Physico-Mechanical Properties of Mortar in Place of Fine Aggregate with Multi-Layer Laminated Packaging

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Abstract The purpose of this experimental study is to investigate the properties of mortar when mixed with multi-layer laminated scrap. By investigating the physical and mechanical properties of multi-layer laminated scrap substituting sand in different combination ratios. It was evaluated to measure water demand, absorption, and compressive strength, with the goal of using multi-layer laminated packaging leftovers as construction materials to further decrease environmental problems. Each specimen, which measured 50 mm by 50 mm by 50 mm, was used to create mortar. A volumetric mixture of cement and fine aggregate was utilized, with a ratio of 1:2.75 by weight. Subsequently, the percentage replacement of the multi-layer laminated scrap with fine aggregate was recorded as follows: 0%, 36%, 64%, and 100%. Then, a pavement brick mold was used to form pavement bricks mixed with multi-layer laminated scrap compare with plain pavement bricks. Compressive strength and water absorption were tested. Each mixture, including the control, had three replications, and the compressive strength was measured at 1, 3, 7, 14, 21, and 28 days of curing. The findings for water absorption showed that when employing more multi-layer laminated scrap, the amount of water used in molding increases. Although water demand reduced, flow values remained within the typical range of 110±5%. After 28 days of specimen aging, the compressive strength of mortar when mixed with multi-layer laminated scrap was 271, 247, 170, and 120 ksc, respectively. The compressive strength of the varied ratios dropped as the amount of multi-layer laminated scrap in the mix ratio increased.

Keywords: Multi-layer laminated scrap, Compressive strength, Water absorption

1. Introduction

Plastic is a material that is widely used and is considered one of the most important inventions of the 20th century. The development of plastic production technology made it possible to create packaging with several layers that combine various materials into a single structure [1]. Every year, more than 25 million tons of plastic waste are generated globally [2]. As a result, the industry was able to integrate functional qualities such as barriers, mechanical strength, and heat tolerance while lowering the average thickness of packaging materials using multi-material plastic [3]. Because of this, multilayer plastic packaging became crucial for a number of applications, preventing both excessive material consumption and the associated expenses as well as inadequate use and product losses [4]. These multilayer, multi-material films and sheets are made by co-extrusion or lamination techniques using a variety of polymers, such as polyesters like PET and PLA, polyolefins like PP and PE, and chemical variants like HDPE, LDPE, LLDPE, and OPP [5, 6]. Robertson (2016) states that sufficient strength is necessary for packaging design in order to contain and resist impacts [7]. Furthermore, sealing performance is crucial for protecting the goods from deterioration. Thus, for packing to work properly, the items must be shielded from abrasion, moisture, oxygen, light, odor, flavor, stiffness, pliability, and heat resistance characteristics [8, 9]. These days, plastic trash poses a major environmental risk to contemporary civilization due to its composition of multiple hazardous compounds, which can contaminate land, water, and air if improperly handled or processed [10]. Additionally, if mixed with soil, plastic waste might slow down the rate of percolation, which will reduce the fertility of the soil [11]. Since the recycling industry is unable to recognize, classify, and separate the various layers using the present standard technologies, multilayer plastic recycling is often complicated [12]. As a result, there have been numerous initiatives around the world, particularly in wealthy countries, to transform plastic trash into valuable items [13]. The only way to lessen environmental problems brought on by trash disposal and the usage of non-renewable resources is through recycling.

Nowadays, most research focuses on the potential for recycling these wastes into concrete in situations where the strength of the concrete isn't the primary factor being examined, such large volumes of PCC (Portland Cement Concrete) being used for pavements [14]. Numerous writers investigated the substitution of aggregates with plastic foams and found certain problems, such as buoyancy, deformability, water absorption, and aggregate proportioning [15]. A significant amount of research has already been done on the use of plastic waste, such as glass reinforced plastic (GRP) [16], polycarbonate [17], polyurethane foam [18], and polypropylene fiber [19], as an aggregate, filler, or fiber in the preparation of concrete. Other examples of plastic waste include polyethylene terephthalate (PET) bottles [20], high density polyethylene (HDPE) [21], and recycled plastic waste [22]. A growing number of researchers are looking into the possibility of using waste plastic materials as aggregate replacement in mortar or concrete due to this and the desire to reduce the use of natural resources in the construction industry, with a focus on the amount of land required for concrete aggregates. Lightweight aggregates were created in this effort to replace sand in mortars. The "end of waste materials" were acquired by the separation and mechanical recycling of small-sized post-consumer packaging films [23].

Based on the feasibility of recycling multi-layer laminated packaging (MP) has been utilized in scrap form to create new materials as a sand replacement material. In this investigation, MP scrap has been used in various ratios to substitute sand in the concrete mixture; the substitution was made by volume rather than weight. Because aggregate materials, such as sand and multi-layer laminated packaging scrap, range greatly in their bulk densities based on factors like compaction, moisture content, and other factors, volume specification takes these differences into consideration. The results of many testing have been presented. Physico-mechanical properties including compressive strength, mortar test, and water absorption are all considered throughout the inspection.

2. Materials and methods

The use of MP in place of fine aggregate in the mortar production process has, however, received little research. Al-Manaseer and Dalal [24] conducted the first studies on the impact of replacing fine aggregate in concrete with plastic particles, examining the effect of increasing the amount of angular waste plastic particles on cylinder strength for three different water-to-binder ratios. Poor bonding between the plastic and cement paste was discovered to be the cause of the diminishing compressive strength observed with an increase in the amount of plastic aggregate. During the compressive testing of the concrete, the plastic was able to pull out instead of splitting in tension. The materials used in this study to manufacture the cement mortar were presenter into 2 parts as follows:

Part 1: Material preparation and testing of basic material qualities such as specific gravity, absorption, mixed design and weight unit. The materials utilized in the research include:

1.1 Type I ordinary Portland cement is the most widely used type of cement. To cement, numerous tests were carried out, among of which include standard consistency tests, setting time tests, etc.

1.2 The manufacturer's multi-layer laminated packaging was sifted using a standard number 4 sieve to remove large particle contaminants. Fine aggregate sizes were then selected for use in mortar testing by passing through sieve no. 16 and retaining sieve no. 100. The water content was then calculated based on ASTM C230 criteria. Sample of multi-layer laminated scrap before and after sizing are displayed in Fig.1.

(a)

(b)

Fig.1 Sample of multi-layer laminated scrap (a) before, and (b) after sizing

1.3 Fine Aggregate: Sand is typically used as the fine aggregate. A minimum void ratio should be achieved by the sand particles; a greater void ratio necessitates the use of more mixing water.

1.4 Water: Water from the Metropolitan Water Supply that complies with ASTM C156 – 03 for water for concreting and curing materials is available.

Multi-layer laminated scrap and river sand were mixed in a container using a stirring rod. The trial-and-error method was used to determine the amount of multi-layer laminated scrap and sand required to manufacture one tile or block. This takes into consideration forecasting and testing the sand- to- multi- layer laminated scrap ratio before to use. Depending on the volume of aggregates, a cement to fine aggregate ratio of 1: 2. 75 by weight was permitted. Following that, the following percentages of fine aggregate were used to replace sand by multi-layer laminated scrap as: 0% , 36% , 64% , and 100% . The substitution of multi-layer laminated waste in mortar may result in a number of expected outcomes. Regarding the potential effects of this approach, the following expectations and presumptions exist by lowering the quantity of plastic trash that ends up in landfills or the environment, adding plastic scrap to mortar can help create a more sustainable building sector. Sand and gravel are examples of natural resources that can be preserved by partially substituting plastic scrap for traditional aggregate materials in mortar. Depending on the kind and quantity of plastic scrap utilized, the mortar's longevity, flexural strength, and compressive strength may all be impacted by its presence.

Part 2: Testing to estimate the water requirements in the mortar mixture in accordance with the ASTM C-230 standard, which is a flow table test to measure the flow of cement mortar. Determine the amount of water used to test for percent flow. The amount of water is obtained from the shaping of sidewalk bricks. Consider the mixing ratio that was evaluated for flow spread. Molded into mortar test blocks for further compressive strength testing, which will be described and demonstrated in the mixing details later. The amount of multi-layer laminated scraps substituting sand in various mixing ratios is tested for compressive strength using ASTM C109/C109M criteria at ages 1, 3, 7, 14, 21, and 28 days. The test ratio of cement, sand, and multi- layer laminated scrap, which results in three samples of compressive strength testing in each age. Mortar test findings are used to compare and discover patterns in subsequent strength development. The second section of the ASTM C230 test results are being examined to identify the volume of multi- layer laminate scrap, the water requirements when replacing sand with multi- layer laminated scrap, and the mixing ratio values for control. Mortar flow and the mix ratio that produces the maximum compressive strength.

3. Results and discussion

Physical properties

The following are the test results for physical properties of materials preparation, such as specific gravity, absorption, analysis of mixed sizes, and weight unit.

1. The average specific gravity of Portland cement Type 1 according to the ASTM C188 standard is 3.17.

2. According to ASTM C 128, the average value for multi- layer laminated scraps is 0.77.

3. According to the ASTM C 128 standard, the specific gravity of sand averaged 2.53, with a percentage of absorption of 1.42 percent while the average unit weight of sand,

according to the ASTM C29 standard, is 1,620 kg/m^3.

For example to prepare materials, the ratio of C: fine aggregate = 1:2.75 by weight when fine aggregate included sand and MP,

In M-1 mix; MP = 0%, so when we need weight of sand = 2,750 kg, volume of sand will be 1.09 m^3 (2,750/(2.53x1000)).

In M-2 mix; MP = 36%, we need volume of MP which replace sand = 0.36x1.09 = 0.39 m^3, so weight of MP = 0.77x0.39 = 0.30 kg.

Mortar Test Results

Water absorption is one of the physical attributes that present performances that are currently being discussed among the authors in the literature, with aspects and scenarios being thoroughly explored [25]. The flow table test is used to determine the water requirements of mortar mixtures in accordance with ASTM C-230 recommendations (Fig.2). The molding yielded information about the fluidity of cement mortar, the volume of water necessary to determine flow spread, and the amount of water. The mixture ratio tested for flow spread was then applied, followed by an evaluation of compressive strength using mortar blocks (Fig.3). Afterwards, the researcher used a flow value of 110±5 for standard mortar while other sample use w/c ratio as shown in Table 1 to make pavement bricks rather than cubes since the conventional flow value causes layers of segregation between the sand and laminated packaging scraps rather than homogeneity. The amount of water was determined by testing the paving bricks, as seen in Fig.4 When using more multi-layer laminated scrap, the amount of water utilized in molding increases. The water demand decreased, but the flow value stayed within the normal range of 110±5%. The compressive strength of the flow test sample cast into the mortar test slump was tested using ASTM C109/C109M standards, and the results are also shown in Table 1. According to Alhasanat et al. [26], the addition of fine recycled plastic particles improves workability, while the addition of fibers and coarse aggregates reduces it. Based on an analysis of the literature on the influence of PP, PE, and PVA fibers, Pakravan et al. [27] concluded that workability is not extremely sensitive to fiber type.

Fig.2 Flow table test according to ASTM C230

Fig.3 Samples of mortar for compressive strength tested using ASTM C109/C109M

Fig.4 Samples of plain pavement bricks and pavement bricks mixed with multi-layer laminated scrap.

The experiment's results revealed that conventional mortar and mortar blended with additional layers of laminated packaging debris required less water due to the sample blocks' reduced water absorption. Almeshal et al. [28] indicate that water absorption increases as the sand-to-plastic replacement ratio increases. This is due to increased porosity in the cementitious matrix. In reality, increasing the size of plastic/rubber particles, the quantity of aggregate and fibers, and the w/c ratio all have an effect on water absorption. The preliminary characteristics testing found that the sand's water absorption values differed from those of multi-layer laminated waste. Even though some water may adhere to the surface of multi-layered laminated scrap. The water utilized in molding has a flow value of 110±5%, which is within the standard range. As a result, the potential use of plastic waste in building would open up a new avenue for managing these plastic wastes and reducing their negative environmental impact. Unlike other potential applications for plastic waste, using plastic waste for construction would pave the door for the usage of a huge volume of plastic trash [29].

Table.1 the flow test combination results for ASTM C230 and compressive strength test results for ASTM C109/C109M.

Sample No.	C	W/C	S (%)	MP (%)	ASTM C230 (%)	Compressive Strength Test, ksc. (days)					
						1	3	7	14	21	28
M-1	1	0.77	100	0	110	103	171	219	241	254	271
M-2	1	0.76	36	64	107	113	202	209	225	242	247
M-3	1	0.75	64	36	105	78	105	125	142	161	170
M-4	1	0.74	0	100	103	79	86	88	105	115	120

Note: C = Cement; W/C = Water to cement ratio; S = Sand; MP = Multi-layer laminated packaging
Cement:Fine aggregate ratio was set as 1:2.75 by weight (Fine aggregate included S and MP)

Overall, the compressive strength of all types of waste-containing mortars reduced as compared to the reference mortar. Fig.5 depicts the mortar's compressive strength test results. It was discovered that the compressive strength of ordinary mortar and mortar mixed with multi-layer laminated scraps increased with mortar curing time in each mixture. Furthermore, it was discovered that as more multi-layer laminated scraps were replaced, the compressive strength declined when the porosity of the sample appears to have risen. Although mechanical values decrease with more multi-layer laminated scraps, they remain sufficient for non-bearing concrete buildings. As a result, the potential utilization of waste materials will enhance the sustainability of construction processes and practices. The sustainable use of multi-layer laminated scraps for building also has economic benefits. Compared to other types of plastic waste, the usage of low-density polyethylene (LDPE) and high-density polyethylene (HDPE) plastics has been found to be the most promising in asphalt mixtures [30, 31].

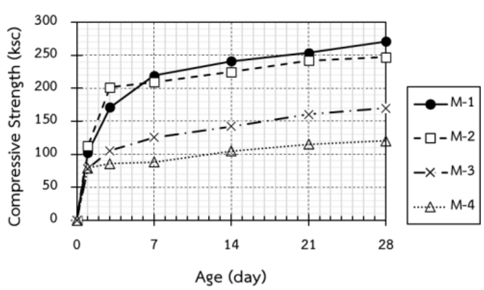

Fig.5 Improving of the compressive strength of mortar per replacement of multi-layer laminated scrap.

The weight of the sample is depicted in Fig.6, which indicates that the relationship between the weight of the sample and compressive strength tends to rise as the sample weight increases. Particularly, because of the pozzolanic reaction, the fineness of fine aggregates, and the acceleration of cement hydration, there is a discernible rise in the mortar's compressive strength, especially during the early curing days at normal temperatures. Concrete loses density and compressive strength when waste plastic is substituted volumetrically for sand; the strength losses increase with higher replacement ratios. This might be the result of a weak connection between the plastic and the surrounding matrix, an accumulation of water because the hydrophobic plastic surface increases gaps, or a breakdown of the plastic under tension [32]. Then, without being activated, MP can only function as inert filler. Greater compressive strength is correlated with increased weight. A high weight will result in a low porosity sample, which will have less space inside the sample and be stronger. The test results, which were plotted on a normal probability paper, demonstrated a modest improvement in the material's compressive strength relative to the weight of the concrete. It follows that the sample's weight should be unable to withstand significant force. When examining the test findings and force development curves, they will be consistent. The results from the average absorption of the sample from Fig.7, which shows the absorption value of the sample and indicates the gaps in the test sample that expand when more multi-layer laminate scraps are mixed. This increases the absorption value, and the data is consistent in terms of absorption, weight obtained, and test sample compressive strength. The cast specimen was subjected to a water absorption test in order to better understand its properties. Water absorption reached a maximum of 21.65% in the 100 percent of multi-layer laminated scrap replacement (M-4), and it was as low as 8.43% in the brick with the 36 percent of multi-layer laminated scrap mix (M-2) while the water absorption of the conventional bricks (M-1) was 6.56%. Several investigations have demonstrated that plastic sand bricks with specific plastic to sand ratios are a viable non-bearing alternative to conventional bricks and concrete blocks, particularly in terms of compressive strength, maximum load crushing, water absorption, and efflorescence testing [33, 34].

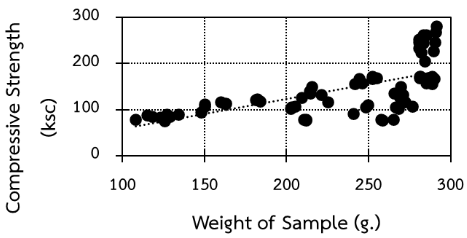

Fig..6 Relationship between sample weight and compressive strength

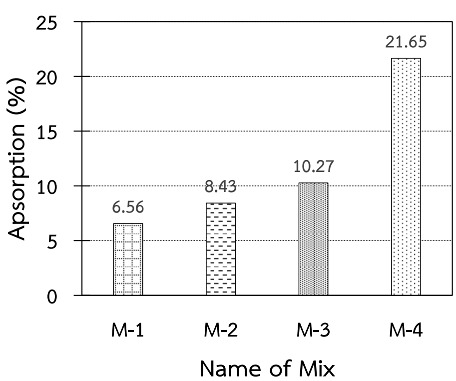

Fig.7 Absorption value of the sample

However, according to the reviewed literature, there are no studies on environmental analyses, such as life cycle assessment (LCA) based on material flow analysis of plastic waste concrete. Several publications emphasize the need to conduct environmental evaluations about plastic waste concrete [35, 36].

4. Conclusion and suggestions

Plastics play an essential part in modern civilization and are utilized in a variety of applications due to their low cost, simplicity of manufacture, and appealing properties. Unfortunately, because plastic garbage is biodegradable, it poses significant environmental concerns to modern society. The percentage of recycled plastic can be enhanced by converting discarded plastic into mortar and concrete products appropriate for residential and other construction projects. In this investigation, multi- layer laminated scrap was employed instead of cement mixed with river sand to make mortar. Replacing cement with plastic trash will help to decrease environmental issues related with both plastic waste disposal and the cement industry itself. The preliminary results of this study show that MP scrap can be blended with variable amounts of sand to create a feasible composite for usage as high-strength construction materials and concrete alternatives. Based on the findings of all research, the following conclusions can be drawn.

1. Flow determination tests with pavement brick molding data reveal that water demand decreases as the amount of MP scrap increases. ASTM C-230 testing results indicate a range of 110±5% for standard mortar. The range of W/C ratio was found between 0.76-0.74 which also

trend to decrease as the amount of MP scrap increases.

2. The outcomes of the tests verify that MP can be utilized in place of fine aggregate. It was found that the weight of the sample reduced while the absorption value increased when the number of MP scraps increased. Nevertheless, the sample's porosity causes its compressive strength to decrease, and as porosity increases, so does the impact of moisture content on compressive strength. There is minimal development in compression strength, despite a rise in compressive strength.

3. The weight of the lightweight sample block clearly demonstrates the benefits of employing multi- layer laminated debris in place of fine aggregate. So, it can be used as an alternative in places that do not require compression, reducing the strain on the structure in another way.

Substituting plastic trash for cement will help to lessen the environmental impact of both plastic waste disposal and cement manufacturing. Finally, a more extensive economic and lifetime analysis is required to establish the cost of this option against concrete, as well as its overall environmental impact. In the future, plastic can be used to replace gravel and cement in the construction of plastic roads, which are popular in some parts of the world. As a result, it can also be utilized to expand macro- scale building, which will gain traction as the globe moves toward a plastic-free zone. Under this scenario, the product might prove to be a viable substitute for existing commercial products, as it would be environmentally friendly and ensure intriguing physical attributes. The gathering of plastic waste prior to recycling is one of the main limitations on its application. Plastic waste are usually contaminated when they are gathered from different streams where they are created with different kinds of plastics and other pollutants. Unlike building materials like steel, it is composed of several plastic grades and types, which could lead to a non-isotropic performance when utilized in construction. However, future research is required to address a number of issues, including handling different plastic types and proportions, chemical properties, comprehending the plastic sand bricks' long- term performance, addressing the flammability and fire resistance of the material, and heat conductivity and potentially the acoustic characteristics of the finished product.

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References

[1] Walker, T.W., et al., "Recycling of multilayer plastic packaging materials by solvent- targeted recovery and precipitation." *Science advances*, vol.6, no.47, pp. eaba7599, 2020.

[2] Ingabire, D., et al., "Recycling High- Density Polyethylene (HDPE) into construction materials as a key step in plastic waste reduction: case of Kigali City." *Rwanda Journal of Engineering, Science, Technology and Environment*, vol.1, no.1, 2018.

[3] Mieth, A., E. Hoekstra, and C. Simoneau, " Guidance for the identification of polymers in multilayer films used in food contact materials." , *European Commission JRC Technical reports*, 2016.

[4] Anukiruthika, T., et al., "Multilayer packaging: Advances in preparation techniques and emerging food applications." , *Comprehensive Reviews in Food Science and Food Safety*, vol.19, no.3, pp. 1156-1186, 2020.

[5] Kaiser, K., M. Schmid, and M. Schlummer, " Recycling of polymer- based multilayer packaging: A review.", *Recycling*, vol.3, no.1, pp.1, 2017.

[6] Wagner Jr, J. R., " Multilayer flexible packaging." , *William Andrew*, 2016.

[7] Robertson, G.L., "Food packaging: principles and practice." , *CRC press.*, 2005.

[8] Ragaert, K., et al., "Design from recycling: A complex mixed plastic waste case study.", *Resources, Conservation and Recycling*, vol.155, pp. 104646, 2020.

[9] Hahladakis, J.N. and E. Iacovidou, "Closing the loop on plastic packaging materials: What is quality and how does it affect their circularity?" , *Science of the Total Environment*, vol.630, pp. 1394-1400, 2018.

[10] Saikia, N. and J. De Brito, "Use of plastic waste as aggregate in cement mortar and concrete preparation: A review.", *Construction and Building Materials*, vol.34, pp. 385-401, 2012.

[11] Silva, R., J. De Brito, and R. Dhir, " Properties and composition of recycled aggregates from construction and demolition waste suitable for concrete production.", *Construction and Building Materials*, vol. 65, pp. 201-217, 2014.

[12] Horodytska, O., F.J. Valdés, and A. Fullana, "Plastic flexible films waste management–A state of art review." *Waste management,* vol.77, pp. 413-425, 2018.

[13] Babayemi, J.O., et al., "Ensuring sustainability in plastics use in Africa: consumption, waste generation, and projections." , *Environmental Sciences Europe*, vol.31, no.1, pp. 1-20. 2019.

[14] Safi, B., Saidi, M., Aboutaleb, D., & Maallem, M., " The use of plastic waste as fine aggregate in the self-compacting mortars: Effect on physical and mechanical properties.", *Construction and Building Materials*, vol.43, pp. 436-442, 2013.

[15] Madandoust, R., Ranjbar, M. M., & Mousavi, S. Y., "An investigation on the fresh properties of self-compacted lightweight concrete containing expanded polystyrene.", *Construction and Building Materials*, vol.25, no. 9, pp. 3721-3731, 2011.

[16] El-Seidy, E., et al., "Lightweight alkali- activated materials and ordinary Portland cement composites using recycled polyvinyl chloride and waste glass aggregates to fully replace natural sand. ", *Construction and Building Materials*, vol. 368, pp. 130399, 2023.

[17] De la Colina Martínez, A.L., et al., " Recycled polycarbonate from electronic waste and its use in concrete: Effect of irradiation. ", *Construction and Building Materials*, vol.201, pp. 778-785, 2019.

[18] Bergamonti, L., et al., "Lightweight hybrid organic- inorganic geopolymers obtained using polyurethane waste. ", *Construction and Building Materials*, vol.185, pp. 285-292, 2018.

[19] Yuan, Z. and Y. Jia, "Mechanical properties and microstructure of glass fiber and polypropylene fiber reinforced concrete: An experimental study. ", *Construction and Building Materials*, vol.266, pp. 121048, 2021.

[20] Wiswamitra, K.A., et al., "Heat resistance of lightweight concrete with plastic aggregate from PET (polyethylene terephthalate)-mineral filler. ", *AIMS Materials Science*, vol.8, no.1, pp. 99-118, 2021.

[21] Selvi, M.T., A. Dasarathy, and S.P. Ilango, " Mechanical properties on light weight aggregate concrete using high density polyethylene granules.", *Materials Today: Proceedings*, vol.81, pp. 926-930, 2023.

[22] Alqahtani, F.K., I.S. Abotaleb, and M. ElMenshawy, " Life cycle cost analysis of lightweight green concrete utilizing recycled plastic aggregates.", *Journal of Building Engineering*, vol.40, pp. 102670, 2021.

[23] Coppola, B., Courard, L., Michel, F., Incarnato, L. , & Di Maio, L. , "Investigation on the use of foamed plastic waste as natural aggregates replacement in lightweight mortar.", *Composites Part B: Engineering*, vol.99, pp. 75-83, 2016.

[24] Al-Manaseer, A. A., & Dalal, T. R., " Concrete containing plastic aggregates.", *Concrete international*, vol.19, no.8, pp. 47-52, 1997.

[25] Marinelli, S., et al., "Waste plastic and rubber in concrete and cement mortar: A tertiary literature review.", *Sustainability*, vol.15, no.9, pp. 7232, 2023.

[26] Alhasanat, M.B., et al., " The Addition of Plastic Waste in Self-Compacted Concrete: A Critical Review the Addition of Plastic Waste in Self-Compacted. ", *International Journal of Current Research.*, vol.8, pp. 33240-33244, 2016.

[27]Pakravan, H.R. and T. Ozbakkaloglu, " Synthetic fibers for cementitious composites: A critical and in-depth review of recent advances." , *Construction and Building Materials*, vol.207, pp. 491-518, 2019.

[28] Almeshal, I., et al., "Use of recycled plastic as fine aggregate in cementitious composites: A review.", *Construction and Building Materials*, vol.253, pp. 119146, 2020.

[29] Jethy, B., et al., "Critical review on the evolution, properties, and utilization of plastic wastes for construction applications.", *Journal of Material Cycles and Waste Management*, vol. 24, no. 2, pp. 435-451, 2022.

[30] Awoyera, P., E. Onoja, and A. Adesina, "Fire resistance and thermal insulation properties of foamed concrete incorporating pulverized ceramics and mineral admixtures.", *Asian Journal of Civil Engineering*, vol.21, no.1, pp. 147-156, 2020.

[31] Jnr, A.K.-L., et al., "Recycling waste plastics in developing countries: Use of low-density polyethylene water sachets to form plastic bonded sand blocks.", *Waste Management*, vol. 80, pp. 112-118, 2018.

[32] Thorneycroft, J., Orr, J., Savoikar, P., & Ball, R. J., "Performance of structural concrete with recycled plastic waste as a partial replacement for sand.", *Construction and Building Materials*, vol.161, pp. 63-69, 2018.

[33] Suriyaa, M., et al., "Experimental study on strength behaviour of plastic sand bricks.", *International Journal of Scientific & Engineering Research*, vol.9, pp. 6-9, 2021.

[34] Tufa, M., et al., "Study of sand-plastic composite using optimal mixture design of experiments for best compressive strength." , *Materials Today: Proceedings*, vol.47, pp. 480-487, 2021.

[35] Li, X., T.-C. Ling, and K.H. Mo, " Functions and impacts of plastic/rubber wastes as eco-friendly aggregate in concrete– A review." , *Construction and building materials*, vol.240, pp. 117869, 2020.

[36] Mohajerani, A., et al., "Recycling waste rubber tyres in construction materials and associated environmental considerations: A review." , *Resources, Conservation and Recycling*, vol. 155, pp. 104679, 2020.

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