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Investigation of the usability of organic wastes as a building material

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Abstract: With global warming, the interest in environmental problems has been increased steadily in the last decades. The most important cause of global warming is the increasingly CO_2 emission with industrialization. The main input in the construction of the infrastructure and superstructure of the cities that developed with the industrialization is concrete and accordingly cement production. In cement factories, emerging in the production process CO_2 and particles are among the top air pollutants, emitting greenhouse gases to the atmosphere to a large extent. With the effect of industrialization and urbanization, the amount of waste increases continuously as a result of excessive use of resources and increasing consumption in the globalizing world. Waste problem that is growing exponentially; It has been affects the society, family and individual, and its negatively affects the quality of life. To solve the waste problem, recycling, which is the reprocessing of collected materials and their use in production, has an important mission in today's world as a necessity. Organic waste includes: agricultural wastes, peanut shell, nutshell, rice husk, sugar cane, palm oil, straw, tea scraps, cotton stalk, sunflower stalk, corn cob, cotton and textile wastes, wood fibers, etc. In this study, studies on the usability of organic wastes in the production of building materials were evaluated. In the study, it has been revealed that by selecting organic origin wastes, reusing or recycling in building material production, it has been shown that it can contribute to the protection of the environment by reducing the rate of resource use and disposal.

Key words: organic wastes; recycling and recovery; construction materials; cement and concrete additives; environmental protection

1 Introduction

In a globalizing world, waste volumes are on a steady upward trend as a result of the excessive and indiscriminate use of natural resources required for industrialization and urbanization. The waste problem emerging on a global scale affects society, families, and individuals. Recycling—the process of reprocessing, remanufacturing, and reusing previously collected materials—plays a significant role in today's world (Gündüzalp and Güven, 2016). The increase in production following the Industrial Revolution, along with technological advancements and their rapid spread, and the goal of raising living standards, have led to an increase in greenhouse gases in the atmosphere. In particular, following World War II, the rapid rise in greenhouse gases has resulted in global warming, leading to an increase in natural disasters that threaten the lives of humans, plants, and animal species. From the last quarter of the 20th century to the present, developments in the industrial sector have led to an increase in greenhouse gas emissions—resulting from the excessive consumption of natural

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raw materials and fossil fuels—and, consequently, to a steady rise in global warming. In addition to directly causing CO_2 emissions during the production phase of industrialization, the waste generated from the raw materials used poses a major problem for the environment. Traditional materials such as clay, sand, stone, gravel, cement, brick, tile, paint, lumber, and steel are used as primary structural components in the construction sector. The production of these materials relies on existing natural resources. Due to the large scale and persistent consumption of its natural resources, the construction sector has a distinctive impact on the natural environment. During the production of the wide variety of building materials, carbon monoxide, sulfur oxides, nitrogen oxides, and particulate matter are released into the atmosphere (Pappua et al., 2007). Population growth, increasing urbanization, rising living standards driven by technological innovations, and activities in industry, mining, households, and agriculture have all contributed to an increase in the volume and variety of solid waste. Globally, the estimated amount of waste generated in 2002 was 12 billion metric tons, of which 11 billion metric tons were industrial waste and 1.6 billion metric tons were municipal solid waste. It is expected that approximately 19 billion metric tons of solid waste will be generated annually by 2025 (Yoshizawa et al., 2004). Considering that industrial raw materials are limited natural resources and that consumption will increase further due to the growing population, most raw material sources are expected to be depleted in the coming centuries. For this reason, the usability of organic, renewable, and environmentally and health-safe agricultural waste in the construction sector has gained importance, both in terms of waste reduction and as a potential raw material source. This study reviews and analyzes research on the feasibility of using organic-based waste in the production of building materials. It has been demonstrated that organic-based waste holds significant potential for use in production processes and can be utilized to produce various environmentally friendly building materials.

Biomass holds significant potential for Turkey, and in this regard, the development of biomass-focused energy policies could make a significant contribution to sustainable, domestic, affordable, and clean energy production in Turkey (Gürel 2020). Agricultural waste is defined as waste remaining from the initial processing of raw agricultural products such as agricultural production and fruits, vegetables, meat, poultry, dairy products, and grains (Öner 2109). A significant amount of organic (agricultural) waste is generated in Turkey (Table 1).

Table 1. Potential agricultural waste in Turkey (Bolat, 2005)

Agricultural Residues	Annual Production (Million Metric Tons)
Sunflower stalks	2.7
Wheat stalks	26.4
Barley stalks	13.5
Corn stalks	4.2
Cotton stalks and bolls	2.9
Sugar beet stalks	2.3
Hazelnut shells	0.8
Oat stalks	0.5
Rye stalks	0.4

2 Usability of organic wastes in concrete production

Cement is one of the main inputs in the construction sector; in 2017, global cement production reached 4.1 billion metric tons, while production in Turkey stood at 79.9 million metric tons (Cement Sector Report, 2018). In the construction

sector, cement plants rank first among particulate air pollutants due to CO_2 emissions during cement production. Gases (SO, CO, NO) generated in rotary kilns used to burn clinker, as well as ground limestone and cement dust, are the most significant pollutants released into the environment by this industry. In addition to these well-known effects of cement plants, another significant impact is the release of cadmium into the environment. Cadmium released into the environment accumulates in the soil, is absorbed by plants, and is subsequently consumed by humans through the food chain (Kartalkanat, 2010). Increasing cement production, driven by rising demand, poses a risk to both the atmosphere and the environment. By substituting cement with organic waste generated from production and consumption activities through appropriate processes, the demand for cement can be reduced, and production volumes can be lowered. However, the mechanical, physical, and rheological properties of concrete produced using organic waste should not differ from those of concrete produced with standard Portland cement (PC).

In studies using organic waste, Alabadan et al. (2005) examined concrete produced by substituting PC with Bambara groundnut shell ash (GSA). GSA, whose chemical composition closely resembles that of cement, was substituted for cement at rates ranging from 0% to 50% by weight. The strength of the produced concrete increased with curing time but decreased as the percentage of GSA increased. While the control sample reached a strength of 31.24 N/mm² at 28 days, the highest strength (20.68 N/mm²) with ash was achieved with a 10% ash replacement. Buari et al. (2013) investigated the replacement of PC with GSA at rates ranging from 0% to 20%. The study found that a 10% GSA replacement yielded the best mechanical results. In a similar study, Nwofor and Sule (2012) investigated the use of Nigerian groundnut shell ash. Portland cement was substituted at rates ranging from 0% to 40%. The results showed a decrease in density and compressive strength as the percentage of rice husk ash substitution increased. All three studies demonstrated that substituting Portland cement with rice husk ash in concrete production is feasible, provided the substitution rate does not exceed 10%.

Rice husk is the natural outer shell of the rice grain, which is abundant in rice-producing countries. Approximately 200 kg of husks are obtained from one metric ton of rice, and after the combustion process, about 18–20% of this is converted into ash (Khan et al., 2012; Le et al., 2014; Aprianti et al., 2015). Rice husk ash (RHA), an agricultural byproduct known to be a super pozzolan, is a mineral admixture frequently used in concrete (RILEM, 2013; Mehta and Folliard, 1992). The behavior of cementitious products varies depending on the source of RHA (James and Rao, 1986; Malhotra and Mehta, 1996). Akeke et al. (2013) replaced PC with RHA at rates of 10–25% by mass. The results showed that the produced concretes had compressive strengths ranging from 33 to 38.4 N/mm² and tensile strengths ranging from 2.4 to 3 N/mm². In a similar study, Kishore et al. (2011) attempted to produce high-strength concrete by substituting PC with RHA. The results showed that concrete with a 10% by mass substitution exhibited very high mechanical properties at 28 days. In his study, Sensale (2005) compared RHA obtained from a rice milling industry in Uruguay with RHA produced in the U.S. via controlled combustion and investigated the compressive strength at 91 days. The two different types of RHA were substituted for Portland cement at 10% and 20% by mass, and three different water-to-cement ratios (0.50, 0.40, and 0.32) were used. While waste RHA had a positive effect on compressive strength at early ages, the 91-day compressive strength of concrete made with RHA produced by controlled incineration was significantly higher. Regarding air permeability results, both types of RHA-containing concrete exhibited higher performance compared to the control specimen due to the pozzolanic effect. Saraswathy and Song (2007) investigated the corrosion performance of RHA-substituted concrete. The corrosion performance of the concrete produced for this purpose was evaluated using open-circuit potential measurements, a rapid chloride ion permeability test, and a compressive stress test. The results showed that substituting up to 30% RHA reduced chloride permeability and improved strength and corrosion resistance properties.

Studies conducted with RHA have demonstrated that RHA can be used as structural concrete at appropriate replacement rates. RHA's reactivity is attributed to its high amorphous silica content and the very large surface area resulting from the porous structure of its particles—in other words, the increased fineness of the material (Mehta, 1978; Mehtra and Folliard, 1992; Cook, 1984; James and Rao, 1986; Kraiwood et al., 2001; Paya et al., 1995; Paya et al., 1997).

Sugarcane bagasse is a fibrous waste product of the sugar refining industry. Yashwanth and Nagarjuna (2016) investigated the effect on concrete of using sugarcane bagasse ash (SBA) and fly ash (FA) as cement substitutes. In the study, SBA and FA were substituted for cement by weight at rates of 0%, 5%, 10%, 15%, and 20%. Compared to normal concrete, the use of SBA and FA as substitutes improved the workability of the concrete, and it was determined that the compressive strength of the concrete increased by up to 15% as the substitution ratio increased. Sreenivasulu et al. (2018) produced concrete using granite dust and SBA as aggregate, replacing cement by mass at rates of 0%, 5%, 10%, 15%, and 20%. As a result, it was recommended that replacing up to 10% of the SBA with cement would be appropriate. These studies suggested that SBA could be used as a cement substitute at certain ratios.

Palm oil, also known as palm kernel oil, is a byproduct of palm oil production, and palm oil fuel ash (POFA) is disposed of in landfills. Researchers have investigated the feasibility of using POFA in concrete production. Tangchirapat et al. (2007) investigated POFA by replacing cement with it at three different fineness levels—10%, 20%, 30%, and 40% by weight, to investigate its pozzolanic properties and the concrete's setting time, compressive strength, and sulfate-induced expansion. The results showed that the use of POFA in concrete caused a delay in setting times. The 56-day compressive strengths of the concrete specimens demonstrated that POFA is an excellent pozzolanic material and can be used as a cement substitute in concrete at 20% and 30% replacement rates. Chindaprasirt et al. (2007) investigated the compressive strength and water permeability of concrete produced by replacing cement with POFA and RHA at replacement rates of 20%, 40%, and 55% by weight. Replacing cement with either material reduced workability and required more water. Test results showed that the compressive strengths of concrete containing 20% POFA or RHA were close to those of concrete produced with PC, while water permeability was lower than that of normal concrete. Although the compressive strengths of concrete containing 40% POFA or RHA were lower than those of concrete produced with PC, its water permeability was lower than that of normal concrete. When the POFA or RHA content reached 55%, the concrete's test results did not meet the required standards. Pone et al. (2018) investigated the early-age strength properties of concrete produced by replacing cement with POFA at rates of 2.5%, 5%, 10%, 15%, and 20% by weight, while maintaining a water-to-cement ratio of 0.5. The results showed that specimens containing 2.5% and 5% POFA exhibited higher early-age compressive strength compared to the control. These studies demonstrated that POFA can be used as a pozzolanic admixture in concrete production. Binici et al. (2008) investigated the effects of corn cobs (CC), wheat straw (WS), and plane tree leaf ash (PTLA) as mineral admixtures on concrete durability. Ten concrete mixtures were produced in three series, with these materials substituted for fine aggregate at rates of 2%, 4%, and 6%. To determine the durability of the concrete, the compressive strength, abrasion resistance, and water permeability of the specimens were tested after 7, 28, 90, and 180 days of normal curing and 18 months of sodium sulfate solution curing. The test results showed that the addition of CC, WS, and PTLA provided better workability and abrasion resistance compared to conventional concrete. Furthermore, the study demonstrated that CC, WS, and PTLA additives significantly increased the sodium sulfate resistance of the concrete specimens. Based on the study's findings, the production of concrete containing CC, WS, and PTLA additives is recommended for the production of durable concrete. Demirbaş and Aslan (1998) investigated the mechanical properties of concrete by mixing it with tea waste, ground hazelnut shells, spruce, and beech wood waste. It was suggested that ground hazelnut shells and beech wood could be used as additives or partial substitutes for Portland

cement. However, tea waste was found to adversely affect the mechanical properties of the concrete. In their study, Baluch et al. (1978) aimed to determine the strength of sisal fiber-reinforced cement mortar by using a model similar to the one proposed for determining the fracture resistance of steel fiber-reinforced cement mortar. The study found that sisal fiber reinforcement improved the compressive strength of the cement mortar.

3 Usability in insulation materials production

Today, interest in energy-efficient and environmentally friendly green buildings is rapidly increasing in the construction sector. In the construction of green buildings, the ability to produce energy-saving insulation materials from organic materials and waste has become an important area of research. To this end, Khedari et al. (2004) developed a new, low-cost particleboard made from a mixture of durian peel and coconut fiber—materials with low thermal conductivity—which is effective for energy savings when used as ceiling and wall insulation. The panel, produced from a 10/90 weight ratio mixture of durian peel and coconut fiber, was found to have a density of 856 kg/m³, a thermal conductivity of 0.1342 W/mK, a modulus of elasticity of 21.867 kgf/cm², and a moisture content of 6.22%. Xu et al. (2004) developed low-density, binder-free, formaldehyde-free particleboard from kenaf seeds. The boards successfully developed a bonded structure using steam injection pressing (steam pressure 1.0 MPa, steam duration 7−10 minutes). With a 10-minute steam treatment, the thermal conductivity of particleboards with a density of 200 kg/m³ was comparable to that of rock wool. Zhou et al. (2010) developed particleboards from cotton stalk fibers using high-frequency hot pressing without a binder. The particleboards, produced with densities ranging from 150 to 450 kg/m³, exhibited thermal conductivity values ranging from 0.0585 to 0.0815 W/mK, which are close to those of expanded perlite and vermiculite within the same density range. Lertsutthiwong et al. (2008) developed new particleboards with low thermal conductivity produced from a waste mixture derived from tissue paper manufacturing and corn husks. As the amount of corn husks added to the mixture increased, the density of the particleboard decreased, and the thermal insulation performance of the final product improved. In the study, thermal conductivity values ranging from 0.058 to 0.081 W/mK were obtained for particle boards with densities between 150 and 450 kg/m³. Zhou et al. (2004) developed low-density particle boards from hollow wheat straw. The study produced insulation panels with densities ranging from 100 to 250 kg/m³ and high thermal insulation performance. Tangjuank (2011) developed particleboard from pineapple leaves using natural rubber latex as a binder. The panels were produced by spraying natural rubber latex onto pineapple fibers to achieve thicknesses of 20 and 1.5 cm. The panels achieved high thermal insulation performance with a density of 210 kg/m³ and a thermal conductivity value of 0.035 W/mK. Paiva et al. (2011) developed particleboard panels 3, 6, and 8 cm thick from corn cob waste. The resulting panels had thermal conductivity values of 0.101 W/mK. Binici et al. (2011) prepared 30 x 40 x 2.5 cm rectangular blocks under pressure for use in building insulation, utilizing cotton textile waste such as sunflower stalks and stubble—materials that pose a serious environmental problem when used for heating.

Depending on the density of the blocks—which were produced using epoxy as a binder—thermal conductivity values ranging from 0.0728 to 0.2616 W/mK were obtained. It has been demonstrated that low-thermal-conductivity insulation materials suitable for use in the construction industry can be produced using organic waste.

Yalınkılıc et al. (1998) conducted studies on the use of tea leaves in particleboard production, taking advantage of their high phenolic extract content and the abundance of tea leaves as waste in tea-producing factories. The particleboard produced from waste tea leaves is expected to be more resistant to biological degradation due to its high phenolic extract content. Urea-formaldehyde resin was used as a binder during the production of the panels. The tested physical and mechanical properties of the produced panels were found to meet standard values. Through a series of applications, wood-cement panels—typically bonded with polywood or phenolic resin—have the potential to form a sturdy, weather-resistant,

and low-cost panel product (Anonymous, 1974). However, the development of wood-cement panels has been somewhat slowed by fundamental differences in understanding the bonding mechanisms (Sandermann and Kohler, 1964; Takano et al., 1977).

4 Cement Composites

Large amounts of lignocellulosic waste produced from various sources worldwide, such as the agricultural, wood, and furniture industries, are causing environmental concerns. The use of this waste in the production of cement-based building materials can contribute to solving these problems (Karade, 2010). Wood-plastic composites, produced using poplar wood and plastic, possess very important properties such as low cost, waste recycling, environmental friendliness, and a low carbon footprint. Wood-plastic composites are expected to offer significant application potential by meeting standard mechanical and physical properties (Özyurt, 2020).

The incorporation of fiber reinforcement into concrete, mortar, and cement paste can enhance many of the materials' fundamental engineering properties, such as fracture toughness, flexural strength, fatigue resistance, impact resistance, and thermal shock resistance. In recent years, the potential applications of natural fiber-reinforced, cement-based composites have attracted significant interest worldwide. Research has been conducted in many countries on the various mechanical properties, physical performance, and durability of cement-based matrices reinforced with natural fibers such as sisal, coconut, jute, bamboo, and wood fibers (Tolêdo et al., 1999). Plant-based natural fibers have a significant advantage over traditional synthetic fibers due to their lightweight, non-abrasive, non-toxic, and biodegradable nature. Bamboo fiber has relatively high strength, a narrow microfibril angle, and low cost, and can be effectively used as a reinforcement in polymer matrix composites, replacing synthetic fibers to a certain extent (Liu et al., 2010).

Pereira et al. (2013) evaluated the use of coconut shell fiber as a reinforcement for a cementitious matrix and the partial replacement of PC with RHA. One of the mixtures served as the reference sample without coconut fibers, while the others contained 5% by weight of coconut fibers and had PC partially replaced with RHA at ratios of 0%, 30%, 40%, and 50%. In composite panels subjected to accelerated aging tests, it was determined that coconut fiber reduced the density of the composite panel and improved its mechanical performance. Zhu et al. (1994) investigated the production, physical, and mechanical properties of banana fiber-reinforced cement composites. Composite products with a flexural strength exceeding 20 MPa were produced using banana fiber. The sisal plant is an important agricultural product used in the production of ropes, rugs, and cement composites, which generates large amounts of waste. To utilize this waste, Lima et al. (2014) investigated the potential of sisal fiber for reinforcing cement composites. The results indicate that reinforcing composites with natural sisal fibers can yield composite materials with superior mechanical properties compared to traditional composite products. Chatveera et al. (2005) aimed to investigate the use of sisal fiber-reinforced cement composites as roofing materials. Test results show that the flexural strength of sisal fiber roofing panels is lower than that of standard roofing panels. However, sisal fiber roofing panels are cost-effective, exhibit waterproofing and fire-resistant properties, and possess sufficient durability. Khorami and Ganjian (2011) investigated the use of Agricultural Waste Fibers (AWF) in the production of cement composites. To produce cement composites, three different types of AWF were used, with the addition of 2% and 4% by weight of meal, wheat, and eucalyptus fibers to the PC matrix. Additionally, the effect of silica fume on the flexural behavior of cement composites was investigated. The results show that the flexural behavior of cement composites depends on the type, length, diameter, aspect ratio, and texture of the fibers, and that fiber reinforcement increased the flexural strength for all groups. Furthermore, silica fume increased the flexural strength for all groups. The studies determined that agricultural waste fibers can be used commercially as an alternative fiber source.

5 Usability in the production of wall materials

The key to increasing the insulation capacity of products such as bricks and blocks is to create porosity within the clay matrix. With the aim of both increasing porosity and utilizing waste, Demir (2006) investigated the potential use of processed tea waste (PTW) in clay bricks and its effects on their durability and mechanical properties. PTW was added to raw brick clay at different ratios (by weight: 0%, 2.5%, 5%). As a result, it was concluded that PTW can be used in building bricks by taking advantage of its low cost and environmental benefits. Demir (2008) also investigated the potential for using various organic wastes, such as wood shavings, tobacco waste, and grass clippings, in clay bricks. Organic waste was added to raw brick clay at different ratios (by weight: 0%, 2.5%, 5%, and 10%) to examine their effect on pore formation in the fired clay matrix. It was observed that organic waste was effective in creating pores in the clay matrix and that the bricks retained acceptable mechanical properties. As a result, it was found that wood shavings, tobacco waste, and grass can be used as pore-forming agents in bricks in an environmentally safe manner. Agbede and Joel (2011) conducted a study to investigate the effects of RHA on the fired properties of clay bricks. Samples produced by adding RHA to clay at 2-10% by weight of RHA were added to the clay, and the resulting samples were fired at 800 ℃. As the RHA content increased, plasticity decreased; however, the addition of 2% RHA resulted in a compressive strength of 18.64 N/mm² and a water absorption value of 14.8%. In a similar study, Khedari et al. (2004) obtained a compressive strength of 2.1 N/mm² with bricks produced using RHA additions. Demir et al. (2005) investigated the potential use of kraft pulp waste produced from wood, straw, and reeds in clay bricks and its ability to create pores in the clay body. Organic waste was mixed into raw clay at different ratios (by weight: 0%, 2.5%, 5%, and 10%). It was observed that adding 2.5% and 5% waste resulted in acceptable mechanical properties and was effective in creating pores in the clay body.

Mahmoud et al. (2012) investigated the production of concrete blocks using groundnut shell ash (GSA) as a cement substitute. Cement was replaced with GSA at different ratios (by weight: 0%, 10%, 20%, 30%, 40%, and 50%). It was observed that the compressive strength of the concrete blocks ranged from 0.26 to 4.50 N/mm², and the compressive strength of 3.58 N/mm² obtained at a 20% replacement rate met the Nigerian Industrial Standard. Oyetola and Abdullahi (2006) investigated the compressive strength of concrete blocks produced using RHA. Portland cement was substituted with RHA at different rates (by weight: 0%, 10%, 20%, 30%, 40%, and 50%). It was determined that at high substitution rates, the compressive strength of the concrete blocks fell below the standards, whereas a 20% substitution rate was found to be the optimal level. Pinto et al. (2012) produced lightweight concrete using granulated corn cobs as aggregate. The results showed that the proposed corn cob concrete could possess the necessary material properties (density of 382.2 kg/m³, compressive strength of 120.0 kN/m²) required for lightweight concrete intended for non-structural applications. Sooksaen et al. (2018) developed lightweight concrete blocks using corn husk fiber, distiller's grains fiber, and coconut shell fiber obtained from agricultural industrial waste in Thailand. Lightweight concrete blocks with optimal mechanical properties were obtained by using up to 30% by mass of coconut shell fiber. Sobuz et al. (2014) conducted a strength and cost analysis of lightweight concrete produced in Malaysia's tropical regions using POFA—a type of solid waste—added to concrete as a lightweight aggregate at different mixing ratios ranging from 0% to 50%. The study showed that the compressive strength of lightweight concrete decreased as the percentage of POFA increased, while a potential cost reduction of up to 15% was observed. It was concluded that the use of POFA holds great potential in lightweight concrete production.

6 Use of cement mortar production

Sangeetha (2016) investigated the effect of RHA, substituted for cement at rates of 10–40%, on the properties of mortar mixtures. The study concluded that RHA is more economical and environmentally friendly than currently produced cement concrete blocks and can be used in the production of construction materials. Chatveera and Lertwattanaruk (2009)

investigated the effect of substituting rice husk ash (RHA) for cement at specific ratios (10%, 30%, 50%) in mortar mixtures with water-to-binder ratios of 0.55 and 0.65 on concrete properties. To measure the mortar's resistance to sulfate attack, 5% sodium sulfate (Na_2SO_4) and magnesium sulfate ($MgSO_4$) solutions were used. The study suggested that RHA can be used as a pozzolanic material in concrete and can improve resistance to sodium sulfate attack, but may reduce resistance to magnesium sulfate attack. Duggal et al. (2020) investigated the effect of replacing cement with RHA and SBA at specific ratios (10%, 15%, 20%) on the properties of concrete used to produce roof tiles. The study demonstrated that replacing cement with RHA and SBA holds environmental potential for the production of roof tiles. Chindaprasirta et al. (2008) investigated the effect of substituting POFA, RHA, and FA cements at specific ratios (20%, 40%) in mortar mixtures with a water-to-binder ratio of 0.5 on the concrete's resistance to chloride penetration. After a 30-day immersion in a 3% NaCl mortar solution, the mortar mixtures were tested for compressive strength, rapid chloride penetration, rapid permeability, and chloride penetration depth. The test results show that the mortar's resistance to chloride penetration improved significantly with the substitution of POFA, RHA, and FA. Canovas et al. (1992) conducted a study using sisal fibers to address the problem of plant fiber mineralization in cement mortars. The materials used demonstrated effectiveness in reducing the mortar's alkalinity, sealing mortar pores, and reducing water absorption in the fibers. The alkalinity-reducing capacity of the additives used is expected to be the subject of new research, particularly regarding the durability of concrete made with alkali-reactive aggregates.

7 Results and discussion

The annual global production of Portland cement, the main component of concrete, is approximately 4.5 billion metric tons, placing it among the top materials in mass production. The production of Portland cement results in significant emissions of the greenhouse gas CO_2; the production of one metric ton of Portland cement generates approximately one metric ton of CO_2 and other greenhouse gases. Studies have demonstrated that organic waste can be used as a cement substitute in specific proportions. Using these wastes as cement substitutes in the production of concrete and concrete products can yield significant environmental and economic benefits. These applications will reduce cement production, thereby lowering carbon emissions and significantly mitigating the harm that waste would otherwise cause to the natural environment. In ongoing studies, organic waste is frequently preferred in cement composites because it serves as an important source of cellulose and because cellulose strengthens the cement matrix. By using organic waste as an additive in the production of lightweight concrete, wall blocks, insulation materials, bricks, roof tiles, and similar products, the reuse and recovery of these wastes will be facilitated, leading to the widespread production of environmentally friendly materials.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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