STUDY OF LITERATURE REVIEW ON THE USE OF PLASTIC IN CONCRETE MIXES

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Plastic waste poses significant environmental challenges due to its widespread use and long-lasting nature. In the search for sustainable construction solutions, this study presents a systematic review of international research spanning two decades on the integration of recycled plastics into concrete mixtures, either as aggregates or fibers. Applying strict inclusion and exclusion criteria, 97 of the 187 articles initially identified were analyzed in depth. Key findings indicate that the introduction of plastics can influence essential concrete properties such as density, compressive strength and thermal conductivity. The effectiveness of plastic integration largely depends on factors such as the type, size and shape of the plastic used. In particular, the research reveals that the use of plastic fibers can improve crack resistance, influenced by the size and type of fiber. Depending on the application, an optimal plastic replacement percentage is usually between 10% and 20%. This review highlights the potential of recycled plastics to increase the properties of concrete, offering an environmentally friendly route to reduce plastic waste and promote sustainable construction.

Keywords: Construction materials recycling, Sustainable materials, Plastic waste, Environment.

1 INTRODUCTION

Numerous studies have demonstrated that various types of plastics, each possessing distinct characteristics, have been incorporated into concrete. Generally, when used at an optimal replacement percentage, concrete can exhibit satisfactory performance. It is critical to consider the morphology, specifically the shape, size, and surface area, of the incorporated plastic, whether introduced as aggregate or fiber. Based on this understanding, it is evident that concrete facilitates the proper recycling of plastics without diminishing their structural capabilities or altering their intended function. For example, when PET plastics are used, it has been observed that the density of concrete decreases. Moreover, when a replacement percentage of up to 10% is used, both the compressive strength and the elastic modulus increase (Hossain et al. 2016, Sambhaji 2016). Additionally, by incorporating 4% by weight of PET, properties such as fracture toughness and energy show a marked improvement (Asdollah-Tabar et al. 2021). With this in mind, concrete presents a viable avenue to properly recycle plastics without compromising its structural effectiveness or intended application. This article presents a meta-analysis of research focused on concrete properties when plastic is incorporated either as a partial replacement for natural aggregate or as fiber. The advantages and challenges of this approach are discussed, and estimates for optimal replacement percentages are provided. Subsequent sections examine the environmental consequences of plastics, different recycling methods, and the feasibility of using recycled plastics in concrete as a sustainable recycling solution.
2 BACKGROUND

Due to its versatility and durability, plastic is currently an essential material and widely used in various sectors worldwide. However, this same durability becomes a challenge when considering its limited degradability, which has led researchers to express significant concerns about its environmental impact. Given this, numerous studies have been developed that seek to incorporate plastic waste into the construction industry, specifically within concrete mixtures.

Concrete is made from Portland cement, aggregates and water. Its key attributes are compression resistance, durability, fire and impact resistance, insulation properties, porosity and density. Denser concretes typically have greater longevity and performance can be optimized by adjusting aggregate and water content. Adding plastic to concrete, as aggregate or fiber, offers an innovation in green construction and a solution for plastic waste management. It is important to mention that studies have revealed that the integration of specific plastics as aggregates can affect the mechanical properties of the material (Zéhil and Assaad 2019), although these changes generally remain within acceptable limits. When plastics are used as fibers, there are often performance improvements such as a delay in crack propagation and a reduction in crack width (Hama 2021). Generally, the consensus among researchers is that these particular variants are suitable for applications where high strength is not imperative.

3 METHODOLOGY

This article provides an extensive review of the research on adding recycled plastics to concrete. Using various combinations of keywords, 187 articles were obtained from 2003 to 2023. After filtering by relevance and methodology, 97 articles remained. These were organized into a database detailing the title of each article, year of publication, authors, institution of the lead author, country of origin of the research, and description of the content. The articles were then classified according to the type of plastic studied and divided into subcategories. During the selection process, the articles were filtered according to established criteria. The exclusions covered out-of-time articles, books, reviews and studies that use plastics or chemically pretreated materials other than standard waste plastics and concrete components. Inclusions focused on articles with detailed conclusions, extensive laboratory testing, and clarity on the types of plastic used. This meta-analysis aimed to exhaustively review the selected articles and highlighting their summaries and conclusions, to produce a concise and complete document.

4 RESULTS, DISCUSSION AND RESEARCH AGENDA

The reviewed documents were classified into 12 groups based on the type of plastic included in the concrete mix. Within each category, subclassifications were made according to the most prominently mentioned properties. A summary table of the results is provided below, followed by a more detailed explanation of the findings.

Regarding the MPW fiber in concrete, a correlation was observed: as workability decreases, the viscosity of the matrix increases and the consistency of the fresh mix decreases. With a substitution of up to 1% the properties of the concrete improve or remain constant, specifically, the appearance and propagation of cracks was reduced (Bhogayata and Arora 2017). PP fibers are noted for their effectiveness in mitigating shrinkage cracking, the effectiveness of which depends on the length and type of fiber. Longer fibers with smaller diameters excel in reducing both the extent and severity of cracks (Banthia and Gupta 2006). In the context of PET fibers, a combination of fine and coarse materials increases fracture toughness, but replacing coarse aggregates produces superior results (Asdollah-Tabar et al. 2021).
Table 1. Properties of concrete by plastic fiber/aggregate type.

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<tr>
<th>Plastic type</th>
<th>Brief summary</th>
<th>References</th>
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<tbody>
<tr>
<td>Polyethylene (PE) plastic</td>
<td>PE aggregates decrease erosion in specific solutions and improves its thermal insulation. PE fibers improve tensile strength and elasticity, maintain density and decrease absorption and porosity.</td>
<td>(Akkouri et al. 2022, Gopi et al. 2020, Sule et al. 2017, Wu et al. 2022)</td>
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<td>Cross-linked polyethylene (XLPE) plastic</td>
<td>8-16mm XLPE aggregates decrease strength, porosity and water absorption, but adjusting the water/cement ratio can solve the loss of strength.</td>
<td>(Zéhil and Assaad 2019)</td>
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<td>Low-density polyethylene (LDPE) plastic</td>
<td>Using LDPE aggregates alone may decrease certain strengths, but including LDPE fibers may actually increase them.</td>
<td>(Agyeman et al. 2019)</td>
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<tr>
<td>High-density polyethylene (HDPE) plastic</td>
<td>In reinforced concrete, HDPE aggregates improve strength and reduce early cracking, but in certain mixes they can reduce strength. HDPE fibers increase tensile strength while decreasing water absorption and density, probably due to higher air content.</td>
<td>(Adnan and Dawood 2021, Belmokaddem et al. 2020, Hama 2021)</td>
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<tr>
<td>Polyvinyl Chloride (PVC) plastic</td>
<td>Replacing coarse aggregate with PVC is ideal for tunnel concrete. Replacing fine aggregate with PVC improves strength, lightens concrete, and improves its overall durability.</td>
<td>(Kamal et al. 2021, Ullah et al. 2022)</td>
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<td>E-plastics</td>
<td>In M25 concrete, E-plastic aggregates maintain properties with a good water-cement ratio. For M20, the substitution of fine aggregate increases abrasion resistance but decreases compression and tensile strength. It also improves the climatic adaptability of concrete.</td>
<td>(Ahmad et al. 2022, Hamsavathi et al. 2020, Ullah et al. 2022)</td>
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<td>Polypropylene (PP) plastic</td>
<td>PP aggregates improve the strength and load capacity of concrete, especially in high-performance concrete. PP fibers minimize microcracks and increase tensile strength. The use of PP in fine aggregates effectively reduce crack size or counteract shrinkage cracks.</td>
<td>(Banthia and Gupta 2006, Shen et al. 2020, Yang et al. 2015)</td>
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<tr>
<td>Polyolefin (PWA) plastic</td>
<td>PWA aggregates decrease the density and mechanical strength of concrete but improve its ductility. PWA fibers increase energy absorption after cracking.</td>
<td>(Colangelo et al. 2016, Signorini et al. 2022)</td>
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<td>Thermosetting plastic</td>
<td>Using this as an aggregate can significantly improve the strength of concrete.</td>
<td>(Dweik et al. 2008)</td>
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<tr>
<td>Mix of plastic in the blend</td>
<td>Minimal replacement slightly reduces the strength of the concrete, but is not suitable for high-strength applications. PET, HDPE and PP improve impact resistance, reduce energy use by 40% compared to standard concrete, and PET optimizes absorption and adhesion to cement.</td>
<td>(Abu-Saleem et al. 2021, Babafemi et al. 2022, Hama and Hilal 2019)</td>
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<tr>
<td>Polyethylene terephthalate (PET) plastic</td>
<td>PET aggregates improve tension but reduces compression. PET fibers increase flexural strength and the consistency of the mixture depends on the water-cement ratio. In general, PET increases the fracture resistance of concrete.</td>
<td>(Anandan and Alsubih 2021, Borg et al. 2016, Frigione 2010, Khatab et al. 2019, Sambhaji 2016)</td>
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<tr>
<td>Metalized plastic</td>
<td>MPW fibers reduce crack initiation and propagation and also improve the conformability of concrete to significant stresses.</td>
<td>(Bhogayata and Arora 2017)</td>
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The introduction of plastic fibers also makes an improvement in slump as well as a reduction in slump loss (Yang et al. 2015). Some studies highlighted that workability is influenced by the shape of the plastic particle. For example, angular-shaped particle decreases settlement, while round-shaped particles improve workability. This behavior can be attributed to the reduction of friction between the concrete components (Hama and Hilal 2019). Future studies should examine how different plastics influence cohesion, consistency, setting time, bleeding, and other factors in concrete mixes, since the quality of the initial mix often dictates the quality of the final product.

Regarding the thermal properties of concrete, current research highlights the exceptional thermal capacity of plastics. Research simulating buildings under various temperature conditions revealed that those constructed with plastic aggregates consume less energy for heating and cooling due to the material's improved thermal regulation capabilities (Elzafraney et al. 2005). Future research can explore how different proportions of plastic affect the energy efficiency of a structure, considering aspects such as thermal conductivity and heat transfer capacity. The influence of the shape and type of plastic particles on these properties also deserves investigation.

5 CONCLUSION
The integration of recycled plastics into concrete has promising potential both for waste management and for improving the properties of construction materials. This review meticulously compiled and analyzed several studies and found that specific plastics, when optimally integrated, can strengthen the mechanical properties of concrete without detracting from its core functionality. Although various plastics, from PET to PE, manifest different influences on concrete properties, their inclusion has been shown to offer benefits such as increased ductility, crack reduction, better thermal regulation and even green construction practices. The shape, size and texture of the aggregate or plastic fiber critically determine these benefits, underscoring the need for precision and careful selection in future applications. As the world faces the challenges of plastic waste, merging this waste with the construction industry appears to offer a double advantage: an innovative approach to waste management and a step towards a sustainable future in construction.

References


