Textile Waste in Civil Construction: A Systematic Review of Applications and Benefits

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This work is a systematic review based on the PRISMA protocol, used to evaluate the use of polymeric materials with textile waste in civil construction. The research was conducted using a search strategy across three databases (Web of Science, Scopus, and ScienceDirect), with a focus on studies published within the last 5 years. The keywords used in these searches were: "Composites AND Architecture AND textile waste." Subsequently, screening and exclusion criteria were established and applied to the group of articles to organize and select the most relevant ones according to the theme. At the end of the analysis of the selected articles, a comparison was made regarding the uses and trends of recycled textile material as a basis for new technologies aimed at greater sustainability in civil construction.
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Tons of polymeric material waste are produced daily worldwide [1]. The production, consumption, and disposal cycle of these materials occurs at a pace that is significantly exceeding current management capacity, often surpassing the recycling limits of conventional methods, both in technological terms and within the scope of environmental and economic policies.

This situation highlights the need for alternative approaches to enable their reuse, given that certain polymers are predominantly intended for single-use applications [1].

In addition to this issue, the textile industry contributes substantially to environmental problems through waste generations. It produces, on average, 5.8 million tons of waste annually, of which approximately 75% is sent to landfills or incinerated [2].

The main textile waste streams originate from wool, cotton, and synthetic fibers, with polymer-derived materials such as acrylic fabrics often present in their composition, even though garments, fabrics, and yarns are among the most common types of waste [1,2].

The reuse of discarded polymeric and textile materials has already been incorporated into the civil construction sector [1, 2], with sustainability increasingly becoming a prevailing trend in the field of architecture [3]. For instance, during important and influential architectural events such as CASACOR Bahia Edition [4] in 2024, the architectural firm Andrade & Schimmelpfeng Arquitetos, in partnership with the store Plasticaria, presented a decorative wall panel produced using recycled plastic materials, designed as a high-value aesthetic product. These materials were arranged in colorful blocks, creating a textured surface, alongside numerous other examples of sustainable material applications [4].

In this context, the present review article, based on a systematic literature analysis using the PRISMA methodology, aims to investigate the applications of polymer composites formulated with textile waste, with an emphasis on the integration between technological innovation and sustainability.

The objective is to understand how such materials have been utilized in innovations in recent years within the architectural and civil construction field, particularly in sectors requiring functional and safe solutions.

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Materials and Methods

The systematic review methodology is essential for gathering and organizing previous studies in a targeted manner, aiming to address relevant questions for a specific research focus, ensuring that the selected works are genuinely useful to the final understanding of the subject. Based on these procedures, inclusion and exclusion criteria are established to guide future research on the topic.

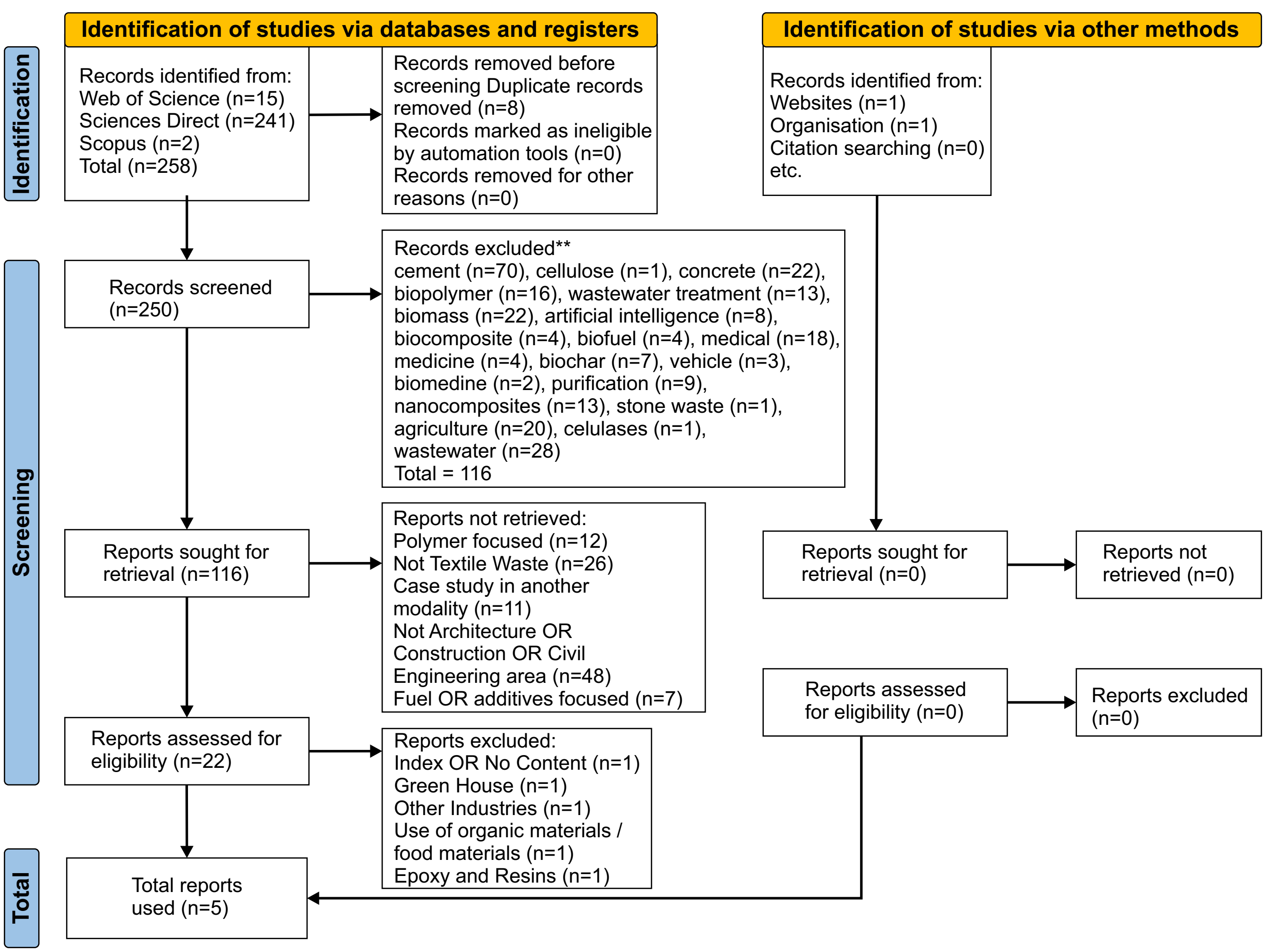
In this article, a systematic review was conducted following the guidelines of the PRISMA protocol (Preferred Reporting Items for Systematic Meta-Analyses), focusing on identifying publications that address the sustainable use of textile waste in composites applied to architecture.

To this end, the Scopus, ScienceDirect, and Web of Science databases were consulted, applying the pre-defined inclusion and exclusion criteria, such as a maximum publication date of five years. The primary search expression used was: (Composites AND Architecture AND "Textile Waste") (Figure 1).

Results and Discussion

Among the studies collected and analyzed, the majority identified applications in the civil construction sector, primarily directed toward the use of discarded textile and polymer waste for thermal insulation purposes, as well as for sound absorption purposes. Publications in journals such as the Journal of Cleaner Production and Waste

Figure 1. PRISMA protocol.



Management demonstrate that, due to their thermal insulation capacity, such waste can be revalorized for this purpose, thereby contributing to the energy efficiency of buildings while mitigating environmental impacts.

The use of textile waste in insulating panels [2] exhibited satisfactory thermal performance as well as technical feasibility when compared to conventional materials. In an experiment, Briga-Sá and colleagues [2] constructed two types of wall systems: one composed of two ceramic masonry walls and the other of concrete masonry, both finished with cement mortar.

An open cavity was left between the walls and subsequently filled with two types of completely dry waste: WFW (woven fabric waste) and WFS (woven fabric subwaste), followed by sealing with polyurethane foam and extruded polystyrene (XPS). A double-wall configuration without any filling was also considered.

Three systems were thus analyzed: a double wall with WFW, a double wall with WFS, and a double wall with an empty air gap. During monitoring, data were collected on heat flux, surface temperature, and ambient temperature, using a domestic heater to maintain a controlled average indoor temperature condition to ensure the reliability of the analyzed results.

The results showed that the thermal resistance of the double-wall system increased substantially, though the degree of improvement differed between WFW and WFS. Compared to the unfilled wall, the WFW system demonstrated a 56% increase in thermal resistance, while the WFS system showed a 30% increase.

The higher efficiency of WFW is attributed to its thermal conductivity being comparable to that of traditional insulation materials, such as EPS and XPS, whereas WFS exhibits a performance more similar to materials like expanded clay and perlite.

In a similar vein, the reuse of disposable face masks [5] made of polypropylene (PP) was investigated by Dehdashti et al. [5] as a sustainable alternative. The process involved manual removal of metallic and elastic components, followed by separation of the melt-blown (MB) and spunbond (SB) PP layers.

These were then fragmented and aligned using a Garnet machine, with precise adjustments to achieve a specific degree of fiber opening for the intended outcome. This process produced new polymeric fibers that were subsequently bonded with a natural adhesive.

Fabrics produced from MB microfibers—discontinuous and randomly oriented—resulted in irregular porous structures, whereas SB fabrics consisted of continuous, thicker filaments, more regularly and compactly arranged, producing a smoother and less porous surface.

Dehdashti and colleagues [5] considered thickness, density, and mixing ratios of SB (thicker fibers) and MB (finer fibers) fabrics as independent variables, given their influence on the sound absorption properties of fibrous panels. The results confirmed that fabrics combining SB and MB fibers possess favorable characteristics for both thermal insulation and sound absorption, partly due to the adhesive not occluding the pores of the textile material.

Similarly, another study by Dongchan Jin and colleagues [6] evaluated the application of post- consumer textile waste for pipe insulation, deliberately avoiding any pre-sorting process to reflect realistic usage conditions in which natural and synthetic fibers are mixed. This approach also accounted for the cost implications of separation. Only decontamination and shredding were performed, producing fibrous strands for thermal insulation.

The fibers were then molded via thermal pressing, using the partial melting of polyester for adhesion, into two types of specimens: flat panels and cylindrical sleeves for pipe insulation. The sleeves were internally coated with aluminum to prevent moisture ingress. These cylindrical specimens were referred to as recycled insulation (RI), general insulation (GI, a commercially available generic thermal insulation material), and Ref (reference, i.e., pipe without insulation). RI panels were also produced for mechanical testing.

Tests revealed that RI outperformed conventional insulation materials such as glass, wool, and mineral wool in thermal performance, even with increased density. Due to its mixed porosity, higher air permeability, and reduced heat transfer, the material also exhibited superior resistance to water vapor penetration—a property that makes it suitable for environments subjected to condensation, thus extending its application potential beyond pipe insulation.

Additional experiments included moisture absorption and desorption tests as well as thermal conductivity analysis. The findings indicated that RI exhibited greater resistance to water vapor transmission than traditional fibrous materials. This characteristic is critical as a moisture barrier, particularly in applications where significant temperature differences between indoor and outdoor environments may lead to condensation.

Consequently, the material also proves suitable for alternative uses beyond problematic pipe insulation where moisture accumulation occurs [6].

Therefore, considering its thermal insulation and waterproofing properties, the application proposed by Dongchan Jin et al. [6] for thermal pipe insulation also demonstrates exceptional potential as a sustainable construction material.

Conclusion

The excessive consumption of single-use polymeric materials, such as expanded polystyrene (EPS), occurs at a rate far exceeding the capacity for their degradation in the natural environment [1]. Such waste causes severe environmental problems, with increasingly catastrophic consequences for life on Earth.

Similarly, the excessive use of materials with limited reuse potential in the textile industry generates another type of waste, discarded in quantities and at a frequency that surpasses the natural degradation capacity of the environment [7].

Given this environmental challenge, there is a constant need for the development of new alternative methods to minimize, replace, or dilute the use of such materials. The pursuit of sustainability has become increasingly important over the years, leading to the creation of these new construction methods, alternative materials, and emerging trends that are significant for the progress of the academic community.

In this article, research in the fields of sustainability and civil construction was reviewed, focusing on the use of repurposed polymeric materials and textile waste. The findings from these studies indicate that this is a rapidly evolving area, often centered on addressing challenges related to thermal and acoustic comfort and their various applications. The analyzed studies demonstrate that post- consumer textile waste and polymeric materials can offer technical performance comparable to, and in some cases superior to, conventional thermal insulators such as EPS, XPS, glass wool, and mineral wool. Additionally, they contribute to energy efficiency and the improvement of thermal and acoustic comfort in buildings.

The proven technical feasibility in multiple studies, combined with the potential for reducing environmental impacts, shows that the reuse of such waste not only fosters a circular economy but also expands opportunities for innovation in sustainable building systems.

However, large-scale adoption still depends on advances in process standardization, optimization of mechanical and thermal properties, and overcoming economic and regulatory barriers.

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