3.4 billion tonnes, per a study by the Central Pollution Control Board (CPCB) of India. You can appreciate the quantity and challenges associated with the disposal of the 25000 metric tonnes of plastic waste produced daily in India. The environmental issues caused by rubbish and its disposal have been the focus of numerous studies and professionals from throughout the world. According to recent studies [4][5][6], one way to deal with trash is to mix it with concrete, which may then be used as a building material without harming Mother Nature. Researchers have been experimenting with a range of materials, including carpet, agricultural, and plastic wastes, as well as foundry, carbon, and glass fibre, to name a few, in order to better understand how various wastes may be used in concrete. To describe their efforts to reduce the amount of cement used in concrete, researchers have coined the term "green-concrete." For waste-based concrete, engineering characteristics and chemical characterization are frequently the focus of research. It is essential to ascertain the dose of a specific waste and the impact it will have on the engineering properties before using concrete as a construction material so that the right safety measures may be taken. Recent research [7][8] shows that academics have been experimenting with a wide variety of waste materials, including various types of plastics. The use of leftover polyvinyl chloride (PVC) powder in concrete, however, has never been investigated. There is a dearth of research on plastic waste in developing countries like India. The objective of this research is to close any information gaps. PVC waste can be utilised in concrete as an aggregate or as a fibre to make it lighter and more eco-friendly [9]. Studies demonstrate that the engineering attributes of the finished product are improved when plastic aggregate is used in place of some coarse and fine aggregate[10]. Plastic fibres also had a stronger impact on the packing density, structural ductility, and tensile properties of concrete [23], reducing crack development and enhancing these abilities. Making lightweight fibre reinforced concrete with plastic fibres is possible in a variety of ways, just like with aggregates [11]. [12]. Globally, academics and practitioners have substituted plastic waste/PVC waste for FA and CA in concrete [13]. There aren't many studies on cement replacement in concrete from developing countries like India. By evaluating the fresh, mechanical, and microstructural properties of M40 grade concrete with various amounts of PVC waste powder used as a partial replacement for cement, this study seeks to fill this information gap. According to the authors, this study will help researchers and practitioners in the building materials business manage the challenges brought on by plastic waste as well as the rising demand for cement. PVC waste powder is created by businesses that make plastic pipes, couplings, tubing, and other goods. This waste material contains chlorinated chemicals that harm the environment and present disposal and health risks. PWP poses a serious risk to the environment and public health since it is difficult to biodegrade and requires particular disposal techniques. This paper attempts to describe the use of PWP in the manufacturing of concrete. PVC waste is quite difficult to dispose of because it doesn't biodegrade well. It can be created by crushing and grinding scrap plastic into a fine powder. PWP can also be created through the manufacturing of plastic and pipe products [14]. This study has attempted to produce M40 grade concrete using PVC waste powder and 10% calcined clay (CC) at various weight percentages of cement (0, 5, 10, 15, 20, 25, and 30%). The objective is to reduce cement consumption in concrete by up to 30%. As "control" specimens in experiments, specimens with 0% CC and 0% PWP are employed. To ensure that the PWP has particle size that is comparable to that of the cement, it is rigorously tested. Using appropriate Indian standards, the mechanical and fresh qualities of concrete have been examined [15]. The authors of this study are therefore reporting the experimental findings of the physical, fresh, mechanical, microstructural, and chemical characterization of cement, calcined clay, and PWP-containing concrete.

Materials

Cement

Ordinary Portland cement with a grade of 43 was used in the experiment; it was purchased from a local supplier and made available by GLA University, Mathura. In this experiment, ordinary Portland cement with a specific gravity of 3.10 in accordance with IS: 8112-2013 was used to prepare PWP and calcined clay embedded concrete [16].

Aggregates

Sand that is readily available in commerce is used in this study as a fine aggregate. Concrete uses fine aggregates (FA) that have a fineness modulus of 2.42 and a particle size that passes through a filter of 4.75 mm. The concrete preparation process uses coarse aggregates (CA) with a fineness modulus of 6.34 that are 20 mm (60 percent) and 12.5 mm (40 percent) in size [17].

Calcined Clay

The major goal of replacing cement with calcined clay is to use Pozzolans to improve the characteristics of cement concrete specimens. By using calcined clay as a weight substitute for cement in concrete specimens, CO2 emissions are significantly decreased. Table 1 displays the chemical makeup of Ordinary Portland Cement (OPC) and Calcined Clay (CC) (OPC).

Table1: chemical composition of calcined clay (CC) and Ordinary Portland Cement (OPC)

Chemical Composition	Ordinary Portland Cement (OPC)	Calcined Clay (CC)
CaO	48.92	15.67

Fe_2O_3	5.21	10.68
Al_2O_3	12.32	18.72
SiO_2	31.24	46.09
SO_3	0.09	0.13
MgO	1.13	2.01
Na_2O	0.24	0.21
K_2O	0.01	2.38

The water

The Indian standard, which is used for both mixing and curing concrete, should be used to determine the water quality. This care was observed when constructing and curing the concrete test samples used in this study [16].

Powdered polyvinyl chloride waste powder (PWP)

PVC is most frequently used in powdered form in the plastic pipe manufacturing business in India. Because of its little weight, it has a lot of handling concerns. Numerous manufacturing processes generate a lot of dust due to pipe, couplings, and tubing. Similar to how consistent sizes are guaranteed, cutting techniques result in significant waste production of PVC powder. PVC powder is frequently gathered during the cleaning and maintenance of boilers used to melt plastics. PVC powder is regarded as trash for these three reasons (it spills to the ground after pouring and transferring, plastic products are chopped to size by two cutting boilers, and cleaning boilers are used to recover the plastic powder). It is regarded as a waste product to prevent contamination and impair product quality. It is challenging to dispose of and reuse such waste plastic powder. After being gathered, it was cleaned and sieved to make sure the powder size matched the size of cement particles.

Research Methodology

With varied amounts of PWP and 10% CC, six different sorts of mixes, CP0, CP1, CP2, CP3, CP4, CP5 and CP6, have been created. Mix CP0 is referred to as control concrete because it contains no PWP or CC at all. By weight, PWP has substituted 5 percent, 10 percent, 15 percent, 20 percent, and 25 percent of cement with fixed 10 percent CC in each mix. In this study, the mechanical properties of fresh concrete, such as slump and flexural, compressive, and split tensile strengths, are examined for all test specimens at 7, 14, 28, and 56 days of curing. As previously reported, as part of this experiment, PVC waste powder was employed in M40 grade concrete. In order to use less cement in concrete, different PVC waste powder percentages by cement weight (0 percent, 5 percent, 10 percent, 15 percent, 20 percent, 25 percent, and 30 percent) are changed. With the exception of the control specimen, all of the mixes contain PVC waste powder and a constant 10% amount of calcined clay. The reporting of experiments in the form of diverse test findings must include a wide range of characteristics and their graphical representations. This is why the relative relevance of various attributes is illustrated in the following section using graphs of varied hues.

Results and Discussion

Slump test

Indian Standard 1199 (1959) [18] is to be regarded. This test determines if mixed concrete is workable. It checks to see if the proper amount of water was added to the mixture. For the purposes of this inquiry, the slump test is run on each specimen. Fig. 1 displays the slump measurement for concrete in mm. Concrete loses workability as PWP % increases. In the control mix, a slump value of 84 mm is reached. Similar to this, from CP0 to CP6, the slump value may drop. CP1 has a maximum slump of 92 millimetres when 10% calcined clay is used, demonstrating an improvement in fresh properties. The CP6, which has the lowest slump value of 60 mm and comprises 30% PVC waste powder.

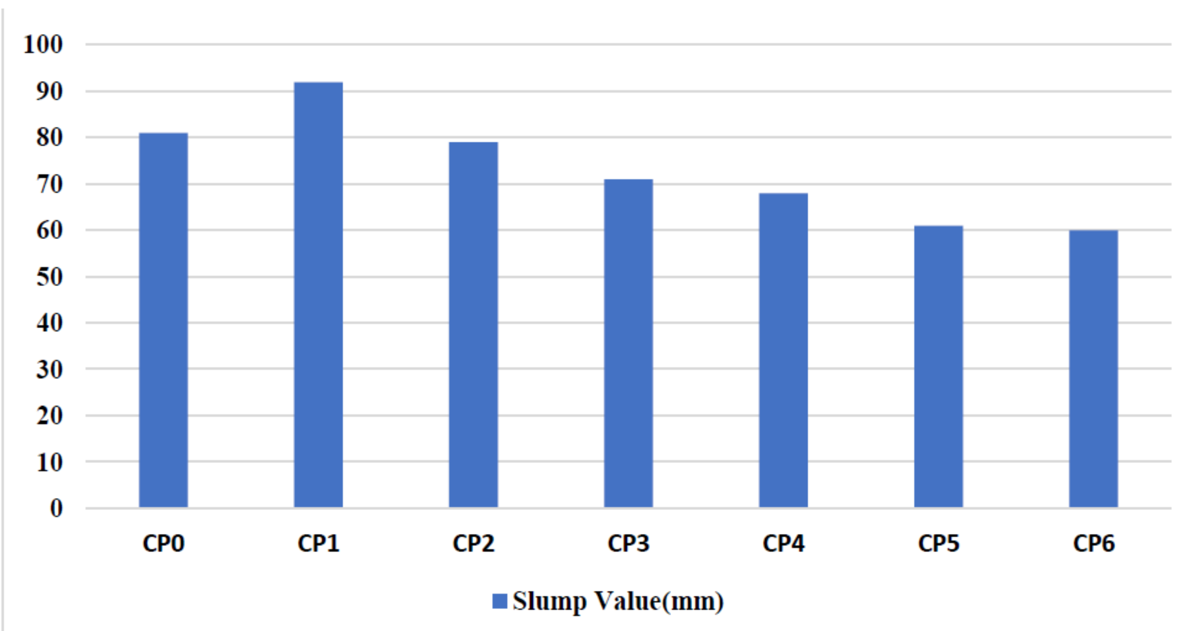

Fig. 1 Slump value of different mixes

Compressive strength

Fig. 2 demonstrates that, when compared to the control specimen, the specimen with PWP up to 5% has the highest compressive strength. However, the most potent CP1 is found in the mixture containing 5% PWP. After 28 days and 56 days of curing, respectively, the compressive strength rises by 9.76% and 12.19% above control specimens at a 5 percent replacement level (CP1). At a 10 percent replacement level, the compressive strength is shown to be 1.92 percent and 0.98 percent higher than the control specimen after 28 and 56 days, respectively (CP2). Additionally, it is demonstrated that when compared to the control specimen, the 15 percent replacement level results in 0.01 and 0.1% higher compressive strength at 28 and 56 days of curing. The presence and chemical interaction of calcined clay, PVC waste powder, and free lime from cement results in the formation of calcium-silicate-hydrate (CSH) gel, which boosts compressive strength. The high binding properties of the gel increase compressive strength. The filling of gaps with calcined clay and PVC waste powder may also contribute to the improvement in strength. PVC waste powder can more easily fill cracks and make concrete denser than a control mix because it has a smaller particle size and specific gravity than cement. Additionally, it has been demonstrated that when PVC waste powder is added at a replacement level greater than 5%, the compressive strength diminishes. The PVC waste powder has been replaced with cement as a result of using significantly more cement than required to fill the spaces in concrete. The cohesion between the component particles may break down with an increase in PVC waste powder, which could result in a reduction in compressive strength. According to statistics on compressive strength, sustainable concrete can be produced with a calcined clay concentration of 10% by replacing 5% of the cement with PWP [20].

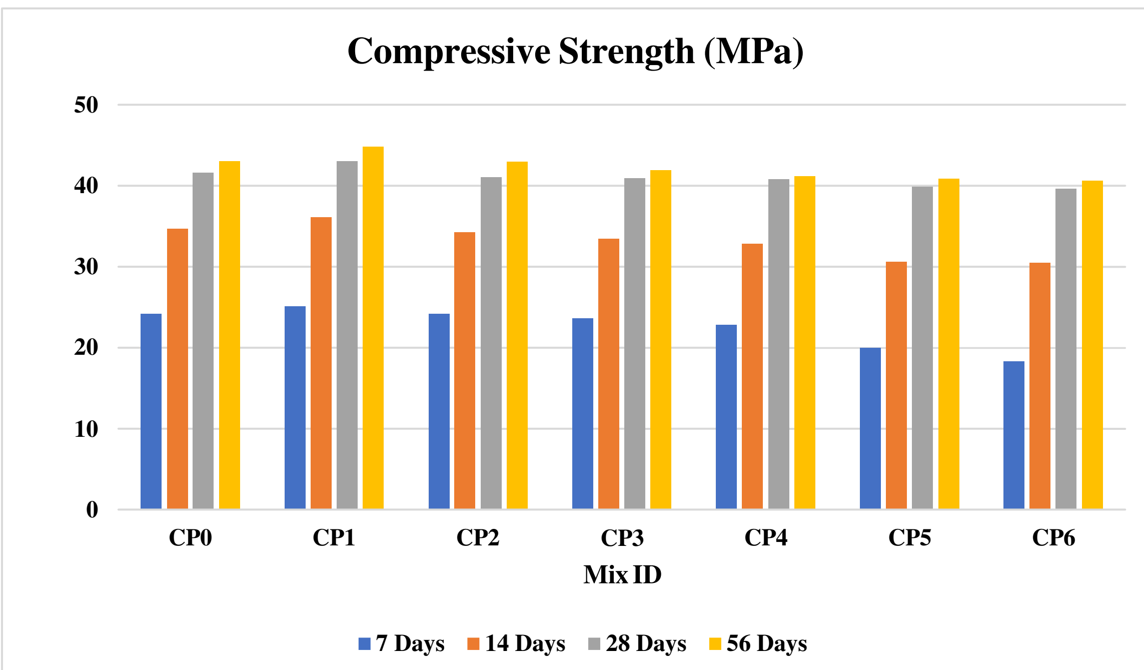

Fig. 2 Compressive Strength

Split Tensile strength

At cure times of 7, 14, 28, and 56 days, all specimens are tested for split tensile strength in line with IS:516-1959. As can be seen in Fig. 3, an increase in PVC waste powder causes a reduction in split tensile strength. Additionally, as curing time increases, the split tensile strength at each step of replacement rises. The control sample CP0's split tensile strength is 4.59 N/mm2 for the 28-day curing period and 5.09 N/mm2 for the 56-day curing period, respectively. The maximal strength of CP1 (5 percent PVC, 10 percent CC) at 28 and 56 days of curing is 4.8 N/mm2. In comparison to the control mix, adding PVC waste powder up to 5% as a partial substitute for cement and 10% CC results in the highest split tensile strength. The split-tensile strength increases by 3.05 percent and 3.95 percent above the control mix at 28 and 90 days of curing, respectively, before peaking at the 5 percent PVC replacement level. At 10 percent (mix-3) replacement level, the split tensile strength is 1.09 percent and 2.95 percent higher at 28 and 90 days compared to the control mix. At 28 and 90 days of curing, the split tensile strengths of the specimens (mix-3 and mix-4) are not significantly different. After 10 percent replacement, the split tensile strength suddenly decreases, and it keeps becoming worse as more PVC waste powder is added. The results of this experiment indicate that when compared to control specimens, concrete containing 10% PVC powder waste and 8% SF exhibits highly promising results.

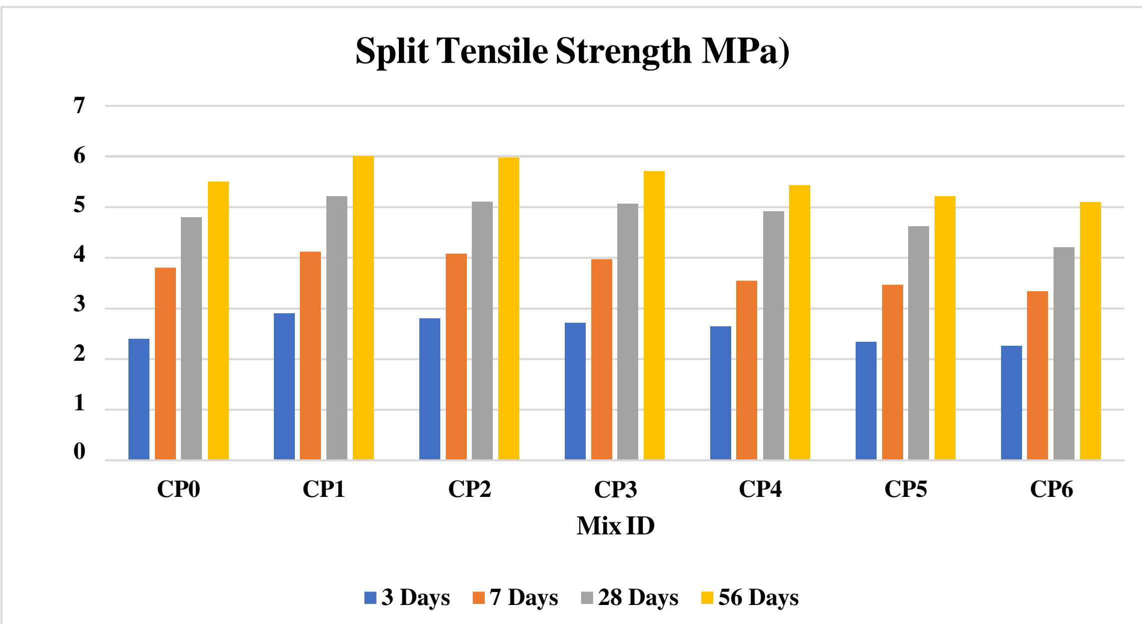

Fig. 3 Split Tensile Strength of different mixes

Flexural strength

As shown in Figure 4 and according to IS:516-1959, the flexural strength of concrete mixes is measured using a 100100500 mm beam specimen at 7, 14, 28, and 56 days after curing. UTM is used to figure out how strong beams are when they bend. Fig. 4 shows a clear comparison of the flexural strength of the specimens. The graph shows that the flexural strength of concrete gets better as it cures. On the other hand, flexural strength goes down a little when the amount of PVC waste powder in the cement goes up above 5 percent. Compared to the control mix, the sample with up to 5% PVC and up to 10% calcined clay has the highest flexural strength. At 28 and 56 days after curing, the 5 percent replacement specimen has 1.67 percent and 2.96 percent more flexural strength than the control specimen.

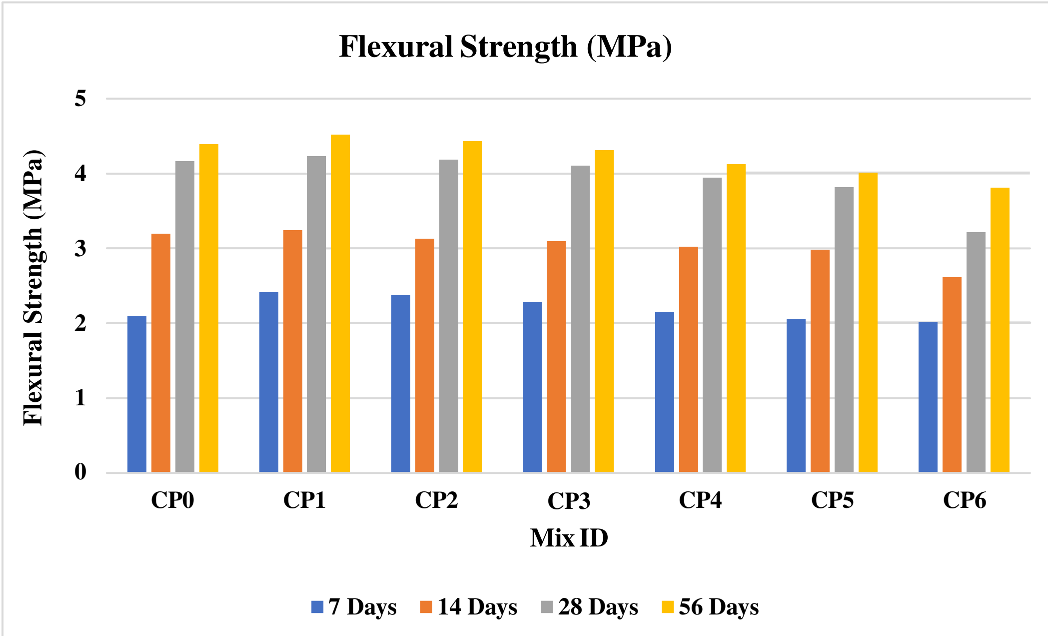

Fig. 4 Flexural Strength

Conclusion

By adding 10% calcined clay to M40 grade concrete as an extra material and using PWP as a partial replacement for cement, the hardened properties of concrete are studied. Based on how the experiments in this study turned out, we can say the following:

Slump tests showed that PWP has a bigger effect on how easy it is to work with concrete because it absorbs more water during mixing. As the amount of PWP in concrete goes up, the graph shows that it becomes harder to work with. Using up to 5 percent PWP instead of Portland cement, along with the right 10 percent CC content, makes it hard to work with the concrete. Some of the cement in concrete can be swapped out for PWP to improve its mechanical properties.

When PWP was added to the mix, the concrete's compressive, flexural, and split tensile strengths all got better. As the percentage of PWP goes above 5 percent, the compressive, flexural, and split tensile strengths drop dramatically. The results show that PWP can be used to replace 5 percent of the cement in M40 grade concrete without lowering its strength. This study shows that up to 5% PVC waste powder and up to 10% calcined clay can be used to get the same mechanical properties as control specimens. To put it another way, it is reasonable to say that PWP can be used in construction as a partial replacement for cement. It will save money and make the world a better place.

Pieces of concrete that are 5 percent PWP and 10 percent CC In the same way, CSH gel formation is smaller than mix-4 (15 percent PVC waste powder). When PVC waste powder is used to replace more than 15% of the cement in concrete, the mechanical and long-term performance of the concrete drops dramatically. This work will help academics and people who work in the building materials industry deal with worries about the rising demand for cement and plastic waste.

References

[1] P. Sharma, M. Verma, and N. Sharma, "Examine the Mechanical Properties of Recycled Coarse Aggregate with MK GGBS," in *IOP Conference Series: Materials Science and Engineering*, 2021, vol. 1116, no. 1, p. 12152.

[2] N. Sharma, P. Sharma, and A. K. Parashar, "Use of waste glass and demolished brick as coarse aggregate in production of sustainable concrete," *Mater. Today, Proc.*, May 2022, doi: 10.1016/J.MATPR.2022.04.602.

[3] M. Verma, N. Sharma, P. Sharma, and P. Singh, "Evaluate the Effect in Terms of Setting Time and Compressive Strength of Oleic Acid as an Admixture in Cement," no. 12422, 2020.

[4] D. Ogundare, F. Polytechnic, O. State, and A. O. Familusi, "Use of Waste Tyre as a Partial Replacement of Fine Aggregate in Concrete School of Engineering Technology Annual International Conference USE OF WASTE TYRE AS A PARTIAL REPLACEMENT OF FINE,"no. November 2020, 2021.

[5] N. Toubal Seghir, M. Mellas, Ł. Sadowski, and A. Żak, "Effects of marble powder on the properties of the air-cured blended cement paste," *J. Clean. Prod.*, vol. 183, pp. 858–868, May 2018, doi: 10.1016/j.jclepro.2018.01.267.

[6] A. K. Parashar, P. Sharma, and N. Sharma, "Effect on the strength of GGBS and fly ash based geopolymer concrete," *Mater. Today Proc.*, Apr. 2022, doi: 10.1016/J.MATPR.2022.04.662.

[7] N. Sharma, P. Sharma, and A. K. Parashar, "Incorporation of Silica Fume and Waste Corn Cob Ash in Cement and Concrete for Sustainable Environment," *Mater. Today Proc.*, Apr. 2022, doi: 10.1016/J.MATPR.2022.04.677.

[8] H. H. Chu *et al.*, "Coupled effect of poly vinyl alcohol and fly ash on mechanical characteristics of concrete," *Ain Shams Eng. J.*, vol. 13, no. 3, May 2022, doi: 10.1016/j.asej.2021.11.002.

[9] A. K. Parashar and A. Gupta, "Investigation of the effect of bagasse ash, hooked steel fibers and glass fibers on the mechanical properties of concrete," *Mater. Today Proc.*, vol. 44, pp. 801–807, 2021, doi: 10.1016/j.matpr.2020.10.711.

[10] P. Sharma, N. Sharma, and A. K. Parashar, "Effects of phase-change materials on concrete pavements," *Mater. Today Proc.*, May 2022, doi: 10.1016/J.MATPR.2022.04.581.

[11] Z. Ullah, M. I. Qureshi, A. Ahmad, S. U. Khan, and M. F. Javaid, "An experimental study on the mechanical and durability properties assessment of E-waste concrete," *J. Build. Eng.*, vol. 38, p. 102177, Jun. 2021, doi: 10.1016/J.JOBE.2021.102177.

[12] K. Ragaert, L. Delva, and K. Van Geem, "Mechanical and chemical recycling of solid plastic waste," *Waste Manag.*, vol. 69, pp. 24–58, Nov. 2017, doi:

10.1016/j.wasman.2017.07.044.

[13] A. Jain, N. Sharma, R. Choudhary, R. Gupta, and S. Chaudhary, "Utilization of non-metalized plastic bag fibers along with fly ash in concrete," *Constr. Build. Mater.*, vol. 291, p. 123329, Jul. 2021, doi: 10.1016/J.CONBUILDMAT.2021.123329.

[14] O. M. Olofinnade, A. N. Ede, and C. A. Booth, "Sustainability of Waste Glass Powder and Clay Brick Powder as Cement Substitute in Green Concrete," *Handb. Environ. Mater. Manag.*, pp. 1– 22, 2018, doi: 10.1007/978-3-319-58538-3_112-1.

[15] D. Yang, M. Liu, and Z. Ma, "Properties of the foam concrete containing waste brick powder derived from construction and demolition waste," *J. Build. Eng.*, vol. 32, p. 101509, Nov. 2020, doi: 10.1016/J.JOBE.2020.101509.

[16] BIS 8112, "BIS 8112 : 2013 ORDINARY PORTLAND CEMENT, 43 GRADE SPECIFICATION," *Bur. Indian Stand.*, 2013.

[17] BIS:383, "Specification for Coarse and Fine Aggregates From Natural Sources for Concrete," *Indian Stand.*, pp. 1–24, 1970.

[18] IS 1199, "Methods of sampling and analysis of concrete," *Bur. Indian Stand.*, pp. 1–49, 1959.