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The Effect of Plastic Waste integration on the Thermomechanical Properties of Mortar

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Abstract: Sustainable disposal of plastic waste is one of the most challenging missions that will save our environment from the harmful impact of plastic pollution. Hence, studies should focus on reusing plastic waste in a beneficial manner. The aim of the present research is to identify the potential of using recycled plastic in building materials with the purpose of developing eco-friendly lightweight, mortar with enhanced thermal properties. An experimental study has been carried out to investigate the effect of implementing High-density polyethylene (HDPE) with different ratios (5%, 10 %, 15% and 20%) on the thermomechanical performance of mortar. Compressive strength, bulk density and thermal conductivity were measured after 28 days to determine the suitable plastic content in the composite. The results showed the highest compressive strength results for 5 % replacement, the lowest density and thermal conductivity for the 20% replacement. This study determines that merging plastic waste in building materials is a valuable energy-efficient practice.

Keywords: **- Plastic Waste, Recycling, Construction Materials, Thermomechanical**

I. Introduction

Plastic waste disposal is one of the most challenging missions that needs innovative solutions. Poor management of plastic waste escalates plastic pollution as well as environmental deterioration. The low biodegradability of plastics increases the amounts of landfills, they break down into small pieces over the years. Besides, burning plastics causes huge damage to the environment and produces tons of CO_2 emissions (Belmokaddem, et al., 2020). Around 100 million tons of plastics are manufactured yearly in Europe (Abouhadid, et al., 2019). The United Nations stated that the world produces about 300 million tons of plastic waste yearly, however, only 9% is recycled (Lamba, et al., 2021). Another report determined that global plastic production accounted for 367 million metric tons in 2020, of which 20% only were recycled (Tiseo, 2022). Hence, studies should focus on reusing plastic waste in a beneficial manner. Selecting adequate building materials with high thermal resistance is one of the primary aspects that influence the building's thermal performance. The demand for efficient construction materials has become necessary in order to save building energy consumption. Previous studies started to focus on implementing plastic waste in the construction industry. However, these studies are still limited and need further investigation. This study serves as an opportunity to provide an alternative thermally enhanced material.

II. Research Methodology

The research methodology consists of two phases, as shown in figure (1), a literature review and an experimental study. In this study, mortar composites were developed with a partial replacement of sand with recycled HDPE. Four different mixtures were prepared and evaluated for compressive strength, unit weight and thermal conductivity on the 28th day of curing to determine the suitable plastic content in the composite.

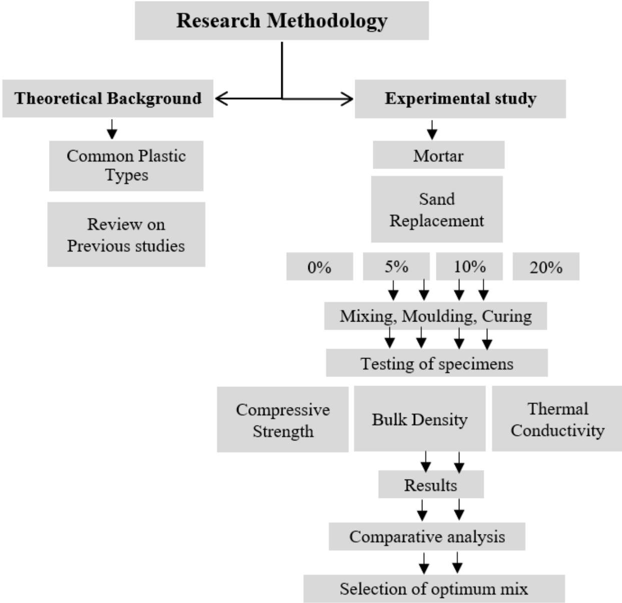

Figure 1Research Methodology Map

III. THEORETICAL BACKGROUND

Plastics are one of the primary consumed products, due to their multi applications and significant properties. The most common types are:

- Polypropylene (PP) is mostly used in storage boxes, food containers and bottles.
- High-density polyethylene (HDPE) is mostly used in the production of containers, packaging and fuel tanks.
- Low-density polyethylene (LDPE) is mostly used in cling- films, food bags.
- Polyethylene terephthalate (PET) is mostly used in water bottles and food packaging (Akindele & Alimba, 2021).

Recycling and reusing waste are one of the best methods to protect the environment and save our ecosystem. Effective selection of alternative building materials with high thermal resistance, such as plastic is an efficient sustainable solution (Sharma & Mallubhota, 2019). Plastic waste can be used as an aggregate in cementitious and asphalt mixtures, as well as a filler, insulation, and other civil practices (Awoyera & Adesina, 2020). Various Studies tested the effect of plastic waste on the mechanical properties of concrete composites and few have tested the thermal properties. The findings of these studies show a common trend of compressive strength and thermal conductivity reduction with high substitution levels. A debate has been noticed for low-level substitution depending on the mixture components ratios and the used plastic type. A study by Ramadevi and Manju revealed that replacing fine aggregates of concrete blocks with 2% of recycled polyethylene terephthalate boosted the compressive strength by 19.23% referring to the reference sample. However, a reduction is observed with 4% and 6% substitution (Ramadevi & Manju, 2012). Thakur et al. explored the partial substitution of coarse aggregates in concrete with shredded PET. To investigate the influence of coarse aggregate substitution on mechanical and thermal properties different ratios were employed; 2.5%, 5%, and 7.5%. The results of the compressive strength showed a reduction of 35%, 40% and 50% for the 2.5%, 5% and 7.5% substitution, respectively. The thermal conductivity measurements indicated a decrease of 23%, 36% and 60% for the 2.5%, 5% and7.5% substitution, respectively (Thakur, et al., 2019). An investigation by Aciu et al. on mortar tested the effect of polyvinyl chloride (PVC) on the mechanical behaviour of mortar after 25%, 50% and 100% of sand substitution. The findings showed 15% reduction in the compressive strength when 25% of the sand was replaced. However, with 50% substitution the compressive strength was reduced only by 12% and with 100% substitution by 48%. A significant reduction has been observed for thermal conductivity; 67%, 76% and 85% decrease was achieved with the 25%, 50% and 100% replacement, respectively (Aciu, et al., 2017).

IV. EXPERIMENTAL STUDY

The aim of the research experiment is to replace mortar's fine aggregate with mechanically recycled HDPE as an alternative lightweight material in order to evaluate the potential of using it in the construction field. A series of laboratory tests are performed in the British University civil lab and the Housing and Building National Research Center to examine the effect of implementing recycled HDPE on the mechanical and thermal properties of different cement mortar composites. Different ratios of volume substitution have been prepared, namely 5%, 10% and 20% and compared to the reference sample with 0% plastic.

4.1 Material properties

4.1.1 Used Materials

- Ordinary Portland cement with a fineness of 42.5 N and a specific gravity of 3.1.
- Sand with a specific gravity of 2.55.
- Mechanically recycled HDPE, with a length of 2mm and a specific gravity of 0.9.
- Water: The used w/c ratio is 0.5.

4.1.2 Materials Mixing Ratios

Four different mixes were prepared for the different substitution percentages (0, 5%, 10% and 20%), as presented in Table (1).

Table 1Materials Mixing Ratios

Mixtures	Cement (kg/m3)	Sand (kg/m3)	HDPE (kg/m3)
M0%	2.19	6.5	0
M5%	2.19	6.1	0.13
M10%	2.19	5.9	0.26
M20%	2.19	5.27	0.58

4.1.3 Test Methods

a) The ingredients were measured and mixed in a mortar mixer, as shown in figure (2).

Figure 2 Materials Preparation

b) Each mixture was poured into two steel cubical moulds with a dimension of 7.5 cm*7.5 cm for the compressive strength test and a wooden mould with a dimension of 25*12*6cm for the thermal conductivity test. The mixtures were left to dry for a whole day.

Figure 3 Casting of Mortar Mixtures

c) The moulds were immersed in a water tank for 28 days to cure.

4.2 Used Measurements instruments

The compressive strength tests were carried out with a compressive strength machine on the 28th curing day. The thermal conductivity measurement was performed with a laser comp heat flow meter fox instrument in the Housing and Building National Research Center according to ASTM C-518-2 standards, as shown in figure (4a) and (b).

Figure 4Used Measurement Instruments a) compressive strength machine b) laser comp heat flow meter fox

V. Results and Discussions

5.1 Unit Weight

The unit weight measurements reveal a reduction with the increase of plastic. M 20% showed the lowest density, while a decrease of 3% and 8% were shown for M10% and M20%, as shown in figure (5)

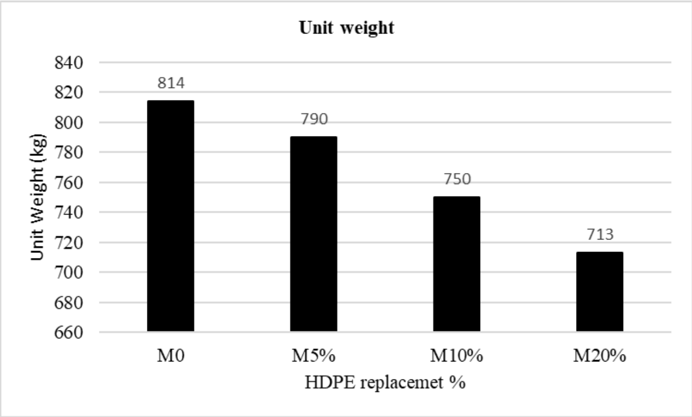

Figure 5Unit of mortar samples

Figure 6 Unit Weight measurements

5.2 The compressive strength

The results indicate an increase of the compressive strength for the M5% and M10% with a percentage of 4% and 11% respectively when compared to the refrence sample. A decrease was noticed for M20% with a percenetage of samples 5%. Figure (7) shows a the compressive strength reults and figure (8) shows the sample failure.

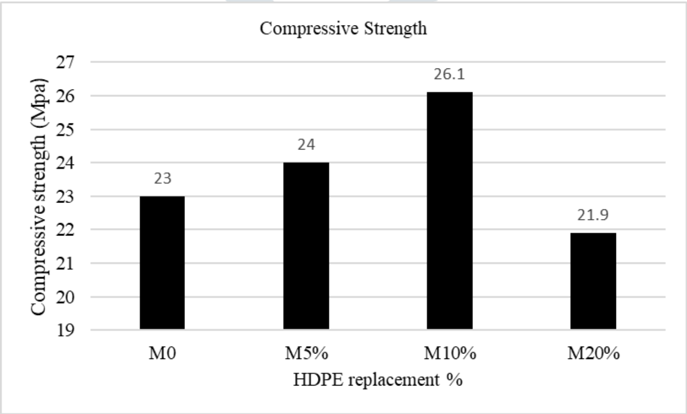

Figure 7Compressive strength of the samples

Figure 8 Compressive strength failure

5.3 Thermal Conductivity

A significant reduction has been noticed for M20%, which is 45% lower than the reference sample. M5% showed a decrease of 11% and M10 with 30%., as illustrated in figure (9).

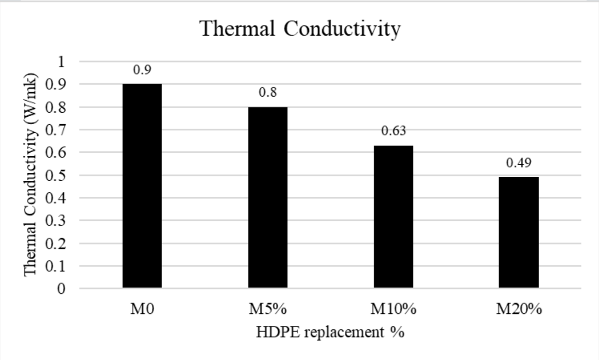

Figure 9Thermal Conductivity of samples

The findings indicate a boost in the compressive strength for low substitution level (5% & 10%). However, higher substitution affected the strength negatively. The reason behind the increase could be due to the shape of the recycled HDPE that may act as microfibers in the composite, Nevertheless, the reduction of the strength can be explained by a decrease in the adhesive strength between the smooth plastic surface and the cement paste. In addition, plastics are hydrophobic materials that reduce cement hydration.

Plastics have low water absorption ability; hence water accumulates around the plastic particles, making the composite more porous allowing air to penetrate. This reduces the unit weight and thermal conductivity as well. In addition, plastic has a low thermal conductivity value which reflects on the developed composite.

VI. Conclusion

This study revealed a promising utilization of plastic waste in the construction industry which may have multiple sustainable aspects, including protecting the environment from the negative impact of plastic waste, reducing CO_2 emissions from plastic burning and enhancing mechanical and thermal properties of developed composites. In addition, utilizing plastic waste as a substitute for natural aggregates will prevent their depletion. The reduction of the unit weight reflects the transportation costs and the construction weight. Increasing the thermal resistance of materials has a great impact on reducing energy demand for cooling and heating as it reduces the heat transfer in the building. Using plastic waste as an alternative material is an efficient method to develop more environmentally friendly and lightweight building materials.

References

Abouhadid, M., Mansour, A., Shafik, R. & EL-Rawy, O., 2019. Thermal Performance of Plastic Bottles Walls Reused in Building Construction for Waste. *International Journal of Innovative Technology and Exploring Engineering (IJITEE),* Volume 9.

Aciu, C. et al., 2017. Recycling of plastic waste materials in the composition of ecolocgical mortatars. *11th International Conference Interdisciplinarity in Engineering, INTER-ENG*, pp. 274-279.

Akindele, E. & Alimba, C., 2021. Plastic pollution threat in Africa: current status and implications for aquatic ecosystem health. *Environmental Science and Pollution Research,* Volume 28, pp. 7636-7651.

Awoyera, P. & Adesina, A., 2020. Plastic wastes to construction products: Status, limitations and future perspective. *Case Studies in Construction Materials* , Volume 12.

Belmokaddem, M., Mahi, A., Senhadji, Y. & Pekmezci, B., 2020. Mechanical and physical properties and morphology of concrete containing plastic waste as aggregate. *Construction and Building Materials,* Volume 257.

Lamba, P., Kaur, D., Raj, S. & Sorout, J., 2021. Recycling/reuse of plastic waste as construction material for sustainable development: a review. *Environmental Science and Pollution Research.*

Ramadevi, K. & Manju, R., 2012. Experimental investigation on the properties of concrete with plastic PET (bottle) fibers as fine aggregate. *Int.Journal Emerg. Technol. Adv. Eng.,* Volume 2, pp. 42-46.

Sharma, S. & Mallubhota, S., 2019. *Zero Wate: Plastic Waste Manegement Practices.* 1 ed. s.l.:CRC Press.

Thakur, G., Aslam, M. & El Ganaoui, M., 2019. Energy Efficient Building Envelope Using Recycled PET in Concrete.

Tiseo, I., 2022. *Statista.* [Online] Available at: https://www.statista.com/search/?q=plastic+production&Search=&qKat=search&newSearch=true&p=1 [Accessed 1 10 2022].