Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
Electronic Journal "Environmental Forum of Alta Paulista"

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

Bibliometric analysis on tire rubber incorporated into cement composites

Cesar Fabiano Fioriti
Professor Doutor, FCT/UNESP, Brasil
c.fioriti@unesp.br

Carolina Lotufo Bueno Bartholomei
Professora Doutora, FCT/UNESP, Brasil
carolina.lotufo@unesp.br

Nayra Yumi Tsutsumoto
Professora Mestre, IFSP/Ilha Solteira, Brasil
nayra.yumi@ifsp.edu.br

Periódico Eletrônico "Fórum Ambiental da Alta Paulista"
Electronic Journal "Environmental Forum of Alta Paulista"

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

ABSTRACT

The use of pneumatic rubber for the production of alternative cementitious materials (concretes, mortars and pastes), linked to the environmental aspect, has been widely studied for more than two decades. During this period, advances related to the improvement of mechanical properties were achieved, mainly when chemical treatments were carried out on rubber particles. However, the objective of this paper focused on implementing a bibliometric analysis, based on data from the Web of Science platform, referring to the scientific production of the last ten years (2014 to 2023) of periodicals (Qualis CAPES A1 to A4) on the incorporation of tire rubber in cement composites. Given the sample universe used, it was found in the period that: (i) mortars are most used in rubber incorporations, (ii) the journal Construction and Building Materials (Qualis CAPES A1 and JCR impact factor 7.693) published more articles, (iii) 63.64% of published articles are from journals with Qualis CAPES A1, (iv) the majority of published articles come from China, and (v) bibliometrics showed the continuity of scientific interest in the aforementioned topic.

KEYWORDS: Alternative material. Sustainability. Construction.

1 INTRODUCTION

Currently, both environmental agencies and bodies around the world are concerned with waste management (ABDOLPOUR et al., 2021). At the same time, the number of vehicles circulating every day leads to an exacerbated consumption of unserviceable tires. In Brazil (AGÊNCIA BRASIL, 2022), around 450 thousand tons of disused tires are annually discarded. This amount refers to approximately 90 million common-sized tires, which can take more than 600 years for their complete decomposition in the nature.

Regarding impact loads on concrete, tire rubber presents itself as an alternative to minimize this problem due to its flexibility, even aware of the impaired mechanical properties, since the appropriate treatment of the rubber helps in the process of overcoming these losses, such as such as: mechanical, thermal, chemical and microwave treatment (ASSAGGAF et al. 2021).

In a study that involved the combined effects of carbon nanotubes and tire rubber particles in verifying the durability and pore structure of concrete, Shao et al. (2023) found that incorporation levels of up to 15% reduced water absorption and chloride penetration by 21.1 and 32.3%, respectively, compared to conventional concrete. Furthermore, the incorporation of carbon nanotubes lightened the coarsening and deterioration of the pore structure caused by rubber particles, i.e., improved pore structure and permeability. However, Etli (2023) stated that self-compacting concrete with rubber incorporated up to a limit of 15%, added to the effect of using silica fume in the composites produced, presents a performance considered sufficient to be applied in civil construction.

The interfacial bond between tire rubber and cement paste can also be less affected by treating the rubber using modified clay, as the compressive, tensile, flexural and impact resistance of concrete using this technique provided reduced results of only 0.45% when compared to the reference paste (NAGARAJAN and SHANMUGASUNDARAM, 2021).

For Li et al. (2019), executing chemical treatment on tire rubber makes it efficient, compensating for losses in mechanical resistance in concrete, improving its ductility and

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

reducing its thermal, electrical and acoustic conductivity, making it an interesting option in the production of thermal insulating concrete. and acoustics.

When it comes to rubber treatments, the innovative study by Liu and Tran (2023) made it possible to increase the compressive resistance in mortars treated with a geopolymer overlay of 10.3%, when compared to mortar with rubber without any type of treatment. In this case, the result's advance is associated with the increase in the stiffness of the particles covered with geopolymer, in addition to the interfacial connection that was improved.

Following this line of reasoning Zhu et al. (2023) modified the rubber surface with tannic acid (TA) and nano-TiO2 for using in mortars. The results showed that the basic mechanical properties and microscopic characterization were improved due to the change in the bonding capacity change between the modified rubber and tire rubber. It is also worth highlighting that the mortar produced developed photocatalytic properties. Finally, it maintained its internal structure stable during photodegradation, becoming a material with potential use for road flooring.

However, Mermerdas et al. (2023) produced mortars with the aim of obtaining rubberized geopolymer composites, using rubber levels of 10 to 40%. The results showed that the fluidity, specific mass, compressive endurance and thermal conductivity of the geopolymer composites decreased, while the water absorption capacity increased. The authors stated that despite the negative effects on mechanical properties, tire rubber can keep being exploited, with attention to a limited level of replacement and under strict control. As for Deng et al. (2023), also concerning polymeric mortars, their studies showed an increase in flexural resistance (attributed to the good bond between the source and rubber particles), resistance to high temperatures (bridging effect of microfibers), and reduction of high sorptivity (increasing the difficulty in capillary water suction and chloride penetration).

As regards resistance to freezing/thawing, Maddalena (2023) observed that in mortars incorporated up to 20% of tire rubber, after 20 freezing/thawing cycles, there was progress in thermal resistivity values and a reduction in their water absorption capacity by up to 52%.

Regarding environmental viability, Santos-Ortega (2023) studied mortars incorporated from 10 to 40% of crushed tire rubber and they concluded that, given the different alternatives evaluated in the project, they achieved a reduction of approximately 37% in kg of CO_2 emissions, and also a reduction of around 42% in the abiotic depletion of fossil fuels (referring to the replacement of 40% of fine aggregate by rubber). However, the study warns that the transport distance of recycled materials to the production site is considered a decisive factor.

Considering the above, controversies are still found in the literature regarding the issue of improving or worsening the mechanical properties of cementitious composites with incorporated tire rubber. And as shown, the inclination to carry out treatment on tire rubber before its application tends to favor the expectation of superior results or even subtle differences when compared to reference composites (without tire rubber). The bibliographies indicate that the treatment of rubber is a field to be further explored in future research involving this alternative material, creating, in fact, a promising expectation that in a near future rubber can be successfully used in the composition of materials that can be used in the

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

construction sector.

Another important factor refers to the dimensions of the rubber particles used, as Yang et al. (2023) reported an unfavorable influence with the increase of rubber particles' size in composites, but this is negatively correlated with their volumetric fraction, furthermore, they stated that smaller rubber fractions provide an improvement in the energy absorption capacity of mortars.

It's also relevant to consider the origin of the rubber used, since most studies do not report the tires' provenance, that is, we normally do not have information whether the rubber was acquired from car tires, trucks, tractors, airplanes, among others. Therefore, the mechanism for obtaining rubber fragments is informed in the papers, i.e., whether the tire went through mechanical crushing, retreading residues (tread scraping), cryogenics, etc.

As stated above, the objective of this paper focused on carrying out a bibliometric analysis, based on data from the Web of Science platform, referring to the scientific production of the last ten years (2014 to 2023) of periodicals (Qualis CAPES A1 to A4) on the incorporation of tire rubber into cement composites.

2 METHODOLOGY

The paper considered the methodology titled as quantitative and exploratory, which development was based on Braz e Silva (2020) and, as reported by Cordeiro et al. (2023), the process aims to measure rates of scientific production and its dissemination. According to Mussi et al. (2019), quantitative research allows us to obtain both indicators and current trends on a given subject, that is, to present data considered representative and objective. In turn, Gil (1996) reported that exploratory research aims greater proximity to the problem, enabling the construction of hypotheses (normally associated with bibliographical research and executing case studies).

The data were obtained through bibliometric analysis, which according to Soares et al. (2016), consists of carrying out a quantitative analysis of a given area of knowledge, that such data measures the scientific contribution of the set of publications in the area concerned.

Thus, the paper in question used the entitled Bradford Law, which performs its own function and, generally, consists of correlating the dispersion of 'papers x periodicals' (QUEVEDO-SILVA et al., 2016; BRAZ and SILVA, 2020).

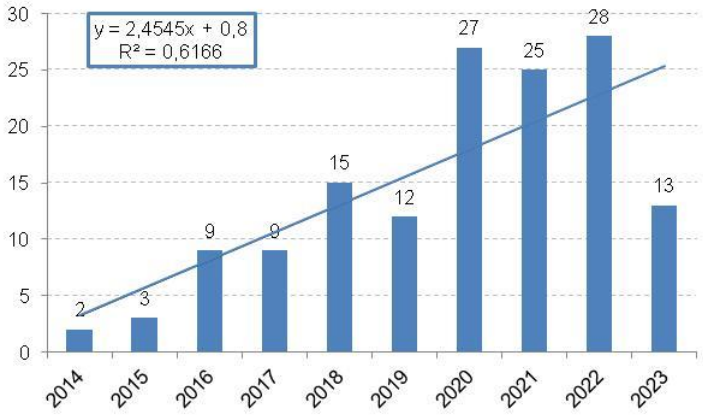
The platform used to search for scientific articles was the Web of Science, which search period enclosed publications accomplished in the last 10 years (between 2014 and 2023), in which the search expression used was 'tires rubber concrete mortar cement', and based on Braz e Silva (2020) the categories selected were: (i) quantitative of annual production, (ii) Qualis CAPES of the periodical, (iii) list of periodicals that had papers published, (iv) areas of knowledge, (v) countries where the papers were originated, and (vi) authors' professional entailement. In the papers analyzed, both the abstracts, the objectives and the conclusion were read. Regarding Qualis CAPES, only papers published in journals A1, A2, A3 and A4 were considered. The areas of knowledge used were: civil construction, materials and engineering.

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

3. RESULTS AND ANALYSIS

The research mad out on the Web of Science platform resulted in a total of 143 papers, of which 136 came from experimental methodologies and 7 bibliographic review papers. Figure 1 shows the scientific production per year.

Figure 1 – Scientific production on the Web of Science platform regarding the topic of tire rubber in cementitious composites per year.

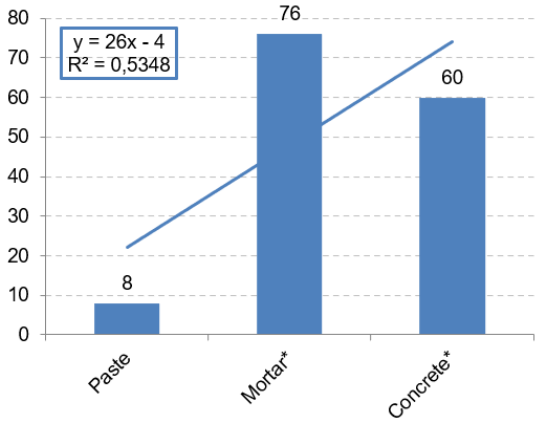


Source: Authors, 2023.

From Figure 1, it is possible to observe that the trend line denotes the growth in the number of publications over the years, except for 2019 and 2023. The peak of publications was from 2020 to 2022, constituting 80 publications in the period. The regression model indicates 62% of the data variance. For information purposes only, considering all articles published in the chosen period, without discriminating the area of activity, the number rises to 479 publications.

As for cementitious composites, Figure 2 shows the classification of papers by material.

Figure 2 – Classification of papers obtained from the Web of Science platform by type of cementitious material incorporated with tire rubber.



* One paper used both mortar and concrete, accounting for one unit for each material.

Source: Authors, 2023.

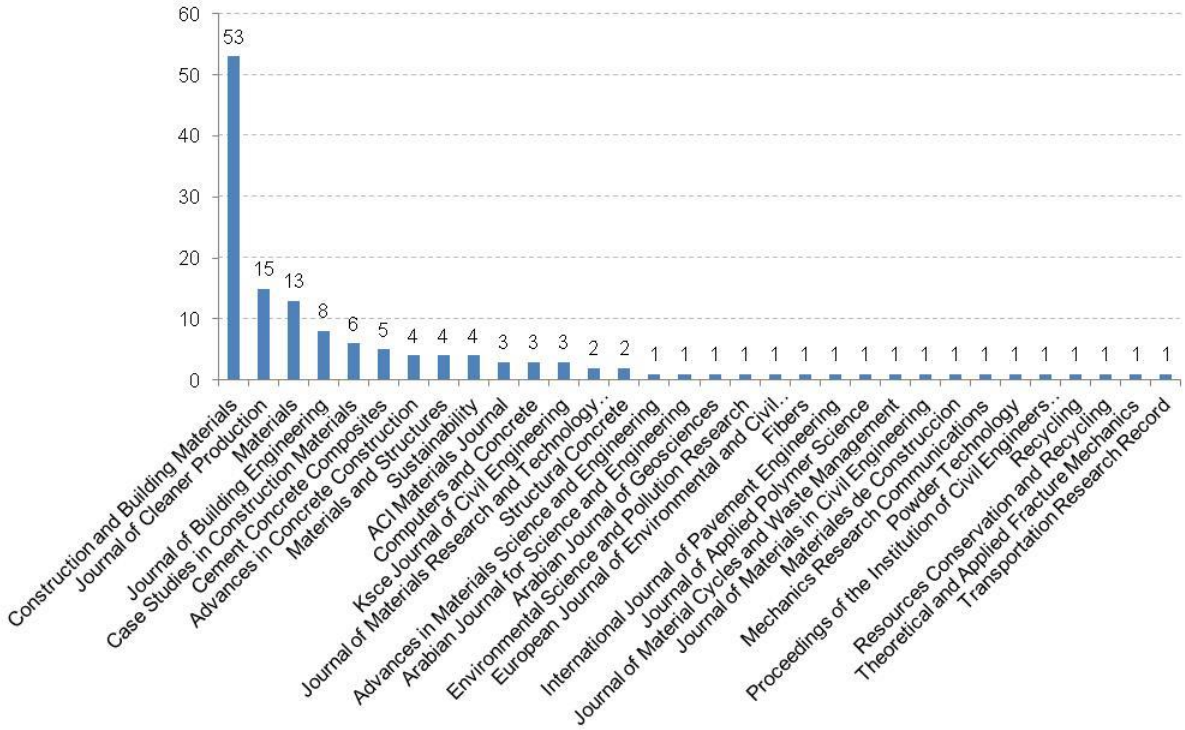
Mortars were the most produced composites in the period (52.78%), Figure 2, while pastes represented only 5.55% and concretes 41.67%. The explanation for this quantity may be

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

related to the fact that mechanical properties tend to reduce when incorporating tire rubber, and in the case of mortars with chemical treatment of rubber, depending on the possible intended final destination, other characteristics such as impact, thermal conductivity , resistance to high temperatures and even flexion end up being more attractive and consequently more explored. The sequence of data in Figure 2 shows the evolution of the constitution of the cementitious material, being paste – mortar – concrete, which regression model in this case indicates 53% of the variance.

The list of journals in which the papers were published is shown in Figure 3.

Figure 3 – Scientific production obtained on the Web of Science platform regarding the topic of tire rubber in cementitious composites, by journal.



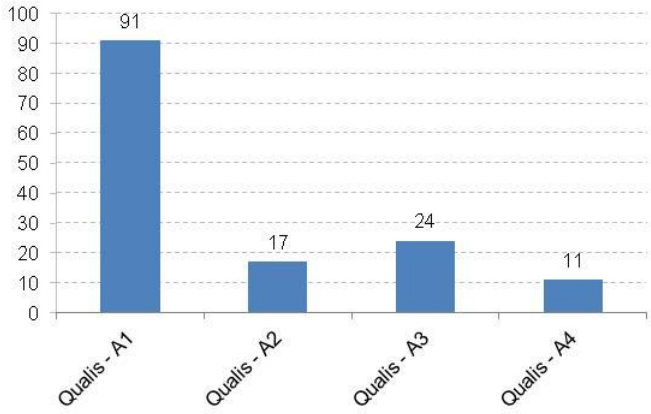
Source: Authors, 2023.

As shown in Figure 3, the journal Construction and Building Materials was the most used to publish papers on the topic in question, representing 37.02% of total publications in the period. It is worth mentioning that the periodical under discussion is international (as well as the others presented), its focus is dedicated to the investigation and contemporary application of materials in construction, with open access, and has a high impact value. In the second and third plan there's the Journal of Cleaner Production and Materials, with 10.49% and 9.09%, respectively.

The Qualis CAPES classification of the journals is shown in Figure 4.

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

Figure 4 – Qualis CAPES classification of journals obtained from the Web of Science platform regarding tire rubber incorporated into cementitious composites.

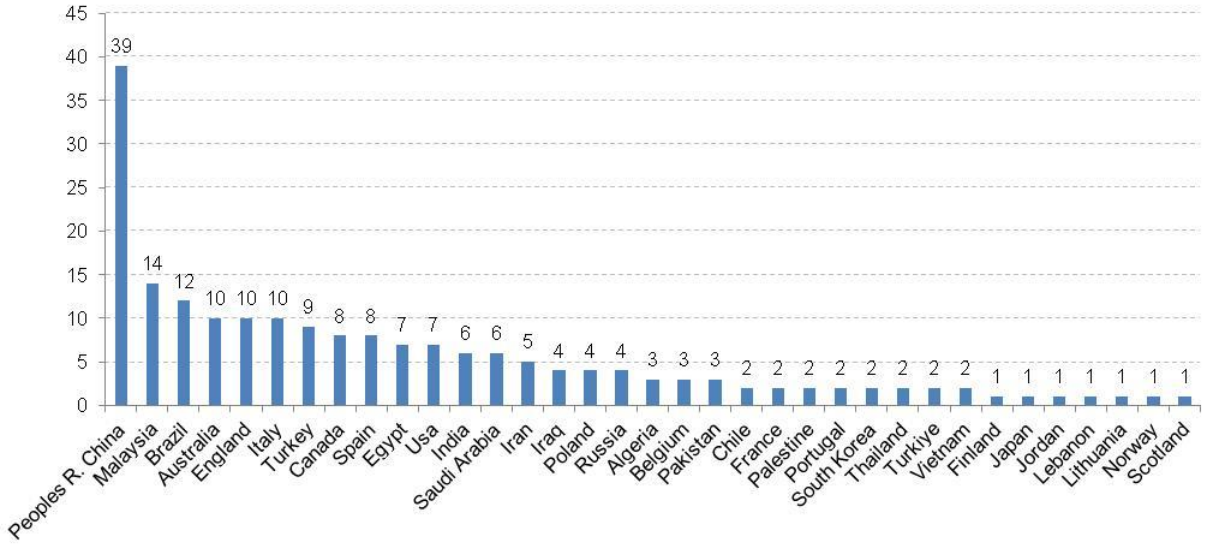


Source: Authors, 2023.

The study of this theme took place more intensely in the mid-2000s. Two decades later, it is clear that the journals with Qualis CAPES A1 (63.64%) overlap with the other A2 (11.89%), A3 (16.78%) and A4 (7.69%), indicating the progress of the subject, as well as the quality of the papers published in the period and, enabling alternatives for subsequent studies. It is pertinente to note that, according to Barata (2016), Qualis is characterized as an instrument used to evaluate intellectual production, in which correlations are produced referring to qualitative and quantitative aspects.

The scientific production regarding tire rubber in cementitious composites by country is shown in Figure 5.

Figure 5 – Scientific production on the Web of Science platform regarding tire rubber incorporated into cementitious composites by country.



Source: Authors, 2023.

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

The graph in Figure 5 shows China as the country that most publishes papers on this topic (27.27%) [6 papers were published affiliated with Tianjin University], despite this country being considered one of the countries that most pollute the planet today. Later, Malaysia (9.79%) and Brazil (8.39%) appear [leveraged by the State University of Campinas – UNICAMP with the publication of 6 papers].

Still referring to the country China, mention must be made that, in the related period, the author who most published the most papers was Han Zhu (affiliated with Tianjin University), as shown in Chart 1.

Chart 1 – List of papers published by author Han Zhu on the Web of Science platform regarding tire rubber incorporated into cementitious composites in the period.

Authors	Year	Periodic	Material	Qualis (CAPES)	Impact Factor (JCR)
Shao, J.; Zhu, H.; Haruna, S. I.; Xue, G.	2023	Arabian Journal for Science and Engineering	Concrete	A2	2.807
Shao, J.; Zhu, H.; Zhao, B.; Haruna, S. I.; Xue, G.; Jiang, W.; Wu, K.; Yang, J.	2022	Construction and Building Materials	Concrete	A1	7.693
Shao, J.; Zhu, H.; Xue, G.; Yu, Y.; Borito, S. M.; Jiang, W.	2021	Construction and Building Materials	Mortar	A1	7.693
Liang, J.; Zhu, H.; Zhang, B.; Zhang, C.; Shao, J.; Duan, F.; Wang, J.	2020	Construction and Building Materials	Mortar	A1	7.693
Yu, Y.; Zhu, H.	2019	Materials	Mortar	A3	3.748
Yu, Y.; Zhu, H.	2016	Materials	Mortar	A3	3.748

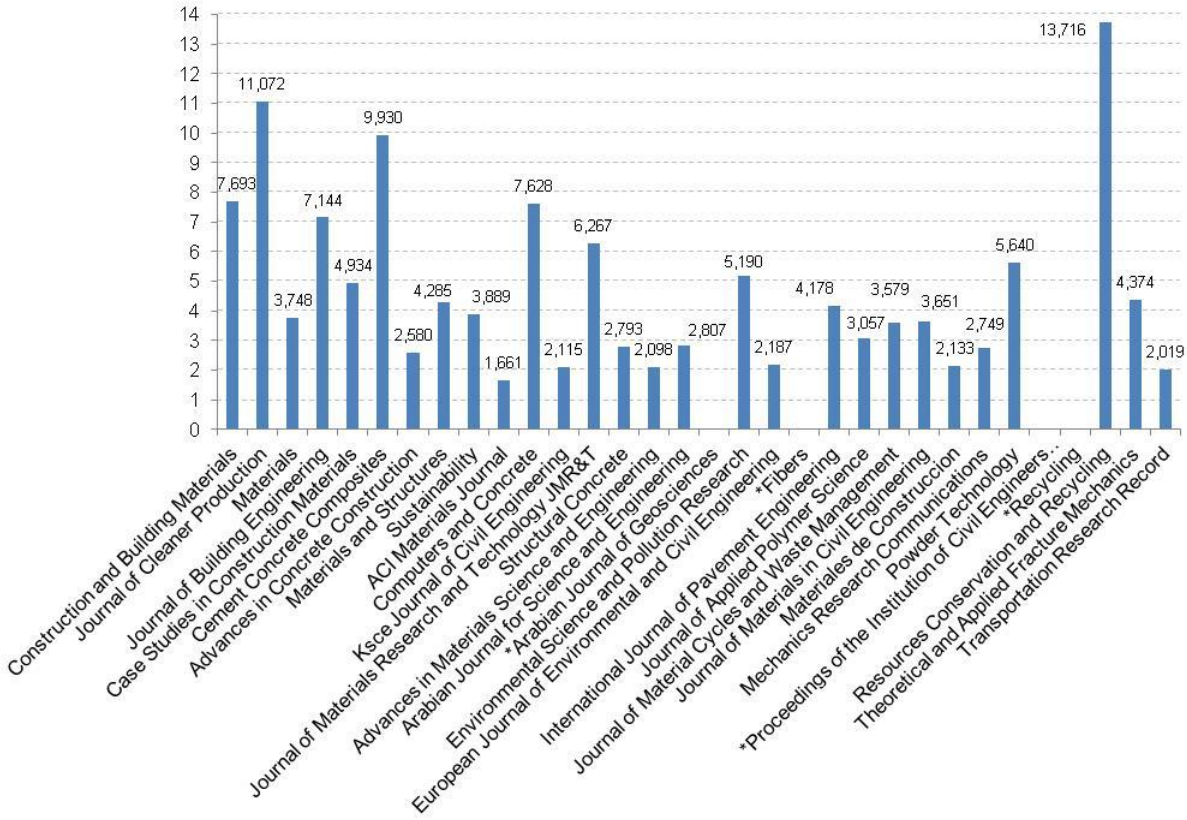
Source: Authors, 2023.

Concerning the authors, the research on the Web of Science platform allows us to confirm the non-existence of an author considered predominant on the topic in question.

As for the Journal Citation Reports (JCR), which consists of assigning an impact factor to journals indexed in the Web of Science, Figure 6 shows the respective values of the metrics that qualify them.

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

Figure 6 – JCR impact factor of journals on the Web of Science platform.



* Journals without JCR impact factor.

Source: Authors, 2023.

Figure 6 corroborates the bibliometric indexes, that is, journals that present higher JCR impact factor indexes have better classification regarding the concepts obtained in Qualis CAPES.

As reported by Guedes et al. (2022), the high bibliometric indexes characterize the journals as quality, indicating that the article evaluation processes are considered rigid, aiming to maintain or expand the impact metrics obtained.

4. FINAL CONSIDERATIONS

Papers related to tire rubber in cementitious composites began to be more commonly published in the mid-2000s. Thus, although only the Web of Science platform was used as a search source in this paper, the sample universe enclosed publications in journals of reference, all international, indicating that there is potential for theoretical references on the topic in question, in the current scenario.

Mortars are most used in tire rubber incorporations, followed by concretes, and lastly pastes. The journal Construction and Building Materials, which has Qualis CAPES A1 impact factor JCR 7.693, was the one that most published the most papers on the subject. From the sample universe used in this paper, 63.64% of the papers were published in journals with Qualis CAPES A1. The largest portion of papers published in the period comes from China.

Finally, after more than two decades of studies, the bibliometric analysis showed the continuity of scientific interest in the use of pneumatic rubber for the production of alternative cementitious materials.

REFERENCES

ABDOLPOUR, H.; NIEWIADOMSKI, P.; SADOWSKI, L. Recycling of steel fibres and spent equilibrium catalyst in ultra-high performance concrete: literature review, research gaps, and future development. **Construction and Building Materials**, v.309, 2021. https://doi.org/10.1016/j.conbuildmat.2021.125147.

AGÊNCIA BRASIL. **Brasil descarta, por ano, mais de 450 mil toneladas de pneus**. Disponível em: <https://agenciabrasil.ebc.com.br/radioagencia-nacional/geral/audio/2022-07/brasil-descarta-por-ano-mais-de-450-mil-toneladas-de-pneus>. Acesso em: 12 out. 2023.

ASSAGGAF, R. A.; ALI, M. R.; AL-DULAIJAN, S. U.; MASLEHUDDIN, M. Properties of concrete with untreated and treated crumb rubber – A review. **Journal of Materials Research and Technology**, v.11, p.1753-1798, 2021. https://doi.org/10.1016/j.jmrt.2021.02.019.

BARATA, R. C. B. **Dez coisas que você deveria saber sobre o Qualis**. RBPG, Brasília, v.13, n.1, janeiro/abril 2016. Disponível em: https://files.cercomp.ufg.br/weby/up/26/o/artigo_10_coisas.pdf. Acesso em: 16 de mar. 2023.

BRAZ, S. N.; SILVA, L. H. V. Pegada de carbono: uma análise bibliométrica. **Caderno Meio Ambiente e Sustentabilidade**, v.9, n.17, p.60-73, 2020. Disponível em: <https://www.cadernosuninter.com/index.php/meioAmbiente/article/view/1542>. Acesso em: 22 de set. 2023.

CORDEIRO, F. N. C. S.; CORDEIRO, H. P.; PINTO, L. O. A. D.; SEFER, C. C. I.; SANTOS-LOBATO, E. V.; MENDONÇA, L. T.; SÁ, A. M. M. Estudos descritivos exploratórios qualitativos: um estudo bibliométrico. **Brazilian Journal of Health Review**, Curitiba, v.6, n.3, p.11670-11681, 2023. https://doi.org/10.34119/bjhrv6n3-259.

DENG, Z.; YANG, Z.; PAN, X. Synergetic effects of recycled crumb rubber and glass cullet on the engineering properties of geopolymer mortar. **Cement and Concrete Composites**, v.137, 2023. https://doi.org/10.1016/j.cemconcomp.2022.104907.

ETLI, S. Evaluation of the effect of silica fume on the fresh, mechanical and durability properties of self-compacting concrete produced by using waste rubber as fine aggregate. **Journal of Cleaner Production**, v.384, 2023. https://doi.org/10.1016/j.jclepro.2022.135590.

GIL, A. C. **Como elaborar projetos de pesquisa**. 3. ed. São Paulo: Atlas; 1996.

GUEDES, F. L.; EL-DEIR, S. G.; ARAGÃO JÚNIOR, W. R.; JUCÁ, J. F. T. Analysis of scientific production of refused derived fuel through scientometric and bibliometric indicators. **Journal of Environmental Analysis and Progress**, v.7, n.2, p.052–061, 2022. https://doi.org 10.24221/jeap.7.2.2022.4509.052-061.

LI, X.; LING, T.; MO, K. H. Functions and impacts of plastic/rubber wastes as eco-friendly aggregate in concrete – A review, **Construction and Building Materials**, v.240, 2020. https://doi.org/10.1016/j.conbuildmat.2019.117869.

LIANG, J.; ZHU, H.; ZHANG, B.; ZHANG, C.; SHAO, J.; DUAN, F.; WANG, J. Experimental research on controlling the floating of rubber particles in mortar based on the layering degree índex. **Construction and Building Materials**, v.247, 2020. https://doi.org/10.1016/j.conbuildmat.2020.118567.

LIU, J. and TRAN, P. Cement mortar containing crumb rubber coated with geopolymer: from microstructural properties to compressive strength. **Construction and Building Materials**, v.383, 2023. https://doi.org/10.1016/j.conbuildmat.2023.131284.

MERMERDAŞ, K.; İPEK, S.; IŞIKER, Y.; RASOOL, H. Effect of waste tire aggregate on thermal and strength characteristics of fly ash–based geopolymer composites produced at various binder contents**. Journal of Materials in Civil Engineering,** v.35, n.10, 2023. https://doi.org/10.1061/JMCEE7.MTENG-15839.

ISSN 1980-0827 – Volume 20, Number 1, Year 2024

MUSSI, R. F. F.; MUSSI, L. M. P. T.; ASSUNÇÃO, E. T. C.; NUNES, C. P. Pesquisa quantitativa e/ou qualitativa: distanciamentos, aproximações e possibilidades. **Revista Sustinere**, Rio de janeiro, v.7, n.2, p.414-430, 2019. https://doi.org/10.12957/sustinere.2019.41193.

NAGARAJAN, C. and SHANMUGASUNDARAM, P. Effect of modified clay treated crumb rubber and silica fume on the properties of concrete. **Structural Concrete**, v.23, p.2288-2300, 2021. https://doi.org/10.1002/suco.202100085.

QUEVEDO-SILVA, F.; SANTOS, E. B. S.; BRANDÃO, M. M.; VILS, L. Estudo bibliométrico: orientações sobre sua aplicação [Bibliometric study: guidelines on its application]. **Revista Brasileira de Marketing: REMARK**, v.15, n.2, p.246-262, 2016. https://doi.org/10.5585/remark.v15i2.3274.

SANTOS-ORTEGA, J., FRAILE-GARCÍA, E., FERREIRO-CABELLO, J. Methodology for the environmental analysis of mortar doped with crumb rubber from end-of-life tires. **Construction and Building Materials**, v.399, 2023. https://doi.org/10.1016/j.conbuildmat.2023.132519.

SHAO, J.; ZHU, H.; XUE, G.; YU, Y.; BORITO, S. M.; JIANG, W. Mechanical and restrained shrinkage behaviors of cement mortar incorporating waste tire rubber particles and expansive agent. **Construction and Building Materials**, v.296, 2021. https://doi.org/10.1016/j.conbuildmat.2021.123742.

SHAO, J.; ZHU, H.; HARUNA, S. I.; XUE, G. Durability and fractal analysis of pore structure of crumb rubber concrete modified with carbon nanotubes. **Arabian Journal for Science and Engineering**, v.48, p.12959-12976, 2023. https://doi.org/10.1007/s13369-023-07653-8.

SHAO, J.; ZHU, H.; ZHAO, B.; HARUNA, S. I.; XUE, G.; JIANG, W.; WU, K.; YANG, J. Combined effect of recycled tire rubber and carbon nanotubes on the mechanical properties and microstructure of concrete. **Construction and Building Materials**, v.322, 2022. https://doi.org/10.1016/j.conbuildmat.2022.126493.

SOARES, P. B.; CARNEIRO, T. C. J.; CALMON, J. L.; CASTRO, L. O. C. O. Análise bibliométrica da produção científica brasileira sobre tecnologia de construção e edificações na base de dados Web of Science. **Ambiente Construído**, v.16, n.1, 2016. https://doi.org/10.1590/s1678-86212016000100067.

YANG, G.; FAN, Y.; LI, X.; XU, Y. Influence of rubber powder size and volume fraction on dynamic compressive properties of rubberized mortar. **Powder Technology**, v.420, 2023. https://doi.org/10.1016/j.powtec.2023.118376.

YU Y.; ZHU H. Effects of rubber size on the cracking resistance of rubberized mortars. **Materials**, v.12, n.19, 2019. https://doi.org/10.3390/ma12193132.

YU, Y.; ZHU, H. Influence of rubber size on properties of crumb rubber mortars. **Materials**, v.9, n.7, 2016. https://doi.org/10.3390/ma9070527.