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Use of Patent Information for Technological Prospecting on the Application of Construction and Demolition Waste on Permeable Pavement

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Abstract: The growing concern regarding environmental issues is mainly related to the fact that natural resources are limited, and the environment is unable to absorb the current amount of generated waste. The construction industry is recognized as one of the sectors that consume the most natural resources and generates waste. A problem resulting from urbanization is the alteration of the natural hydrological cycle, due to an increase in the rate of soil waterproofing, resulting in an increase in the volume and constancy of the floods. The production and publication of knowledge are essential for the development of research, however, studies directed at the feasibility of applying and commercializing this knowledge are insufficient. The patent information serves as a source to map the technological prospecting, presenting relevant information to the application of the invention with the purpose of commercialization. This study applied a survey of patent information about permeable pavement using construction and demolition waste (CDW) as an alternative raw material. The authors conducted an exploratory study based on a survey of existing patents in international databases, through Google Patents, EPO (Espacenet), and WIPO (Patentscope), verifying the degree of technological development, holders of inventions, and potential markets. We used the terms “construction and demolition waste”, “pavement” and “paving” to obtain the patent results. As a result, 65 patents were filed, highlighting as depositing countries, the dominance of the United States, Brazil, Japan, and China. The knowledge contained in patents can collaborate to make decisions related to sustainability in the civil construction sector.

Keywords: Patent information, Construction and demolition waste, Permeable pavement, Sustainability, Innovation, Data mining.

Adherence to the BJEDIS’ scope: The data analysis process is essential for the development of knowledge. This article demonstrates the use of patents as an important source to perform data mining because they contain technical knowledge that serves as technological indicators and market trends. Therefore, the knowledge acquired in patents can assist researchers and professionals in their decision-making.

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1. INTRODUCTION

Discussions on environmental issues have been taking place ever since the United Nations conference on the environment in Stockholm in 1972. This stems from the realization that natural resources are limited, and the environment is unable to absorb the current amount of generated waste (1).

Environmental issues are closely linked to sustainable development since to meet sustainability, environmental, social, and economic dimensions must be concurrently met. Therefore, organizations must be concerned with the social impacts of innovations on human communities inside and outside the organization, with environmental impacts from the use of natural resources and emissions and/or generations of pollutants, and with economic efficiency, without which they would not sustain themselves (2).

The civil construction industry is one of the most important sectors of Brazilian economic and social development, conversely, it is still one of the sectors that most negatively impact the environment. The accelerated growth of urbanization intensifies the activities of the construction sector, consequently, resulting in higher rates of generation of construction and demolition waste (CDW) and extraction of raw materials. Furthermore, with the advance of urbanization, there is an increase in impermeable areas, where natural infiltration ceases to exist and there is only surface runoff, aggravating problems related to floods, and flooding in certain regions (3).

Based on sustainable development, companies must present something new that helps and accompanies global growth. Currently, with the approach of the countries' financial markets, it is necessary to create a differential that highlights their product from other companies. Therefore, it is essential that there is an increase in new technologies, resulting in the encouragement of companies to innovate and generating a cycle of continuous development (4). In this context, innovation is defined by the Oslo Manual as the implementation of a technically new or significantly improved product or process, a new marketing method, or a new organizational method (5).

According to Freeman and Soete (6), innovation is essential for economic progress and an indispensable element for competitive positioning among companies.

Casagrande Jr (7) reiterates that it is no longer possible to ignore the added value that a sustainable product represents, becoming a strategy for business competitiveness. The term sustainable is based on a concept by Elkington (8), which is based on the integration of social, environmental, and economic issues. Therefore, sustainable innovation is defined as the introduction of a product or process, new or considerably improved, and that meets economic, social, and environmental aspects (2, 9).

As an example of sustainable innovation, we can mention the reuse of construction and demolition waste to obtain permeable pavements. The disposal of this waste is one of the recurring adversities in Brazil, as well as the common problems of floods and/or flooding resulting from the waterproofing of the soil.

The process of producing new technologies tends to grow at an accelerated rate, as a result of the availability of information and knowledge in modern society. The dissemination of information favors the advancement in the construction of knowledge. Therefore, discovering the alternatives for sharing information is essential for the construction of new knowledge (10).

There is a gap between the production of new knowledge and its implementation, considering that not all knowledge is implemented.

Few studies dealing with the commercialization of this knowledge, and there are few studies on patenting and licensing the generated technologies. Organizations can guarantee the appropriation of all the results obtained in their Research and Development (R&D) investments through the patent, which grants temporary legal protection. The patent allows the exploitation of the knowledge generated since it contains detailed information on a substantial part of the technical content contained in that document protected by law (11).

Patent data can identify changes in the technological structure and development of a country's inventive activities, industries, and companies. Patents can also show changes in dependencies for a particular technology, in addition to their diffusion and technological penetration (12).

Patents are presented as important sources of information for innovation since the technological results presented for the realization of the patent application are rarely replicated in other publications. Therefore, to develop more effective strategies for a technological design, patents can serve as a source for data mining.

To address this, this work has as its main objective to conduct a survey of the patents on the use of construction and demolition waste (CDW) as an alternative raw material for obtaining permeable pavement through international patenting databases.

1.1. Theoretical Review

The main concepts related to the main constructs of work will be described below: sustainable innovation, construction and demolition waste, permeable pavement, and patent information.

1.1.1. Sustainable Innovation

Access to technological information is part of the competitive strategy between companies. The countless uncertainties and changes that involve research and development activities have encouraged organizations to innovate. Thus, organizations must improve the creation process to seek innovative alternatives for products and processes that are increasingly more efficient and effective (11, 13).

Technological innovation can be defined by the introduction of a product on the market, or a technologically new or substantially improved production process (5).

Innovation is more than just having a good idea, it involves the whole process of transforming opportunities into new ideas that have a wide practical use and generates value, that generates economic gains through practice (14).

Elkington (8) uses a triple bottom line (TBL) metaphorical language to explain sustainability, where there must be a balance between economic, social, and environmental dimensions. The success of the future market will depend on the ability of an organization to satisfy not only the economic dimension but also the social and environmental dimensions.

In this context, there is sustainable innovation. The term sustainable comes from the concept of sustainable development. According to the document “Our Common Future” (Brundtland Report), sustainable development is one that meets present needs without compromising the needs of future generations (15).

Barbieri *et al.* (2) define sustainable innovation as the introduction of products, production processes, management, or business methods, new or significantly improved for the organization, adding economic, social, and environmental benefits.

Martens *et al.* (9) argue that sustainable innovation can be conceptualized as the innovation process that considers the sustainability tripod, that is, a new or improved process and/or product that generates economic, environmental, and social variables.

Therefore, it is not enough for companies to just constantly innovate, but to innovate with consideration for the social impacts generated by innovations in human communities inside and outside organizations, with the environmental impacts by use of natural resources and pollutant emissions, and concern for economic efficiency (for companies this dimension means making a profit) (2).

Currently, there are practices in the civil construction market that are already incorporated into the orientation of sustainability. Management practices that aim to reduce costs are often also practices that reduce energy consumption. What can be observed is that sustainability has been seen not only as a conservation and environmental measure, but also as an opportunity to combat waste, reduce costs, improve processes, innovate, and develop new businesses (16).

1.1.2. Construction and Demolition Waste

The civil construction sector assumes a significant role in the global scope of sustainable development, which is one of the sectors of human activities that most consumes natural resources, varying between 20 and 50% (17). Allied to this impact, there is still concern about the generation and destination of construction and demolition waste, which in large part is irregularly disposed of, resulting in the aggravation of social, economic, and environmental impacts.

Construction and demolition waste (CDW) is considered waste from construction, renovation, repair, and demolition of civil construction works and the result of the preparation and excavation of land, consisting of bricks, ceramic blocks, concrete, soil, rock, wood, mortar, plaster, tiles, asphalt pavement, etc., commonly called construction debris (18).

Brazil begins to tackle the problems arising from the generation of the CDW in 2002 when Resolution No. 307 of the National Environment Council (19). came into effect. In 2004, Resolution No. 348 (20) was created, amending Resolution No. 307, changing item IV of Article 3, through which the consideration of materials containing asbestos was added, which are now considered harmful to a person's health. In 2010, Brazil approved the National Solid Waste Policy (NSWP), through Law No. 12,305 / 2010 (21), which joined forces with the National Environment Council (NEC) Resolution No. 307, where both assist in the aspects of establishing guidelines, criteria, and preconditions for the management of construction waste, disciplining the necessary actions to minimize negative environmental impacts.

Construction and demolition waste can represent approximately 50% of the total mass of solid urban waste (SUW) (22). In 2018, the generation of SUW in Brazil reached 1,039 kg/inhabitant/day, while the total amount of CDW collected (which the project manager is responsible for) by municipalities in Brazil in the same period was 0.585 kg/inhabitant/day. In this sense, the generated CDW portion is worrying since it represents more than half of the SUW. These data presented by the Brazilian Association of Public Cleaning and Special Waste Companies (BAPCSWC) regarding the collection of CDWs, for the most part, reflects only what was abandoned in public roads and public places, not comprising the portion collected by the project manager, that is, the CDW portion generated is higher than the values presented in the collection (23).

The use of CDW for a given application reduces public spending and construction materials. The CDW recycling policy in civil works provides an increase in the useful life of the operating landfills since the current landfills would have an increase in their capacity, and the reduction of illegal discharges along public roads would improve the visual aspect of cities and would impede additional expenses for removing the residue (24).

The management of CDW is costly, which is why many generators irregularly dispose of this waste, without any prior environmental license. Consequently, disposal in vulnerable places causes damage to the population, water, soil, and air, creating problems for the public administration, due to the degradation of watercourses and the depletion of landfill areas (25). Hortegal, Ferreira, and Sant'Ana (26) also highlight the problems caused by the increase of vectors in the accumulated debris, causing problems in the sanitary scope.

1.1.3. Permeable Pavement

The accelerated growth of urbanization has increased urban waterproofing, the coverage of natural soil by pavements makes it difficult for water to infiltrate, generating water accumulation in regions where urban drainage is insufficient.

The progress of urbanization has directly impacted the increase in the waterproofed area and on the reduction of infiltration, causing an increase in surface runoff, causing floods, which can be classified as disasters, which generate human, equity, and environmental losses, in addition to constant challenges to the agencies responsible for emergency care (27).

The drainage of water is done through the soil, however, the flow and return of water to the water tables are hampered in urban areas, resulting in changes in river and channel beds, as well as in an increase in the volume and constancy of floods (28).

Virgiliis (29) emphasizes that accelerated urbanization implies interventions in hydrological processes, in particular direct action on watercourses and on the surface of hydrological basins, consequently reducing permeable areas and superficial storage. Coupled with this, the increase in runoff speed contributes to more severe flood events, simply by increasing flood peaks. Gonçalves, Ribeiro, and Baptista (30) report that the increase in the occupation of urbanized lands, results in the expansion of impermeable areas, significantly altering the destination of rainwater, causing changes in the natural hydrological cycle.

The construction of permeable pavements serves as an alternative technique that explores an appeal to urban drainage. In the case of an infiltration device, this adds to the increase of permeability of urban soil, becoming a drainage tool (29).

The permeable pavement can be built on permeable layers and be made of hollow blocks, concrete, or asphalt. In the case of concrete, the surface layer of the permeable pavement is usually composed of coarse aggregates, cement, water, and additives, having a low percentage or no percentage of fine aggregate in its composition (3).

According to Tucci (31), the use of the permeable pavement reduces the runoff, the drainage channels, and the water depth of parking lots and sidewalks and reduces the costs of the storm drainage system.

There is a need to seek alternatives that help urban drainage, as a way to delay and/or cushion flood peaks, contributing to the reduction of flood constancy. The use of permeable pavement appears as an option to face the problems of drainage and urban permeability.

1.1.4. Industrial Property – Patents

Intellectual Property encompasses the field of Industrial Property, Copyright, and Sui Generis Protection. Industrial property is the set of rights that comprise invention and utility model patents, industrial design registrations, trademarks, and geographical indications, as well as industrial secrecy and the suppression of unfair competition (32).

The purpose of industrial property is to guarantee the right of commercial exploitation of intellectual property to holders for a certain period, restricting unauthorized use by third parties. On the company side, the patent consists of a market reserve guaranteed by the patent during its term, on a novelty from a technical-scientific point of view. For the university, the patenting and commercial exploitation of a certain technology guarantees resources for the university to finance new research, in addition to disseminating and bringing academic research closer to market needs (11).

Searching knowledge in large databases has become a common practice in most organizations, due to the evolution of information technology. The search for information and knowledge on a given subject becomes of paramount importance for research, especially regarding the notions regarding technological prospecting. The sources of information that can be exploited for the development of organizational knowledge and innovation are numerous, and new sources are constantly emerging due to the technological evolution movements and new habits these technologies provide. Although still poorly explored, patent databases can be a valuable source of information and organizational knowledge (33–35). Patents are presented as vital sources of information for innovation since the technological results presented for the realization of the patent application are rarely replicated in other publications.

A patent is a legal document that grants its holder the exclusive right to control the use of an invention, as set out in the patent claims, within a limited area and time, preventing third parties from reproducing, using, or selling the invention without authorization. Furthermore, the inventor undertakes the work to reveal in detail all the technical content of the matter protected by the patent (32, 36).

Patents are seen as a way of expressing purely technical and technological research to the market. The information contained in the patents can assist in solving the problems of companies and public sectors, in addition to serving as indicators of levels of investment in research and development (R&D), technological trends, and estimates of public and private investments to support decisions in various industries (35).

According to Borschiver, Almeida, and Roitmant (37), technological prospection and informational monitoring are fundamental stages of the competitive intelligence process since through prospecting and informational monitoring, it is possible to establish an initial map of information and knowledge sources essential to a greater competitiveness of a given sector.

Hirata *et al.* (11) cite the patent as a tool for the dissemination of information, which can be used as a source of data to indicate technological and economic development, as a method of monitoring technological evolution, and as a way of identifying holders of competing technologies, technological trends, and potential markets. The authors also emphasize that the patent can conduct research, in addition to strict technical investigation.

Technological prospecting in patent databases is attractive, as it reveals the technical content in detail, which helps to map scientific and technological developments, to visualize market trends, indicating competitors, which facilitates decision making. The objective of studying technological prospecting through patents is not to discover the future, but to help outline and analyze the various strategies to achieve the desirable future (13).

Integrating patent studies to obtain information has the potential to support a development strategy that skips steps and takes shortcuts to avoid heavy investments like R&D processes (38).

2. MATERIALS AND METHOD

The methodological procedure addresses the approach of science to reach a previously proposed place. Therefore, the methodology offers several routes and, it is up to the scholar to define procedures, tools, and paths to be taken (39).

The exploratory study of this work evaluates information on patent applications and results involving the use of CDW as an alternative raw material in permeable paving. The technological mapping through patents explored consists of the following steps (13):

a) Definition of the databases to be searched, depending on the focus of the mapping.

b) Construction of the scope for patent search, to guarantee the quality of the methodology.

c) Search and selection of documents retrieved for download.

d) Removal of duplicates, repetitions, and false documents.

e) Preparation of spreadsheets for statistical studies and qualitative considerations.

The methodological trajectory adopted began with the collection of information obtained from free access patent databases during August 2020, through Google Patents (40), European Patent Office (EPO) through Espacenet (41), and World Intellectual Property Organization (WIPO) using the Patentscope tool (42), using the search terms: “construction and demolition waste”, “pavement” and “paving”. The objective of this step was to identify the patents obtained in response to the three search platforms.

2.1. Patent Information

The research on the patent base was accomplished in the period of August 2020 through the Google Patents, EPO (Espacenet), and WIPO (Patentscope) platforms.

The research was conducted following the search criteria described in Table 1, to verify the number of responses on the search platforms, excluding the duplication of patents found between the platforms. In the first survey, we sought to raise patents that use CDW in any type of pavement, using the terms: “construction and demolition waste”, “pavement” and “paving”.

As one of the objectives of the research is a pavement that meets the problem of urban drainage, that is, permeable pavement, a second survey was administered seeking to evaluate the terms “permeable pavement” and “permeable paving”.

The second survey obtained a significantly reduced patent return; therefore, the first survey will serve as a more robust base for the use of CDW in paving. Although the first survey does not restrict the permeable term, it will serve as a basis for technological prospecting in paving and may serve as parameters to develop a pavement that meets the permeability bias.

Query	Search Term	Quantity of Patents
1	"Construction and Demolition Waste" AND ("Pavement" OR "Paving")	65
2	"Construction and Demolition Waste" AND ("Permeable Pavement" OR "Permeable Paving")	2

Table 1: Search criteria in the patent database and the number of patents obtained.
Source: Prepared by the authors.

3. RESULTS AND DISCUSSIONS

This section presents the main results obtained from patent research on the use of CDW in permeable paving.

3.1. Patent Search Results

Through the 65 patents resulting from the research, the number of classifications was verified, according to the International Patent Classification (IPC), represented by Figure 1. The results presented are related to all recovered patents, and a patent can contain more than a classification. The IPC serves to classify the technical content of a patent document as a basis for investigating the state of the art.

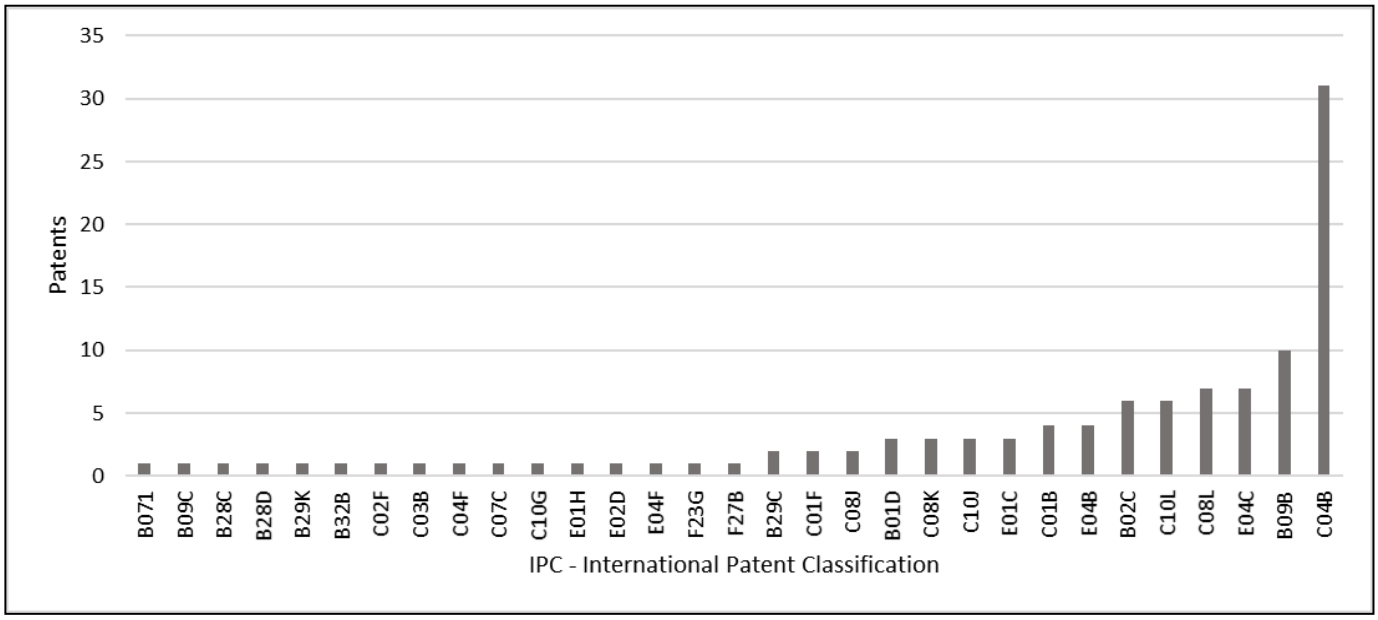

Figure 1: Ranking of the International Patent Classification (IPC) according to the search criteria.
Source: Prepared by the authors.

IPC	Section	Class	Sub-class	Total	%
B02C	B – Processing Operations; Transport	Crushing, spraying, or disintegration; Preparatory treatment of grain for grinding.	Crushing, spraying, or disintegration in general; Grinding Grain	6	5,5
B09B		Elimination of solid waste; recovery of contaminated soil.	Elimination of solid waste.	10	9,2
C04B	C – Chemistry; Metallurgy	Cement; Concrete; Artificial stone; Ceramics; Refractories.	Lime; magnesia; slag; cement; their compositions, for example, mortar, concrete or similar construction materials; artificial stone; ceramics; refractories; natural stone treatment.	31	28,4
C08L		Organic macromolecular compounds; Its preparation or chemical work; Compositions based on this.	Compositions of macromolecule compounds.	7	6,4
C10L		Oil, gas, or coke industry; Technical gases containing carbon monoxide; Fuels; Lubricants; Peat.	Fuels not included elsewhere; Natural gas; Synthetic natural gas obtained by processes not covered by subclasses C10G or C10K; Liquefied petroleum gas; Use of additives in fuels or fire; Firelighters.	6	5,5
E04C	E – Fixed Constructions	Construction.	Structural elements; Construction Materials.	7	6,4

Table 2: Main subclasses of IPC classification identified in patents related to the search criteria.
Source: Elaborated by the authors through the International Patent Classification.

The highest percentage of patent application deposits is in section C (Chemistry; Metallurgy), with approximately 57.8% of deposits, followed by section B (Processing Operations; Transport) with 24.8%, section E (Constructions Fixed) with 15.6%, and section F (Mechanical Engineering; Lighting; Heating; Weapons; Explosion) with 1.8%.

Table 2 illustrates the codes with more than five citations, representing more than 60% of the total deposits. The codes C04B and B09B, present the highest indexes referring to this research, with 28.4% and 9.2%, respectively. Code C04B refers to the composition of cement products, artificial stones, and ceramics, while code B09B refers to the disposal of solid waste.

Figure 2 depicts the evolution of patent filings with the search criteria in the last 15 years. The data presented in the graph revealed that the years 2017 and 2018 were the years with the highest quantities (11) deposits.

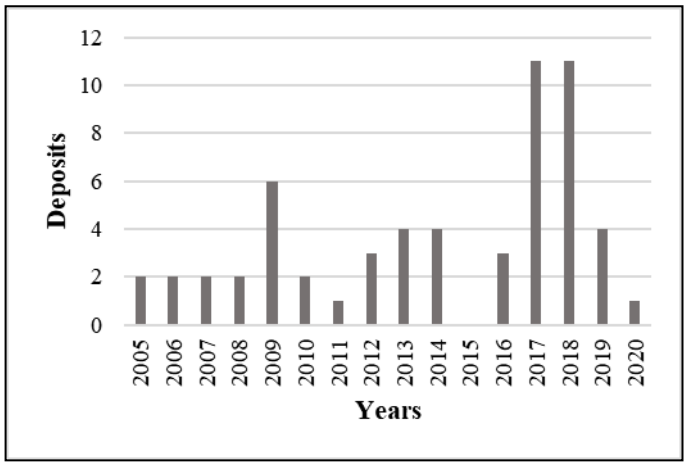

Figure 2: Evolution of patent deposits with RCD in the pavement in the last 15 years.
Source: Prepared by the authors.

Figure 3 shows the American predominance with 14 patents, representing about 22% of the filed patents, followed by WIPO with 11 (17%), Brazil and Japan with 9 (14%), and China with 7 (11%) patents. These data reveal the places where the market for the use of CDW in paving is more active.

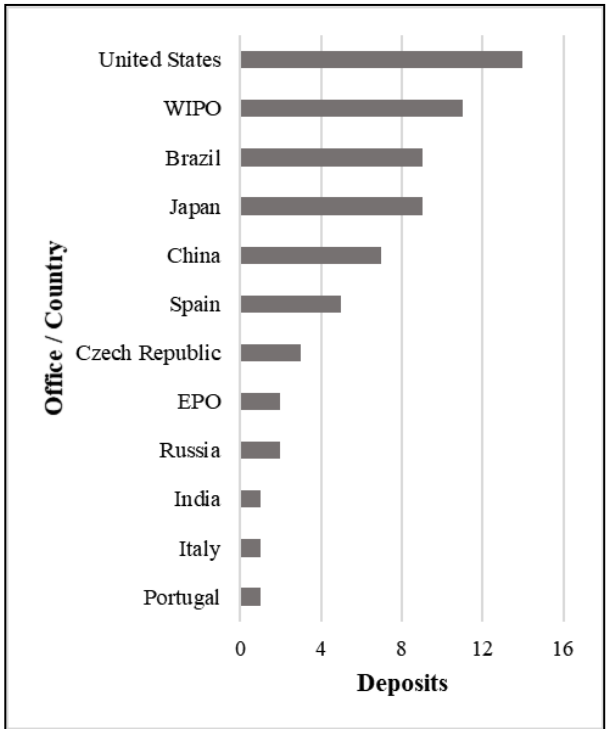

Figure 3: Number of Patents deposited on CDW in paving by country in the databases.
Source: Prepared by the authors.

Figure 4 shows the main applicants. Teaching institutions, in particular universities, stand out for the number of requested patents. The King Fahd University of Petroleum and Minerals contains 6 deposits with the chosen search term, highlighting the academic interest in the topic.

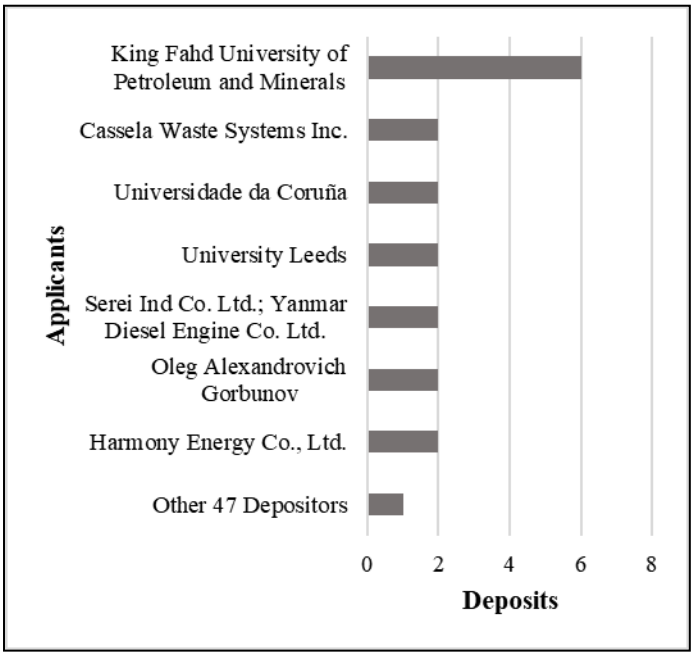

Figure 4: Main patent applicants for the use of CDW in recovered paving.
Source: Prepared by the authors.

4. CONCLUSION

The construction of new technologies is fundamental for success, that is, technological innovation serves as a way to generate a competitive advantage for organizations. The innovation and sustainability factors are ways to obtain a differential advantage from the others, the latter being the one that pursues environmental, social, and economic gains. To achieve a new process and/or product it is not so fundamental to obtain the greatest amount of knowledge, but the quality that knowledge transmits. Currently, the means of obtaining information are increasingly faster and more dynamic, therefore, intelligent monitoring is essential to generate competitiveness in the market. The information contained in patent searches collaborates for decision making, indicating applications, techniques, and strategies previously used, thus helping to reduce costs for R&D investments, being an alternative for learning. In this sense, the present study listed data that can be extracted from patent databases, aiming at the use of CDW in permeable paving. As much as the patent does not address the specific topic desired, it still contains information that can guide the researcher. The results presented can contribute to the aspect of strategies that value CDW as an alternative raw material for paving. We suggest further studies on the subject studied and investigate different search terms for CDW and permeable pavement.

CONFLICT OF INTERESTS

The authors declare that they do not know of financial interests or personal relationships that may have influenced the study reported in this article.

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All authors of this article contributed to the realization of this work:

(I) Conception of the research: Lucas Souza, Marco Figueira, Daniela Lima, Karen Sales and Cláudia Kniess.

(II) Data collection: Lucas Souza, Marco Figueira, Daniela Lima, Karen Sales and Cláudia Kniess.

(III) Analysis and interpretation of data and discussion of results: Lucas Souza, Marco Figueira, Daniela Lima, Karen Sales and Cláudia Kniess.

(IV) Review and approval of the final version of the article: Lucas Souza, Marco Figueira, Daniela Lima, Karen Sales and Cláudia Kniess.

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