Polymeric Walls: Technologies and Fire Safety in Non-Conventional Building Systems

Moisés Silva[1*], Ryan Carvalho[1], Mariana Novaes[1], Ariane Rubin[1], Adriano Puglia[1], Juliana Guerreiro[1], Luciano Pisanu[1], João Jesus[1]
[1]SENAI CIMATEC University Center; Salvador, Bahia, Brazil

This article analyzes the use of plastic materials in civil construction, especially in wall sealing systems. Plastics offer easy assembly, quick execution, reduced physical effort, and recyclable and durable, thus reducing environmental impacts. The incorporation of flame-retardant treatments is necessary to meet fire safety criteria. Materials such as vermiculite, ceramic fiber, and fiberglass show heat resistance, contributing to safety in fire situations. Despite the challenges, using plastics in civil construction is promising, allowing the replacement of traditional materials and providing greater agility in construction works.
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In order to meet the growing demands of society, several materials have been developed or modified, aiming to improve performance and/or expand their applications. Construction materials play a significant role in this context, emphasizing polymeric materials like plastics.

Plastic materials are used in civil construction, mainly as reinforcement or bonding material (screens, blankets, and tapes), conduits for installations (electrical conduits and pipes), protection (covering for metal wires), and, more recently, used as part of wall systems, providing some advantages over traditional masonry models. These advantages include easily assembled and quickly executed construction modules, reduced physical effort required by labor, excellent finishing, and being recyclable and durable, contributing to minimizing environmental impacts [1,2].

Plastics can adapt to dry construction systems, which, given the aggravated environmental challenges in recent decades, also present ecological advantages. Dry construction technologies lead to lower energy and water consumption, reduce material waste, and enable the use of recycled materials [1,2]. Additionally, sustainability certification entities, such as the US Green Building Council, responsible for LEED certification, support the adoption of recycled plastic materials in construction systems.

Furthermore, incorporating plastic in civil construction increases the material's lifespan, especially when using non-biodegradable materials in short-term activities, such as disposable bottles, which increase post-consumer waste, whose degradation occurs exceptionally slowly. The production of solid waste in Brazil has exceeded 78 million tons. Among these, 14% corresponds to plastic waste, positioning the country as one of the largest global producers of this type of residue [3]. Interestingly, the packaging industry stands out as the main responsible for transforming virgin plastic into products, despite contributing to a shorter lifespan of these items (Table 1).

Another relevant factor consists of the numerous cases of natural disasters caused by climate change, which have been affecting Brazil and the world, making it necessary to adopt construction techniques that are safe, comfortable, and can be built in a short period in order to shelter the victims permanently or in emergencies. A tragic example was the flood in Santa Catarina 2008, which affected 60 cities and 1.5 million people and left 80 thousand homeless, demonstrating the unpredictability of these events and post-disaster control measures [4].

Polymeric structures enable the production of parts with complex geometries thanks to

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Address for correspondence: Moisés Silva. Av. Orlando Gomes, No. 1845 - Piatã, Salvador -Bahia, Brazil. Zipcode: 41650-010. E-mail:moises.silva@fieb.org.br.

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Table 1. Plastic production and recycling in the world

Country	Total plastic waste	Total waste incinerated	Total waste recycled	Recycling VS plastic production
United States	70,782,577	9,060,170	24,490,772	34.60%
China	54,740,659	11,988,226	12,000,331	21.92%
India	19,311,663	14,544	1,105,677	5.73%
Brazil	11,355,220	0	145,043	1.28%
Indonesia	9,885,081	0	362,070	3.66%
Russia	8,949,132	0	320,088	3.58%

their rheological and processing properties. Additionally, they offer hardness and impact resistance, allowing them to meet the requirements of sealing systems. However, other essential characteristics are necessary in polymeric structures, such as low flammability, high resistance to ultraviolet (UV) rays, and thermal and acoustic insulation, to achieve such a purpose.

Therefore, considering the mentioned demands, this article aims to evaluate aspects encompassing the science of plastic materials, considering the requirements established by NBR 15575 [5] for housing wall systems in fire situations.

Materials and Methods

An advanced investigation was conducted using available academic and technical publications to understand the progress and obstacles related to the production and application of polymeric structure systems, including sealing, partition, panel, or structural wall. Keywords, combined and isolated, were used as the selection criteria for the studies in the Scopus database [6], aiming to obtain a comprehensive overview of the information totaling 133 documents. The utilized words are described below.

- Sandwich panels – painéis sanduíche;
- Panels – painéis;
- Walls – paredes;
- Partitions – divisórias;
- Sandwich panels – painéis sanduíche;
- Polymers – polímeros;.
- Modular construction – construção modular;
- Composite – compósitos

The Bibliometrix tool [7] was used to enable the analysis of information from the selected documents, allowing us to understand the importance of the subject regarding the challenges of civil construction, the predominant study approaches, and the frequently employed terms.

Relevance of the Topic to the Scientific Scenario

Figure 1 presents the frequent words associated with the subject. Thus, one can observe the predominance of sandwich-type enclosures, in which polymers are used for the panels and the filling materials. Another approach used is the implementation of honeycomb geometry within the sandwich walls, significantly increasing the system's rigidity and saving on filling materials. Fibers are also associated with using polymers in enclosures to enhance their mechanical characteristics.

Figure 2 shows the terms associated with the previously mentioned keywords. The terms in the first quadrant have higher relevance, indicating the interest of technological and scientific institutions in this subject. The terms "concrete," "foam," "precast," and "glass" are related to the materials used in association with the polymer to compensate for the limitations of its physical

Figure 1. World cloud about the theme.

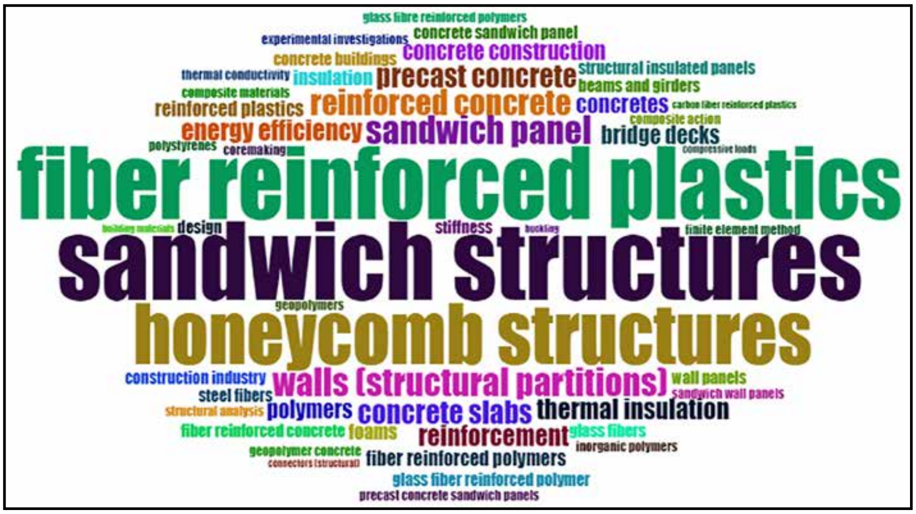
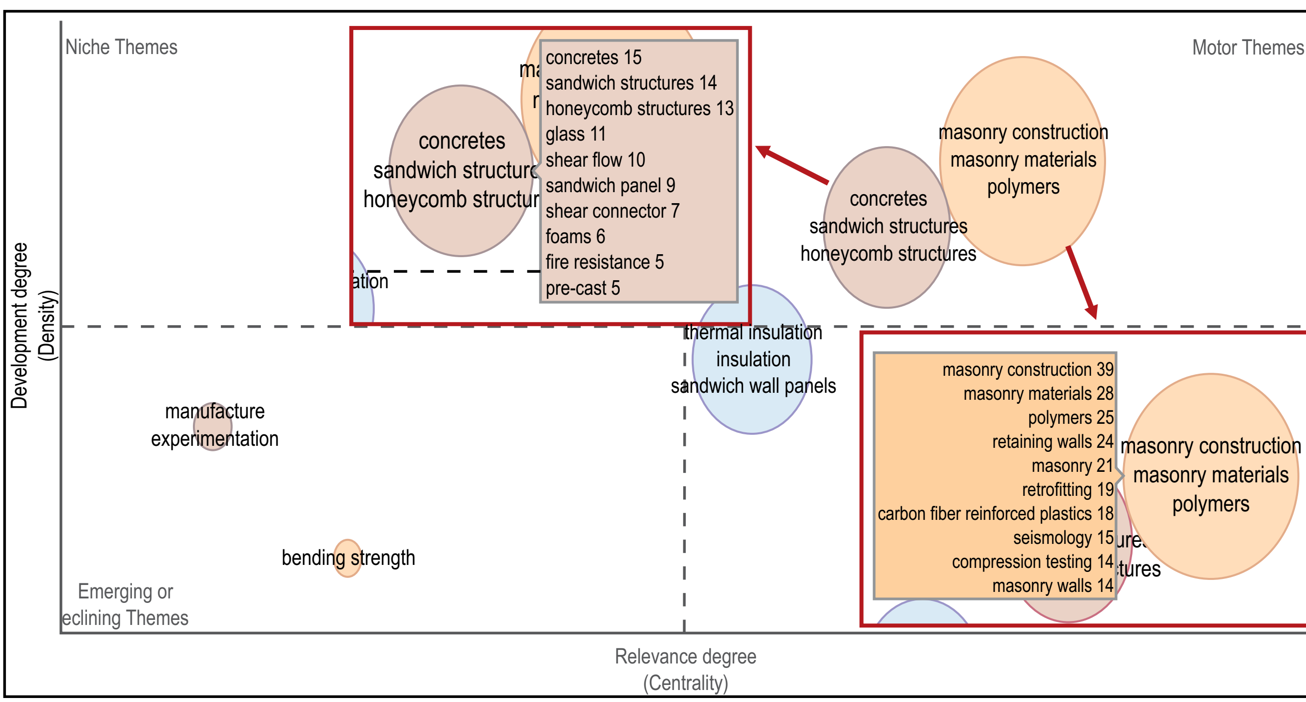


Figure 2. Study density and relevance topics.



and chemical properties, especially regarding its fire performance. The other terms demonstrate the primary applicability of polymers, used as raw materials for specific components, such as connectors for sandwich panels. In the fourth quadrant, relevant terms are found; however, they still have a low volume of academic production, showing the gap relevant to the topic. Polymer materials are currently being used in retrofit works and seismic-resistant to wall systems.

Results and Discussion

Namely, regarding the behavior of polymers under fire, there is a significant challenge related to their compatibility with wall systems, as plastic materials are easy to burn. When heated, they form combustible substances, which generate molten droplets in the presence of oxygen and an ignition source. During combustion, polymers release a considerable amount of heat (highly exothermic reaction) and toxic smoke (CO, CO_2), limiting their areas of application [8]. However, concerning the current regulations in Brazil, they establish that wall systems must meet the criteria below, regardless of the material, when exposed to fire situations:

1. Make it difficult for the fire to start
2. Facilitating the user's escape
3. Reduce widespread inflammation
4. Make it difficult for the fire to spread.

Most materials used in civil construction are typically thermoplastics; therefore, when subjected to a heat source, they soften, become fluid, and then flow. Such a situation compromises their use in wall systems, as plastics do not maintain tightness, insulation, and structural capacity in the face of fire situations, failing to meet requirements 1 and 2. Thus, the association of the material with other efficient flame-retardant treatments is being discussed to make its application viable. Generalized ignition (3) and fire propagation (4) are avoided through flame-retardant additives incorporated into the polymeric matrix; however, this situation is associated with the high cost of raw material production.

The technical tests described by NBR 15575-4 [5] must be carried out to verify compliance with fire safety requirements (Table 2).

Furthermore, for implementing polymer wall systems in Brazil, it is necessary to comply with the recommendations of the National System of Technical Evaluations for Innovative Products and Conventional Systems (SiNAT) through its guidelines. These documents expand on the guidelines provided by NBR 15575 [3]. A Technical Evaluation Document (DATec) is issued in cases of innovations to demonstrate compliance with the guidelines for buildings. This document is valid for 2 years, and it is the responsibility of the constructor to seek its renewal. Table 3 presents all valid DATecs that use polymeric materials as construction elements in sealings.

To comply with the presented regulations, wall systems can use some tactics to enhance their effectiveness in a fire, highlighting fire-retardant coatings and filling elements in sandwich panels, such as fibers, clay materials, and expanding solutions. There is also the possibility of using fire-resistant paints, such as intumescent paints, which serve as an alternative to preventing the generation and spread of flames in plastic materials. These paints can be applied directly to the material's surface, making their use even more practical.

Investigating additional alternatives to safeguard the polymer in fire situations, the following materials renowned for their remarkable heat resistance are revealed:

1.Vermiculite - material calcined at 900ºC to form expanded vermiculite, which, due to the release

Table 2. Normative requirements and their respective technical tests.

Test method	Requirement	Standard
FIRE SAFETY		
Evaluation of the reaction to fire of the internal face of vertical fencing systems	8.2	NBR 9442
Evaluation of the reaction to fire of the external face of the vertical fences that make up the facade	8.3	NBR 9442
Fire resistance of structural and subdivision elements	8.4	NBR 14432 and NBR 5628

Table 3. Normative requirements and their technical tests.

Datec	Description	Guideline SINAT	Evaluated Requirements
Nº 005-C	The system idealized by HOBRAZIL consists of solid walls molded on-site using lightweight concrete with polymer and fiberglass reinforcement protected with polyester for detached and semi-detached houses, single-story and two-story.	Nº 001	Walls are composed of non-combustible materials.
			Appropriate characteristics in terms of smoke development.
			Fire resistance (tightness, thermal insulation, and structural stability) of the walls for 30 minutes.
Nº 017-A	Constructive System developed by Global, in partnership with other companies, consisting of walls made of PVC panels filled with concrete.	Nº 004	Fire reaction of PVC profiles.
			Fire resistance of the walls for 30 minutes.
Nº 038	Modular construction system "Fischer Houses," composed of prefabricated panels made of thin sheets linked by a rigid thermal insulating core.	Nº 010	Reaction to fire of wall panels.
			Fire resistance of the walls for 30 minutes for the panels installed in the kitchen area.

of water between its layers, causes expansion, increasing the original particle size by up to 30 times. The expanded vermiculite particles are lightweight and porous, with low thermal conductivity and a small capacity for noise propagation [9].

2. Ceramic Fiber - obtained from the electrofusion of silica and alumina at high temperatures (approximately 2000°C). With this fiber, different refractory components, such as blankets, modules, boards, tapes, and other products, have various applications in industries ranging from construction to the aerospace sector. The main characteristics of materials produced with this fiber are the high melting point and low thermal conductivity, making it an excellent thermal insulator with high fire resistance [10].

3. Fiberglass - fibers manufactured from chemical compounds are also used for glass production, such as sand, magnesium, and calcium oxide. Since the Second World War, fiberglass has been extensively studied as a reinforcement for polymeric matrices and ceramic materials, allowing the production of filters for thermal and acoustic insulation, threads for fabric manufacturing, special blankets, and structural components for vessels and aircraft [9]. Fiberglass fibers have softening points close to 850°C and a melting point at 1070°C, demonstrating the capability of this material to withstand extreme temperatures [11,12].

Conclusion

A methodical overview was conducted to understand the primary hurdles associated with utilizing plastics in civil construction, focusing on delineating the essential criteria and prerequisites for an avant-garde sealing system, particularly emphasizing fire safety. Thus, relevant information was systematized, mainly for designers and builders, who must ensure compliance with the normative criteria of the designed or built sealing systems. The primary normative texts are the Performance Standard, ABNT NBR 15575 - Part 4, and the National System of Technical Evaluations of Innovative Products and Conventional Systems (SiNATI) guidelines. Furthermore, given the number of criteria to consider, it became necessary to synthesize and organize this information in tables, facilitating the work of designers and builders. In addition, it was possible to verify the main tests or analyses relevant to the determination of the fire performance of the seals.

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