EVALUATION OF MARBLE RESIDUES AND SYNTHETIC FIBERS APPLICATION POTENTIAL FOR THE DEVELOPMENT OF FLOORS THROUGH THE ANALYSIS OF PATENTS

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Abstract: The concept of a circular economy proposes that industrial waste be used as raw material for making new products to reduce the environmental impact and stimulate economic growth. Thus, many scientific studies and patents have aimed to take advantage of different waste compounds in the development of new composite materials. The goal of this study is to assess the potential for using marble and synthetic fibers for the development of new materials through the analysis of patent documents filed worldwide. We analyzed prospective documents in the Derwent Innovation Index database. A total of 129 documents related to the research area of interest was identified between 1958 and 2019. The construction sector had a higher total number of patents and active patents relative to the industrial sector with a focus on structural, antimicrobial, and covering applications. Japan, the United States, and South Korea were the countries that filed the most patents related to the research topic.

Keywords: Composite; Synthetic fiber; Marble; Floor; Technological prospecting.

AVALIAÇÃO DO POTENCIAL DE APLICAÇÃO DE RESÍDUOS DE MÁRMORE E FIBRAS SINTÉTICAS PARA O DESENVOLVIMENTO DE PISOS ATRAVÉS DA ANÁLISE DE PATENTES.

Resumo: O conceito de economia circular propõe que os resíduos industriais sejam utilizados como matéria-prima para a fabricação de novos produtos que reduzam o impacto ambiental e estimulem o crescimento econômico. Assim, muitos estudos científicos e patentes têm como objetivo aproveitar as vantagens de diferentes compostos residuais no desenvolvimento de novos materiais compostos. O objetivo deste estudo é avaliar o potencial da utilização de mármore e fibras sintéticas para o desenvolvimento de novos materiais por meio da análise de documentos de patentes depositados em todo o mundo. Analisamos documentos prospectivos no banco de dados do Derwent Innovation Index. Um total de 129 documentos relacionados à área de pesquisa de interesse foi identificado entre 1958 e 2019. O setor de construção teve um maior número total de patentes e patentes ativas em relação ao setor industrial com foco em aplicações estruturais, antimicrobianas e de cobertura. Japão, Estados Unidos e Coréia do Sul foram os países que mais depositaram patentes relacionadas ao tema de pesquisa.

Palavras-chave: Compósito; Fibra sintética, Mármore; Piso; Prospecção tecnológica.

1. INTRODUCTION

Ornamental stone is a natural material widely used in the construction sector and can be classified into three groups, granites, marbles and quartzite. Granite is an igneous stone with large amounts of quartz and feldspar, as well as iron minerals. Marble is a carbonate stone normally composed of calcite and dolomite. Quartzite is a metamorphic stone composed almost entirely of quartz [1]. The global production of natural stones has been following an upward trend in recent years. In 2018, 83.4 million tons of stone material were produced worldwide, with a total revenue of 25 billion dollars [2]. With a production of 8 million tons, Brazil is among the five largest producers of ornamental stones in the world with a market share of 5.4%. Although concentrated in traditional regions such as Espírito Santo and Minas Gerais, this production is growing in other states, such as Bahia and Ceará [3]. Air and water pollution represent the most direct and hazardous problem in this industry. Up to 30% of the material used to produce ornamental stone is converted to waste during the extraction and processing stages of production [4]. One way to mitigate the environmental impacts of ornamental stone production is to utilize these waste products in the development of new products [5,6].

To create a circular economy industrial waste needs to be used as raw materials for making other products. This new approach to industry will reduce our carbon footprint and stimulate economic growth. Already, there are many examples of the circular economy in action, particularly in the production of composite materials [7-9].

Green waste-based composites are becoming more popular in the civil engineering sector with applications in additive manufacturing of buildings (3D printing), reinforcement of and reduction in the use of cement in concrete, and development of polymeric wood and various products for the market [10-14]. The introduction of residues from ornamental stone production into concrete mixtures resulted in a significant improvement in compressive and flexural strength, as well as good resistance to chloride ion penetration [15,16]. Further, the use of stone cutting residues as raw material in new geopolymer formulations showed a promising enhancement of the material's compressive strength [17].

Stone waste composites have been used to create product alternatives for a variety of applications and many of these ecologically minded products are able to compete with the properties required of standard goods. For example, researchers manufactured polymeric composite bricks composed of 90% ornamental stone residue that have a compressive strength that is six times the required strength of building bricks [18]. In a similar study, researchers fabricated stone waste composites with low permeability, high dielectric constant, and high flexural strength, suggesting feasibility as a sustainable electrical insulator [19]. Another study used quartz, granite and marble waste as a raw material for glass production and succeeded and producing a material with properties similar to soda-lime glass [1].

Patent analysis is a useful method to forecast technology innovation patterns and establish technology development strategies. Patents include integrated information on developed technologies and can offer objective indicators that reflect technology trends. Also, potential competitors can be determined from patent analysis, which includes information on the period of technology development and developers [20, 21]

With these objectives in mind, this work analyzes patents related to the development of polymeric composites composed of marble residues and synthetic

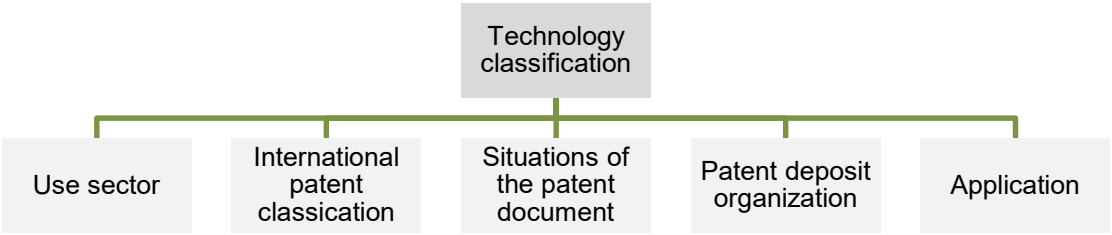
fibers, and identifies potential applications for these new materials, primarily floor manufacturing.

2. METHODOLOGY

The patent analysis was carried out using the Derwent Innovation Index database (Thomson Innovation with license of use by the University Center SENAI CIMATEC – Salvador, Bahia, Brazil) that compiles the collection of patents available worldwide. The search was performed using the keywords selected in the titles, abstracts, descriptive reports and claims of the documents (using the Text-Fields option in the database). For collection in the Derwent Innovation Index database, combinations of the keywords "composite", "polymer", "synthetic fiber", "marble" and "floor" were used Data collection took place in June 2020 and all patents related to the subject were reviewed, however it is important to note that the World Intellectual Property Organization (WIPO) determines that all documents go through a confidentiality period of 18 months before publication [22].

To interpret the information about the protected technology, each document was analyzed and the relevant information describing the invention was extracted and discussed. Figure 1 shows the method used for analyzing the patents. The patent analysis was carried out in 5 steps. The indicators considered for data analysis were as follows: year of deposit of the document in the country of origin (assessed by the priority date), international patent classification (IPC), patent document status, patent deposit organization, and the application of technology. Graphs were generated using Origin 8.1. The term “patent document” includes published patent applications as well as granted, expired, or filed patents.

Figure 1 - Patent analysis process.



3. RESULTS AND DISCUSSION

Based on the Derwent Innovation Index database, 129 documents were identified related to the research area of interest. It was possible to verify the historical evolution of the researched technology, the main holding countries, the main assignees/claimants, the most relevant international patent classification codes, and to identify the active patent documents. Figure 2 shows the annual evolution of the last 20 years in which documents related to the research topic were deposited. The largest number of publications occurred in 2017, which represents 7.7% of the total documents found in the survey, however, due to the confidentiality period, it is important to note that the years 2018, 2019 and 2020 do not represent the real value of protected inventions in the surveyed area.

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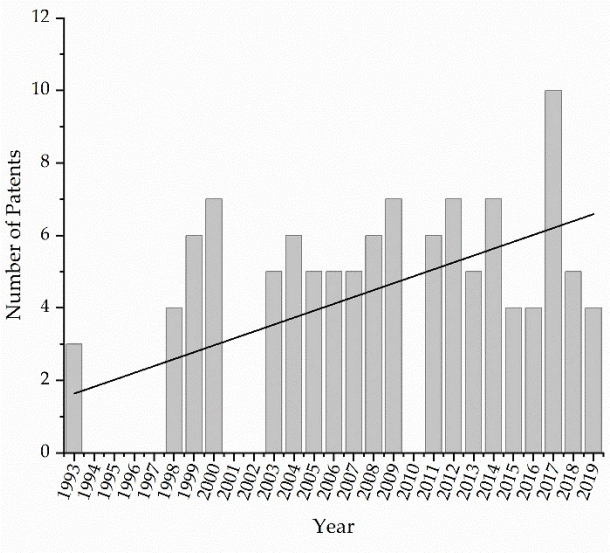
The increase in the number of deposits may be related to a worldwide trend in the use of ecological products and in the optimization of industrial processes [7,8]. A good example of optimization in the industrial sector and reduction of environmental damage comes from the metallurgical sector. The strong investment in new technologies in recent years has allowed the sector to reach an efficiency rate of 97.6% in world steel production, a reduction of 58% in CO2 emissions and 60% in energy consumption [23]. The photovoltaics industry has promoted significant investments in waste recycling leading to developments in solar panel and silicon waste recovery [24, 25]. Worldwide, less than 10% of all polymers ever produced have been recycled. South America is not above this reality with annual recycling rates below 20%. Thus, the recycling of plastic waste represents an opportunity for economic development [26]

An important milestone in the encouragement of recycling practices by the industrial sector occurred in 2015 when the UN (United Nations) created the 17 Sustainable Development Goals (SDGs), with the goal of implementing these objectives globally by 2030 [27].

Figure 2 - Annual evolution of the last 20 years in which documents related to the research topic were deposited.



The first patents about stone-waste being used in composite materials were described by Packaged [28] and Toyoda et al [29]. These two American patents were granted in 1958 and 1978 successively. The first patent document number US3111569A was filed in 1958; the registration is related to the manufacture of laminated products based on resin and glass fibers to be used as reinforcement or decorative components in construction structures [28]. The second document, number US4213926A, was created in 1978; this patent describes a method for the manufacture of decorative plates for use in buildings [29]. Figure 3 shows the patent analysis matrix related to marble powder and synthetic fibers for the manufacture of floors. It was identified that 59% of the documents were intended for use in the building sector and 41% for use in the industrial sector. Sections C, B, and E were the most used to classify patents according to the international patent classification (IPC). Fifty-four percent of the analyzed patent documents are expired,36% are current, and the status of 10% of the documents could not be identified due to lack of information in the Derwent database. Japan (26%), the United States (20%), and the Republic of Korea (16%)

were the nations that filed the most patents related to the research topic. According to the application of the technology, 48% of patents are intended for covering surfaces, 20% structural function, 19% antimicrobial, 4% waterproofing, 3% soundproofing, 2% electrical insulation, 2% thermal insulation, 1% chemical agent resistance, 1% corrosion protection and 1% water drainage.

There are studies for the application of polymeric composites in different segments of civil construction, such as bridge decks, floors with high temperature resistance, road rehabilitation, and waterproofing [30-35, 4]. On the other hand, there is a growing demand, driven by the COVID-2019 pandemic, for products resistant to the proliferation of microorganisms. The low number of patents in this segment indicate an investment opportunity in the development of new technologies [36-38]. Researchers have already developed polymeric composites with significant antimicrobial activity on their surface against foodborne pathogenic bacteria such as Escherichia Coli, Staphylococcus Aureus, Salmonella Enteritidis and fungus Candida Albicans [38-42].

Figure 3 - Patent analysis matrix.

Use sector		Patent deposit organization		Application	
Construction	59%	Japan	26%	Covering	48%
Industrial	41%	United States	20%	Structural	20%
International patent classification		Republic of Korea	16%	Antimicrobial	19%
Section C (chemistry; metallurgy)	64%	European Patent Office	11%	Waterproofing	4%
Section B (performing operations; transporting)	15%	China	9%	Soundproofing	3%
Section E (fixed constructions)	12%	World Intellectual Property Organization	8%	Electrical Insulation	2%
Section A (human necessites)	7%	Australia	4%	Thermal insulation	2%
Section D (textiles; paper)	2%	Germany	2%	Chemical agent resistence	1%
Situations of the patent document		Brazil	1%	Corrosion Protection	1%
Expired	54%	India	1%	Water drainage	1%
Current	36%	Canada	1%		
Indeterminate	10%	Mexico	1%		

Figure 4 shows the relationship between the application of the technology described in the document and the intended sector. In both sectors, the most common application is as a covering material, but the application as a material with structural functionality is more prevalent in the construction sector while in the industrial sector, antimicrobial applications are more pervasive. The waterproofing, soundproofing, and thermal insulation applications have obtained more extensive numbers in the construction sector.

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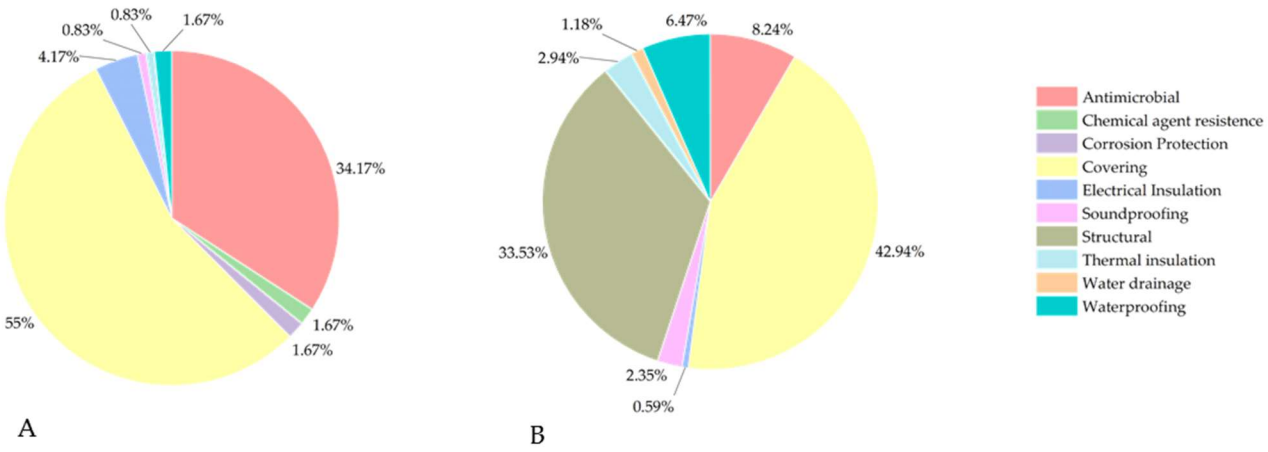
Figure 4 - Relationship between the application of technology and the intended sector (a) industrial and (b) construction.



Reviews of concrete impregnated with stone waste indicate that the inclusion of marble residues at certain concentrations is adequate to replace the coarse/fine aggregate, cement, and additive material. The resulting concrete presented greater compressive strength [16 e 34]. The addition of marble residues to concrete, has also been shown to improve sound permeability, thermal conductivity and water permeability [35].

Although Brazil occupies a prominent place in the world in the ornamental stone sector, the country is lacking in the research and development of this industry, despite the fact that nearly 30% of stone material is lost during processing [1-4]. In the specific case of Brazil and other South American countries, the low number of patents may indicate insufficient interest in the study area or a cultural dearth within local companies and universities in the deposit of documents, despite the high potential for product on the market (30-35, 4). Unfortunately, developing countries have been characterized by the lack or inefficiency of cooperation policies that guarantee greater international communication and competitiveness. The patent document allows public access to detailed information about a specific technology (inventions) and provides guidance on what research is carried out by certain companies, institutions or individuals. The report with the world intellectual property indicators published by WIPO - World Intellectual Property Organization in 2019, points out that China leads the ranking in all categories (patents, utility models, trademarks, industrial design, plant varieties), followed by the United States, Japan, South Korea and Germany respectively in the number of patents filed in 2018. Brazil ranks 26th on this list [43].

Table 1 - The ten active patents with the greatest potential for technological development of new products.

Publication number	Title	Nation	Synthesis	Market application
US10329195B2	Method for forming melt-resistant glass fiber product, and associated apparatus [44].	US	Fibrous polymeric product for covering surfaces with an insulating and fire retardant function.	BLH Technologies Inc

US9057163B1	Pavement repair system [45].	US	System for pavement repair using self-regenerating cohesion in solid phase and homogenization by liquid asphalt oligopolymerization technologies.	No recent marketing information for this product
JP2012035628A	Antimicrobial and antistatic polymers and methods of using such polymers on various substrates [46].	JP	Product for application in the construction sector, formed by polymeric composition with antimicrobial and / or antistatic properties adaptable to a wide variety of substrates and materials.	Mallard Creek Polymers Inc
US8030430B2	Stain resistant polyurethane coatings [47].	US	Chemical compound used as a coating for concrete and other hard surfaces, contains oligomers and high resistance to the appearance of stains.	3M Innovative Properties Co
US20190330107A1	Fiber cement decking products and methods for the production thereof [48].	US	Method for the manufacture of pigmented fiber cement sheets, cured with the use of compressed air for use in the construction sector.	Exex Services Nv Eternit NV
JP2010216223A	Heat insulating structure [49].	JP	Structure with thermal insulation function and that can be used on several surfaces.	No recent marketing information for this product
EP2735251B1	MAT [50].	EPO	Carpet composed of bundles of hydrophilic type fibers with high water absorption properties, anti-allergic, antibacterial and deodorizing function.	Shouei Co Ltd Daiwa Corp Yachiyo Co Ltd
EP1573148A1	Method for producing a continuous waterproofing flooring [51].	EPO	Production of floors for continuous waterproofing, consisting of a fibrous reinforcement layer, impregnated by a two-component liquid, followed by a polymer-based coating layer	Nord Resine SpA
JP05749425B2	Covering tile [52].	JP	Floor covering tile, has a damping layer placed on the face of the tile to provide vibratory energy dissipation properties.	Compagnie De Saint-Gobain
AU2013299616A1	Solid Surfaces and antimicrobial treatments and processes for prepare the same [53].	AUS	Composite used as a finishing product. Comprises particles of polymeric resin and uniformly dispersed copper oxide and optionally filler. Can be used on hospital surfaces.	EOS Surfaces LLC Cupron Inc

4. CONCLUSION

In this study, an analysis of the technologies and patents related to marble powder and synthetic fibers for the manufacture of floors was conducted to characterize market trends. Based on the Derwent Innovation Index database, 129 documents related to the research area of interest were identified between 1958 and 2019. The documents were analyzed and classified according to the sector and type of application. As a result of the analysis, the construction sector had the highest total number of patents identified and the highest number of active patents compared to the industrial sector. Covering, structural and antimicrobial were the most present applications. Japan, the United States and South Korea were the countries that filed the most patents related to the research topic. The results of this research will provide guidance on investment in technology for the development of composites composed of marble powder and synthetic fibers for the manufacture of floors.

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