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Bibliometric analysis on magnesium oxide as a binder in civil construction

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Abstract

Portland cement production requires substantial natural resources and energy and generates significant greenhouse gas emissions. As a more sustainable alternative, magnesium cement – comprising magnesium oxide (MgO) and silicon dioxide (SiO_2) – has gained attention due to its comparable properties to traditional Portland cement and its potential to significantly reduce carbon dioxide (CO_2) emissions. This study conducts a bibliometric analysis using data retrieved from the Web of Science digital platform. The analysis focuses on the scientific production from the 2020–2024 quinquennium in indexed journals classified in the A tier of the Qualis/CAPES system, specifically addressing the theme of magnesium oxide as a binder in civil construction. The sample data provided by the digital platform revealed the following trends during the quinquennium: (a) a decline in scientific production, expected to recover in the post-pandemic period; (b) the journal Construction and Building Materials accounted for the highest number of publications (43.75%); (c) the Journal of Hazardous Materials had the highest Journal Citation Reports (JCR) impact factor of 12.2 and is classified as A1; (d) China exhibited a significant disparity in publications, contributing 47.15%; and (e) the scientific interest in this topic underscores its potential as an open avenue for future research.

Keywords: Alternative material; Sustainability; Magnesium cement; Bibliometric analysis; Source of silica; Magnesium oxide

1. Introduction

Magnesium oxide cement is a promising alternative binder owing to its versatility in producing cementitious products with characteristics similar to those of traditional Portland cement combined with its sustainable attributes (Dhakal, et al., 2021; Hay et al. 2021; Shah e Scott, 2021; Sonat e Unluer, 2017; Zhou et al., 2024; Zhang et al., 2024).

Magnesium oxide (MgO) is a binary compound composed of magnesium and oxygen, typically known as magnesia or periclase (Arruda, 2014; Dolores, 2017).

MgO has been extensively investigated due to its potential applications in various fields, including anti-corrosion systems (Vermileya, 1969; Apud Arruda, 2014), refractory concretes (Szczerba, et al., 2013), and the production of alternative binders for civil construction (Dhakal et al., 2021; Capelo et al., 2023; Shah e Scott, 2021; Sonat and Unluer, 2017; Nie et al., 2024).

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As reported by Walling and Provis (2016), calcination of magnesium carbonate ($MgCO_3$) is the primary method of obtaining MgO for use in magnesium cement. The thermal treatment and calcination conditions of the ore directly influence the reactivity of the resulting MgO product. This is because the higher the temperature and calcination time, the lower the reactivity of MgO (Amaral et al., 2010; Arruda, 2014; Capelo et al., 2023; Shand and Jin, 2020; Zhou et al., 2024).

Notably, when hydrated, MgO produces magnesium hydroxide (Mg $(OH)_2$), also known as brucite (Li et al., 2021; Ilango et al., 2024). The resulting hydroxides can exhibit different properties depending on the precursor oxide and hydration rate (Rocha et al., 2004; Amaral et al., 2010). Moreover, Arruda (2014), Rocha et al. (2004), and Amaral et al. (2010) reported that the hydration of MgO initially occurred with its dissolution, followed by the precipitation of Mg $(OH)_2$. Supporting this, Li et al. (2021) observed that upon contact with water, MgO particles initially dissolve, leading to an increased concentration of magnesium ions in the solution. This process continues with the growth of brucite crystals until supersaturation is achieved.

In MgO-based bonding systems, brucite formation has been reported to enhance the mechanical strength of the system (Tran e Scott, 2017). While brucite itself is not responsible for the increase in compressive strength, this effect may be associated with the consumption of the product in question during the formation of other hydration products, such as hydrated magnesium silicate gel (MSH), which in turn imparts mechanical properties to the composites (Wang et al., 2024). It is formed by adding MgO to materials rich in silicon dioxide (SiO_2).

Magnesium cements consist of MgO with other materials, designed to supply the necessary elements, which react with water to form chemical bonds between the constituents, producing compounds with binding properties. Walling and Provis (2016) and Sonat and Unluer (2017) have reported approaches for producing MgO-based cement in combination with carbonates, oxysalts, and silicates to form mineral binder gels. These studies indicated that MgO-based cements are well suited for producing pastes, mortars, and concrete (Capelo et al., 2023; Tran e Scott, 2017; Unluer e Al-Tabbaa, 2015; Ilango et al., 2024).

MgO cement originated with magnesium oxychloride cement in 1867, as described by Sorel (Dolores, 2017; Jin, 2020; Walling and Provis, 2016), and was obtained from the reaction between an aqueous solution of magnesium chloride and MgO. Thus, several combinations of MgO with other products began to be investigated for different purposes. Different binders based on the basic formulation with MgO have been reported in literature, including magnesium oxysulphate (formed by the reaction between MgO and magnesium sulfate in an aqueous solution), magnesium phosphate cement (formed by the reaction between MgO and soluble phosphate), and magnesium silicate cement (a combination of MgO and SiO_2) (Dolores, 2017; Shand, 2020; WALLING e PROVIS, 2016; Huete-Hernández et al., 2024).

Currently, there is considerable interest in $MgO–SiO_2$ binders among various alternative material combinations. This interest is driven by the formation of MSH when MgO combines with SiO_2-rich materials. The resulting product provides binding characteristics similar to those of traditional Portland cement (Shah e Scott, 2021; Tran e Scott, 2017; Sonat e Unluer, 2017; Zhang et al., 2021; Ilango et al., 2024). Examples include incorporating rice husk ash (Capelo et al., 2023; Sonat and Unluer, 2019) and fly ash (Kumar et al., 2020), ground granulated blast furnace slag (Ruan and Unluer, 2017; Kumar et al., 2020), volcanic ash (Abdel-Gawwad et al., 2020), pozzolanic materials like calcined kaolinitic clay, which contain a significant amount of SiO_2 and can serve as a source of binding compound in the system (Dhakal, et al., 2021; Shah e Scott, 2021; Huete-Hernández et al., 2024).

1.1. Development

The analysis used a quantitative and exploratory methodology based on Braz and Silva (2020) and Fioriti et al. (2024). According to Soares et al. (2016), the data presented in the bibliometric analysis are derived by conducting a quantitative analysis in a specific area of knowledge, enabling the verification of the scientific contribution of the publication collection in a given field. It has become a vital link for assessing the scientific stage of a particular area, as bibliometric indicators are increasingly recognized for their contribution in advancing science and technology (Macedo et al., 2009; Beira et al., 2020).

The work involved applying Bradford's Law, a helpful tool in the management of information and scientific knowledge from journals, to assess the dispersion of specific scientific knowledge across journals, generating correlations between articles and journals (Quevedo-Silva et al., 2016; Braz and Silva, 2020; Rodrigues and Vieira, 2016; Guedes and Borschiver, 2005).

The digital platform used for selecting scientific articles was the Web of Science, with a search period covering publications from the last five years (2020–2024). The keyword used in the digital platform was “magnesium oxide cement.” Based on Braz and Silva (2020) and Fioriti et al. (2024), it focused on the following categories: (a) annual scientific production, (b) scientific production by journal, (c) Journal Citation Reports (JCR) impact factors, and (d) scientific production by country.

The abstracts, objectives, and conclusions of the selected studies were included in the bibliometric analysis. Regarding the journal evaluation system, only articles from Brazil classified in A Stratification of Qualis/Coordination for the Improvement of Higher Education Personnel (CAPES) were considered, which lists and classifies journals based on circulation and quality by field. The following five areas of knowledge were examined: (1) materials science, (2) construction technology and building engineering, (3) engineering, (4) environmental sciences and ecology, and (5) science and technology.

2. Discussion

Since scientific journals are the primary means by which researchers disseminate the results of their studies (Urbizagastegui, 2016), bibliometric analysis can be classified as a technique for the qualitative assessment of scientific publications in indexed journals, focusing on authors and their affiliated institutions (Souza e Ribeiro, 2013).

The bibliometric survey conducted through the Web of Science digital platform identified 123 articles, of which 115 pertained to experimental research and eight were derived from literature reviews. Figure 1 illustrates the distribution of the variables obtained from the Web of Science platforms.

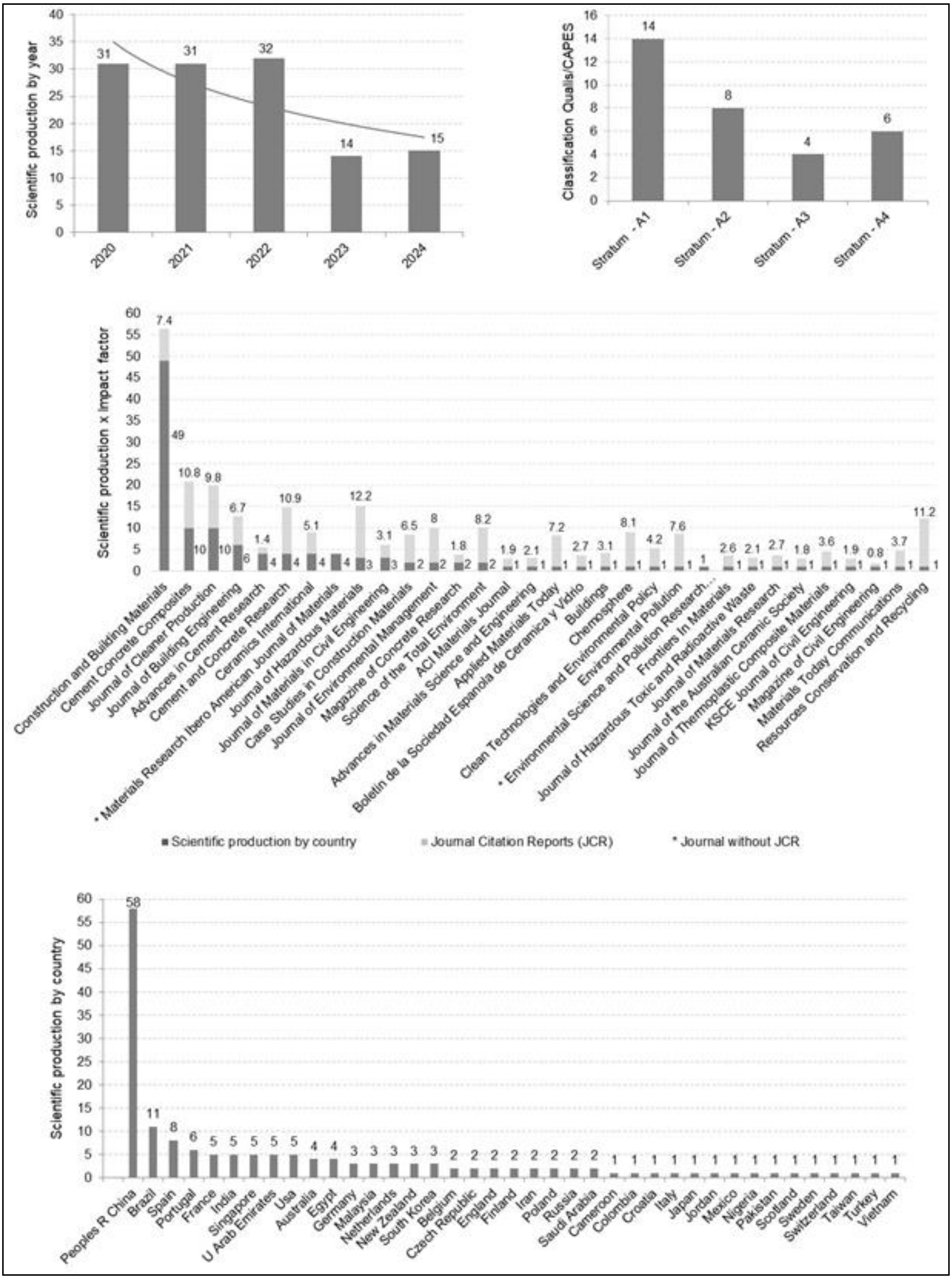
According to the four categories presented in Figure 1, the variable of scientific production per year showed a downward trend in publications over the last two years (2023 and 2024), with a reduction of approximately 50% compared to that in the 2020 – 2022 period. However, this also highlights a renewed increase in the number of publications, with a rise of 28.57% between 2023 and 2024. The regression analysis applied explained 70% of the data variance. Notably, considering the five-year period in question and without distinguishing specific fields of study, the number of published articles was 193.

Regarding the bibliometric analysis of journals classified under the Qualis/CAPES system within tier A (A1, A2, A3, and A4), 43.75% of the journals fell into A1 tier, followed by 25% in tier A2, 12.50% in tier A3, and 18.75% in tier A4. This highlights the quality standards of the published articles and suggests opportunities for future studies focusing on using MgO as an alternative binder in construction. For informational purposes, as reported by Barata (2016), this refers to an evaluative instrument for intellectual production, in which quantitative and qualitative aspects are developed based on the establishment of correlations.

Regarding the journals in which articles were published, Construction and Building Materials accounted for the largest share of publications during this period (39.84%). This open-access journal focuses on research and the innovative use of materials applied in civil construction and repair, serving as a critical link for the dissemination of innovative and original research related to construction. Subsequently, Cement and Concrete Composites and the Journal of Cleaner Production accounted for 8.13% of the publications.

The Journal Citation Reports (JCR) impact factor is an annual publication by Clarivate Analytics incorporated into the Web of Science and is accessible through the Web of Science-Core Collections platform. It allows retrieving information related to journals, including their respective impact factors, which are derived from the compilation of citations received from the Science Citation Index Expanded and the Social Sciences Citation Index (Garfield, 2007). Most journals classified in the A1 tier (qualis/CAPES) had the highest JCR impact factor indices. For example, the three journals with the most publications during the analyzed five-year period were Construction and Building Materials (7.4), Cement and Concrete Composites (10.8), and Cleaner Production (9.8).

The analysis of scientific production by country revealed a notable disparity, with China leading in publications on the topic during this period (47.15%), with five published articles affiliated with the Nanyang Technological University College of Engineering. Brazil (8.94%) and Spain (6.50%) were the following leading countries in publications on this topic. Among the authors who published the most articles on the subject during this period, Celik, Kemal (five articles), and de Brito, Jorge (four articles) stand out. However, no author emerged dominant in the research on using MgO as a binder in civil construction.



Source: Authors (2024).

Figure 1 Distribution of variables obtained from the Web of Science database.

In light of the above, a bibliometric study is a rigorous method for analyzing scientific research, not limited to its quantification, as it enables the assessment of its quality standard, scientific impact, and the promotion of thematic correlations (Beira et al., 2020). As stated by Ribeiro (2017), this type of study allows for an analysis of the diversity of the topic in question, facilitated by the extensive scope it achieves.

3. Conclusion

Research on magnesium oxide as a binder gained more attention in publications starting from 2012. It is worth mentioning that the Web of Science digital platform enabled the analysis of a sample universe composed of indexed journals considered as references, indicating that the researched topic has the potential for theoretical frameworks.

Composites using magnesium oxide as a binder typically employ other sources of silica, including active silica (or microsilica), metakaolin, and fly ash. In essence, these composites consist of pozzolanic materials (amorphous materials with considerable silica content).

Due to the methodological procedures used, the results allowed us to identify that in the analyzed five-year period, the last two years showed a decline in scientific productions, with a subsequent recovery in publications in 2024 (the decline may be attributed to post-pandemic recovery). The sample universe indicated that 43.75% of the publications belonged to the A1 tier of Qualis/CAPES. Construction and Building Materials contributed the highest number of publications during the five-year period (49 articles), and this journal is classified in the A1 tier of Qualis/CAPES, with a JCR impact factor of 7.4. Notably, the journal with the highest impact factor was Journal of Hazardous Materials, with a JCR of 12.2. Regarding scientific publications by country, China showed a significant disparity in this variable, with 47.15% of publications, compared to 8.94% from Brazil and 6.50% from Spain.

Finally, a bibliometric analysis highlighted the scientific interest in MgO as a binder in civil construction, considering this topic as an open window for new research activities.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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