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Valorization of Plastic Waste in the Manufacture of Paving Stones in Congo Republic: The Case of Polyethylene Terephthalates (PET)

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Abstract

This study aims to contribute to the valorization of plastic waste—one of the leading contributors to environmental pollution—by proposing a practical recycling approach that utilizes waste plastics as a binder in road surfacing materials. Specifically, the research investigates the use of thermoplastic waste, with a focus on *polyethylene terephthalate* (PET), collected from the streets of Brazzaville, in the production of eco-friendly paving blocks. These blocks are composed of a sand matrix and contain 53.33% recycled plastic by weight. The study employed an experimental methodology, with water absorption rate as the primary performance indicator. The results indicate a consistently low water absorption rate across samples, regardless of variations in plastic content, suggesting a stable and durable material performance. These findings highlight the potential of recycled plastic-based paving blocks as a sustainable alternative for road surfacing, contributing to both waste reduction and infrastructure development.

Keywords: Plastic Waste Valorization; Recycled Thermoplastics; Eco-Friendly Materials; Paving Blocks; Water Absorption

INTRODUCTION

Industrial development has profoundly transformed our era, notably through the increase in goods production. This production is naturally followed by consumption, then the disposal of unusable residues, thereby generating waste. When poorly managed, this waste becomes a major source of pollution, particularly plastic materials. Indeed, plastic waste management today represents a significant environmental challenge worldwide, and more specifically in the Republic of the Congo, due to their non-biodegradable nature. According to Doublier, plastic waste does not naturally decompose and contributes to environmental degradation [1]. Fanny, for her part, notes that their lifespan can reach up to 500 years [2]. The uncontrolled accumulation of these wastes in nature poses a serious threat to both human health and ecosystems. While developed countries implement various recycling methods, this practice remains very limited in Congo. It is within this context that the present research is situated, aiming to propose an innovative solution: the use of used plastic as a binder in the manufacture of paving stones.The main objective of this work is to valorize plastic waste by transforming it into eco-friendly paving stones tailored to local needs. To do so, the collected plastics were melted, mixed with sand, and then molded to obtain the desired shape. Two analyses were conducted on the produced paving stones: the water absorption rate and dimensional shrinkage. The results obtained were then compared with those found in the existing scientific literature.

MATERIALS AND METHODS

Materials Used

The raw materials used in this study include plastic waste, specifically thermoplastics of the terephthalate type, as well as natural sand, all collected from the city of Brazzaville, Republic of the Congo. The equipment used for this work consists of a precision balance, a heating tank, a furnace, a mold, and a manual wooden stirrer.

Fig. 1: a) PET bottles b) Tank, wood, sand c) Mold

Formulation and Manufacturing of Paving Stones

Plastic-based paving stones are manufactured from used thermoplastics, notably polyethylene terephthalate (PET), mixed with sand. The production of these paving stones was carried out in five main steps.

The first step involved preparing the raw materials. In the second step, the tank actually a cooking pot was heated, and the used plastics (PET) were placed inside to melt. Then, during the third step, sand was gradually added to the molten plastic. The heating time for the plastic ranged from 25 to 30 minutes, while the mixing with the sand lasted between 5 and 10 minutes.

The fourth step involved molding: the hot mixture of plastic and sand was poured into a steel mold to shape the paving stones. Immediately after molding, the paving stones were still hot and fragile.

The fifth step was demolding, carefully performed after the interior surface of the mold had been previously oiled to facilitate the process, which took about five minutes.

Finally, the finishing phase consisted of allowing the paving stones to cool for approximately one hour, then inspecting them to remove any excess material or irregularities. Paving stones that did not meet the quality criteria were discarded.

Fig. 2: a) Molten plastic b) Molded paving stone c) Demolding d) Finished paving stone

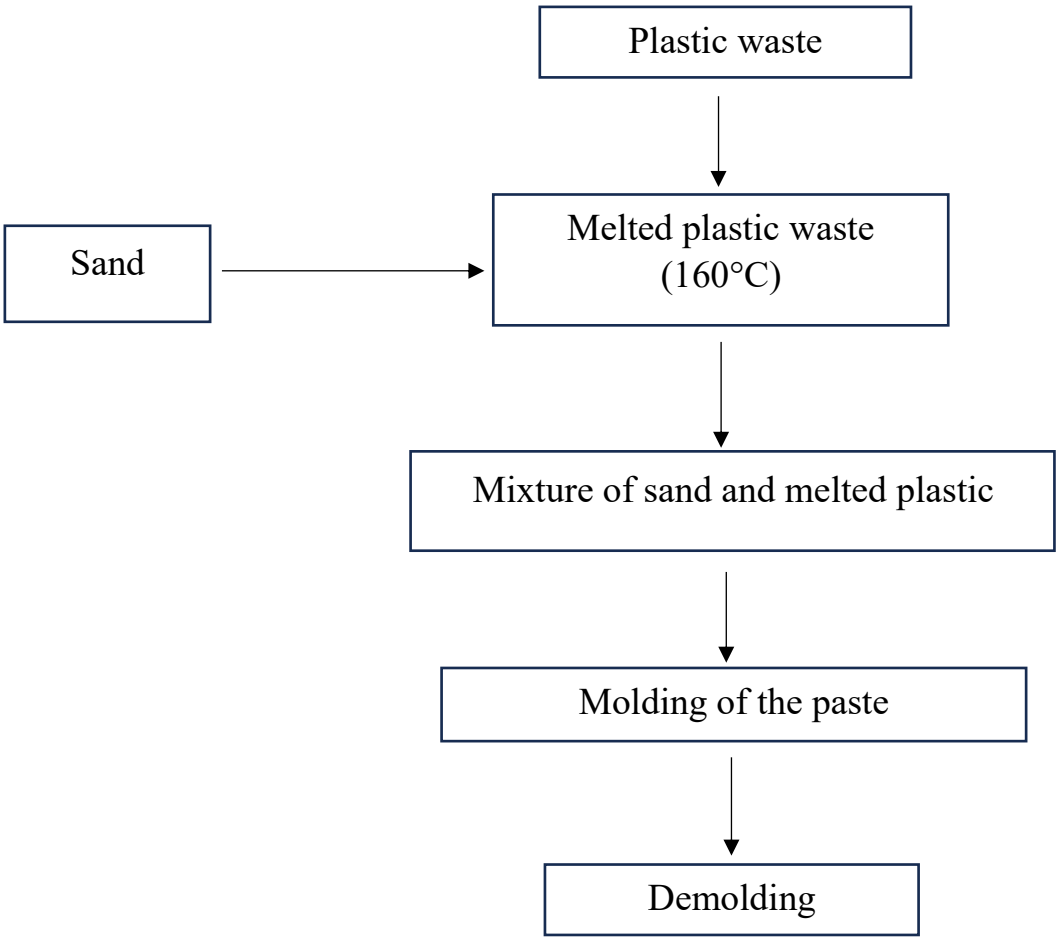

Figure 3: Schematic diagram of the paving stone manufacturing process.

Quality Tests

Water Absorption Rate

This test was carried out in the Chemistry Laboratory of the African School of Development in Brazzaville (EAD-BZV). It aims to determine the behavior of the paving stone when exposed to rain and other physical agents. The absorption by immersion is expressed as a percentage and is calculated using the following formula:

$$\mathbf{Abs = (M_h - Ms) / Ms \times 100} \quad (1)$$

Where: M_h is the wet mass after immersion, and M_s is the dry mass of the sample.

Shrinkage Tests

Shrinkage refers to the reduction in volume of the paving stone after cooling, caused by the contraction of the material's internal structure. This phenomenon is mainly due to the shrinkage of the plastic during the cooling phase. It is measured using the following formula:

$$\mathbf{R= (V_{moul} -V_{pavé})/ V_{moul}} \quad (2)$$

Where: V_{moul} is the volume of the mixture poured into the mold, and $V_{pavé}$ is the volume of the finished paving stone.

RESULTS

The tests conducted on the paving stones focused solely on shrinkage and water absorption rate. The results obtained were compared with those from the study by Cyrille Prosper Ndepete et al. (2022), which involved paving stones containing more than 50% plastic. These data are presented in Table 1.

Table 1: Characteristics of the paving stones compared with those reported in the literature (Cyrille Prosper Ndepete and al., 2022).

Parameter	**Value Found in This Study**	**Value found by Cyrille P.N. et al.**	**Unit**
Taux d'absorption d'eau	1,25	9.46 -1.2	%
Le retrait	10.8	0-10	%

DISCUSSION

The shrinkage observed in these materials results from the reduction in the volume of the paver after cooling, caused by the collapse of its internal structure. Mariam (2011) believes that this phenomenon is mainly due to the contraction of the plastic during the cooling process. Cyrille P.N. et al. (2022) also suggest that the significant shrinkage can be attributed to the high proportion of plastic in the composition of the pavers. Furthermore,

the studies by Mariam (2011) and Ledru (2009) show that the addition of plastic waste who are impermeable materials that act as binders significantly reduces the water absorption rate. According to civil engineering standards, a material is considered to be of good quality when its water absorption rate does not exceed 6% by mass. Based on this criterion, it appears that with a plastic content of 50% or more, the pavers meet the required standards and can be considered to have good resistance to water absorption.

CONCLUSION

This study falls within the current context of plastic waste management, which represents a major environmental challenge. Its aim was twofold: first, to develop a method for repurposing plastic waste by using it as a binder in a sand-based matrix; and second, to produce pavers and analyze their physical properties.

The key findings of this work are as follows:

- The composition of the plastic-based concrete demonstrates good workability, making it easy to handle and apply in the field;
- The measured water absorption rate is 1.25%, which is well within the limits set by civil engineering standards, where a maximum of 6% is recommended for quality materials;
- A significant shrinkage was observed when the plastic content exceeded 50%, which is attributed to the considerable contraction of plastic during the cooling phase.

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