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Trends in construction and demolition waste management: current approaches and emerging strategies

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Tendências na disposição dos resíduos da construção civil: caminhos atuais e estratégias emergentes

RESUMO

Objetivo – O estudo tem como objetivo analisar os resultados de pesquisas que investigam o uso de Resíduos de Construção Civil (RCC) como subsídio para o melhoramento de solos em áreas de risco a deslizamentos, por meio de uma Revisão Sistemática de Literatura (RSL).

Metodologia – Trata-se de uma pesquisa aplicada, conduzida por meio de uma RSL sem delimitação temporal, empregando como termos de busca: resíduos de construção e demolição, resíduos de construção civil, melhoramento de solo e deslizamentos. As fases metodológicas envolveram seleção e busca em bases de dados, extração das informações, além de análises descritiva e bibliométrica.

Originalidade/relevância – A pesquisa se insere no gap teórico relacionado a sistemização de evidências científicas sobre o potencial geotécnico do RCC, evidenciando uma lacuna de pesquisas consolidadas acerca de sua aplicação em áreas de risco a movimento de massa, ao mesmo tempo em que destaca sua importância para a sustentabilidade urbana.

Resultados – São reveladas tendências de pesquisa, frequência de publicações e abordagens metodológicas utilizadas, confirmando o potencial do RCC como material alternativo para o melhoramento das propriedades do solo.

Contribuições teóricas/metodológicas – O estudo fortalece a compreensão sobre o emprego de resíduos de construção como solução geotécnica, bem como aponta caminhos para futuras investigações baseadas em técnicas mais robustas de análise experimental e aplicação em campo.

Contribuições sociais e ambientais – A pesquisa reforça que o uso do RCC apresenta-se como alternativa economicamente viável e ambientalmente sustentável, ao promover a destinação adequada dos resíduos e reduzir a pressão sobre recursos naturais, além de contribuir para a mitigação de riscos associados a deslizamentos em áreas urbanas vulneráveis.

PALAVRAS-CHAVE: Deslizamentos. Melhoramento de solos. RCC.

Trends in construction and demolition waste management: current approaches and emerging strategies

ABSTRACT

Objective – This study aims to analyze the results of research investigating he use of Construction and Demolition Waste (CDW) as a subsidy for soil improvement in landslide-prone areas, through a Systematic Literature Review (SLR).

Methodology – It is applied research, conducted through an SLR without temporal restriction, using the following search terms: construction and demolition waste, construction waste, soil improvement, and landslides. The methodological phases involved database search and selection, data extraction, and both descriptive and bibliometric analyses.

Originality/Relevance – The research addresses the theoretical gap related to the systematization of scientific evidence on the geotechnical potential of CDW, highlighting the lack of consolidated studies regarding its application in landslide-prone areas, while emphasizing its importance for urban sustainability.

Results – The study reveals research trends, publication frequency, and methodological approaches, confirming the potential of CDW as an alternative material for soil property improvement.

Theoretical/Methodological Contributions – This study strengthens the understanding of the use of construction waste as a geotechnical solution, while pointing out directions for future research based on more robust experimental analysis and field application.

Social and Environmental Contributions – The findings reinforce that the use of CDW is an economically viable and environmentally sustainable alternative, promoting proper waste management, reducing pressure on natural resources, and contributing to the mitigation of landslide risks in vulnerable urban areas.

KEYWORDS: Landslides. Soil improvement. CDW.

Tendencias en la gestión de residuos de construcción: caminos actuales y estrategias emergentes

RESUMEN

Objetivo – El estudio tiene como objetivo analizar los resultados de investigaciones que abordan el uso de Residuos de Construcción y Demolición (RCD) como insumo para el mejoramiento de suelos en áreas de riesgo de deslizamientos, mediante una Revisión Sistemática de Literatura (RSL).

Metodología – Se trata de una investigación aplicada, realizada a través de una RSL sin delimitación temporal, utilizando como términos de búsqueda: residuos de construcción y demolición, residuos de construcción, mejoramiento de suelos y deslizamientos. Las fases metodológicas incluyeron la búsqueda y selección en bases de datos, la extracción de información, así como análisis descriptivos y bibliométricos.

Originalidad/Relevancia – La investigación se inserta en la brecha teórica relacionada con la sistematización de evidencias científicas sobre el potencial geotécnico de los RCD, destacando la ausencia de estudios consolidados sobre su aplicación en áreas de riesgo de movimientos de masa, al mismo tiempo que resalta su importancia para la sostenibilidad urbana.

Resultados – Se revelan tendencias de investigación, frecuencia de publicaciones y enfoques metodológicos, confirmando el potencial de los RCD como material alternativo para el mejoramiento de las propiedades del suelo.

Contribuciones Teóricas/Metodológicas – El estudio fortalece la comprensión del empleo de residuos de construcción como solución geotécnica, además de señalar caminos para futuras investigaciones basadas en técnicas más robustas de análisis experimental y aplicación en campo.

Contribuciones Sociales y Ambientales – La investigación refuerza que el uso de los RCD constituye una alternativa económicamente viable y ambientalmente sostenible, al promover una disposición adecuada de los residuos, reducir la presión sobre los recursos naturales y contribuir a la mitigación de riesgos asociados a deslizamientos en zonas urbanas vulnerables.

PALABRAS CLAVE: Deslizamientos. Mejoramiento de suelos. RCD.

1 INTRODUCTION

Urban expansion is one of the most aggressive interactions between rapid population growth and environmental sustainability, driven by increasing demand for housing, urban spaces, and infrastructure (Lee *et al.*, 2024; Silva and Miotto, 2021; Voukkali *et al.*, 2024). Population and urban growth are central issues addressed by the United Nations 2030 Agenda for Sustainable Development, particularly SDG-11: Sustainable Cities and Communities, which promotes actions to mitigate environmental disasters (ONU, 2015).

In this context, urban development, combined with a lack of public policy and monitoring, can significantly contribute to adverse events such as the occupation of landslide-prone areas and the destabilization of natural environments due to deforestation, improper slope modifications, high rainfall, and poor waste disposal practices (Franco, 2021; Maurício *et al.*, 2023; Nunes and Costa, 2023). Moreover, the improper disposal of Construction and Demolition Waste (CDW) poses threats such as water contamination, environmental degradation, and the release of hazardous gases (Ding *et al.*, 2022).

Soil erosion refers to the displacement and transport of soil particles from their origin to other locations (Rehman *et al.*, 2022). This process significantly contributes to land degradation. In tropical countries like Brazil, intense rainfall and unsustainable human activities further exacerbate the risk of landslides (Francisco *et al.*, 2023; Polovina *et al.*, 2024; Wang *et al.*, 2021).

According to Pazare *et al.* (2023), soil stabilization can be achieved through three main methods: mechanical stabilization, chemical stabilization, and the addition of materials such as bitumen, concrete, or polymers. In this regard, many studies have investigated the incorporation of CDW as a sustainable alternative for waste disposal, applying it to low-bearing-capacity soils (Fangfang *et al.*, 2024; Jili and Hao, 2020; Safi and Singh, 2022).

The construction industry plays a vital role in economic and social development (Nunes *et al.*, 2020). In Brazil, it contributes approximately 4–6% of the GDP, considering investments in infrastructure, commercial developments, and public projects (IBGE, 2022). However, this sector is also a major source of environmental impact due to large-scale resource extraction and improper waste management (Oliveira *et al.*, 2020).

Construction and Demolition Waste (CDW), also referred to as Civil Construction Waste (CW), originates from construction, renovation, repair, and demolition activities within the civil construction sector (Quaglio and Arana, 2020; Ray *et al.*, 2024). In Brazil, according to the Brazilian Association of Waste and the Environment (ABREMA), approximately 45 million tons of CDW were generated in 2022. The Northeast and Southeast regions were the most significant contributors, with 8 million tons (19.6% of the national total) and 22 million tons (50.6%), respectively (ABREMA, 2023).

The National Environmental Council (CONAMA), through Resolution No. 307/2002, classifies construction waste into four categories: Class A, Reusable waste as aggregates; Class B, Waste recyclable for other purposes; Class C, Non-recyclable waste; Class D, Hazardous waste from construction processes.

This SLR focuses on the potential of Construction Waste as a resource for soil improvement in landslide-prone areas, aiming to develop solutions that promote greater soil stability, quality, and safety for the population. The research seeks to answer the following guiding questions: (1) Why are studies using waste materials for soil improvement? (2) What improvements have been observed in soils treated with CDW? (3) What are the most commonly used classes of CDW?

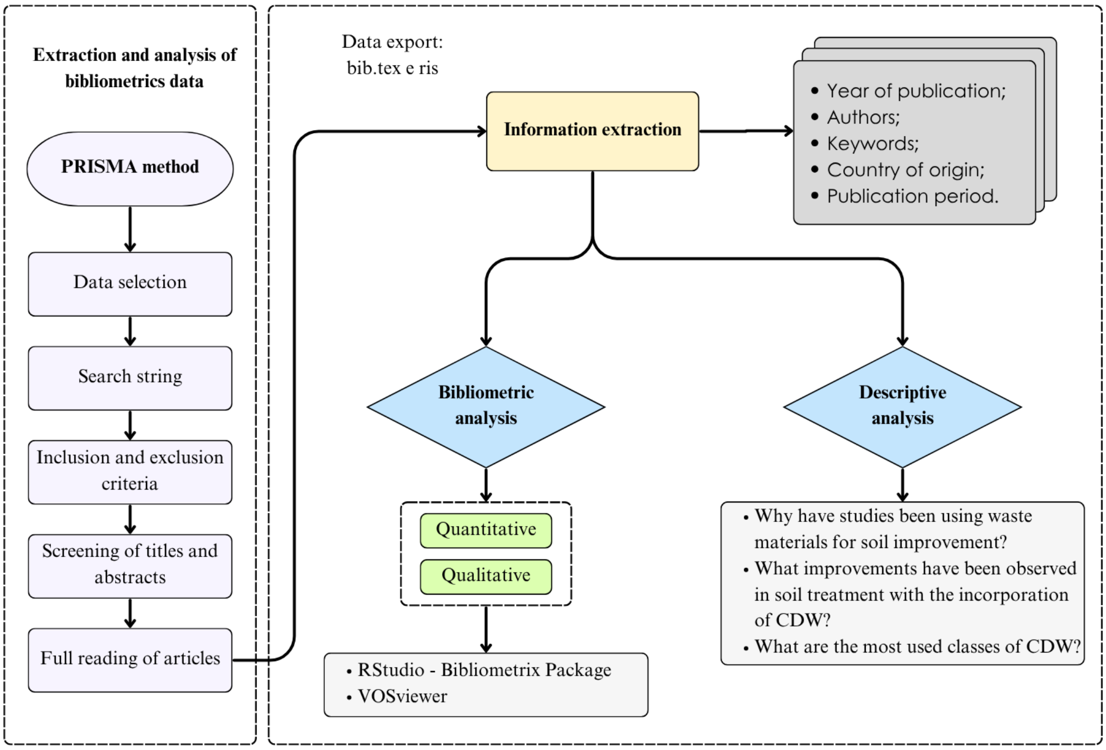
2 METHODOLOGY

This review is an applied study aiming to synthesize the findings of existing research on the use of construction waste (CDW) as an alternative material for soil reinforcement. By compiling this information in a structured and systematic manner, the study contributes to a deeper understanding of the subject while also offering insights for future research (Galvão; Pereira, 2022; Lim; Kumar; Ali, 2022).

The Systematic Literature Review (SLR) methodology was chosen due to its growing relevance in academic research. It enables a comprehensive synthesis of current knowledge, supports the development of theories explaining how or why phenomena occur, and allows for a more rigorous and transparent exploration of data (Page *et al.*, 2021).

In this study, the SLR was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Key search terms included "soil improvement" and "CDW" (Construction and Demolition Waste). The extraction and analysis of bibliometric data followed the process illustrated in Figure 1.

Figure 1 – Methodological Flowchart



Source: Prepared by the authors (2025).

The literature was obtained via the CAPES Portal of Journals, specifically using the Web of Science and Scopus databases. The search was conducted in October 2024. The search strings combined selected keywords and Boolean operators: (“Construction waste” OR “Demolition waste”) AND (“Risk areas” OR “Landslide” OR “Soil improvement”).

Searches were conducted using article titles, abstracts, and keywords. The aim was to include articles published in English, Spanish, French, and Portuguese, with no restrictions on the publication period. This approach was chosen to capture trends and developments over time, thereby making the review more comprehensive and relevant to the advancement of knowledge in the field of civil construction. The search was limited to journal articles, excluding books, book chapters, reports, conference papers, theses, dissertations, and other forms of gray literature.

Inclusion criteria required that articles be fully accessible through the database and specifically address the use of waste as an alternative material for soil reinforcement. Exclusion criteria eliminated duplicate entries, articles lacking abstracts or detailed methodologies and results, and those that did not mention soil improvement. Following this, selected articles were screened based on title, year of publication, authors, keywords, country of origin, type of study, and publishing journal. This information was then used for descriptive and bibliometric analysis.

3 RESULTS AND DISCUSSIONS

In this section, based on the information extracted from the articles selected in this Systematic Literature Review, a descriptive analysis is presented to address the research questions, along with a qualitative and quantitative bibliometric analysis.

3.1 Descriptive analysis

Keski *et al.* (2023), Sandiano and Tanzadeh (2020), Imade *et al.* (2023), and Islam *et al.* (2022) observed that population growth, urban and economic development, increasing consumption patterns, and the depletion of natural resources have led to a rise in waste generation. This issue has drawn the attention of researchers, government agencies, institutions, and companies due to the high costs of waste management and its negative impact on the environment.

With rapid urbanization, the demand for housing has increased significantly, resulting in the occupation of areas with low-bearing-capacity soils, such as steep slopes. These settlements often disregard appropriate construction methods, compromising the structural integrity and lifespan of buildings (Bagriacik, 2022; Bargiacik *et al.*, 2021; Rimal; Poudel; Gautam, 2019; Truong; Thi; Thanh, 2020). Consequently, geotechnical engineers have faced growing challenges in improving soil properties and have sought various methods to stabilize slopes (Islam *et al.*, 2023; Kang; Kim, 2024; Silva; Lafayette, 2024).

According to Cinar (2024), Pastor; Chai; Sánchez (2023), Pastor *et al.* (2019), Waheed *et al.* (2021), Woldesenbet (2022), and Zaini; Hasan (2023), soil stabilization is used to improve the geotechnical properties of natural soils when they lack the necessary strength or stiffness for construction. The goal is to reduce soil deformability, increase shear strength, and enhance durability and overall engineering performance.

Silva; Fucale; Ferreira (2019) found that Construction and Demolition Waste (CDW) contributes to several issues, such as illegal dumping near public areas, vacant lots, water bodies, and roads. These sites often attract additional waste, worsening environmental degradation and promoting the spread of disease vectors. Furthermore, the limited availability of soils suitable for engineering projects, combined with the scarcity of non-renewable raw materials, underscores the need to consider CDW as a viable alternative for soil improvement.

In recent years, the recycling of construction waste has gained importance as a cost-effective and environmentally sustainable solution (Gucek *et al.*, 2024; Jain; Jha; Shivanshi, 2020; Keskin *et al.*, 2023). Bagriacik (2022) highlights the advantages of reusing CDW, including reducing the volume of waste, preserving natural resources, boosting the economy, and advancing recycling technologies.

Hidalgo; Carvajal; Munoz (2019) noted that CDW represents a significant portion of global waste generation, with bricks forming a major part of this waste in many countries. In their study, they explored the use of brick powder to control soil erosion, confirming its effectiveness in improving compaction, strength, and workability, while also presenting an economically attractive solution.

Perera *et al.* (2023) reveal that approximately 130 million tons of glass waste are generated annually worldwide, with an average recycling rate of only 21%. In light of this, the authors evaluated the effect of using recycled crushed glass in clayey soil with low plasticity. Their findings showed that the non-biodegradable nature of glass helped maintain the soil's physical and chemical properties. Additionally, the mechanical strength was satisfactory, and the treated soil exhibited low permeability, good workability, and enhanced durability.

Geçkil; Sarici; Ok (2022) observed that the recycling and reuse of rubber tires not only improve engineering properties through granular filling but also contribute to sustainably reducing environmental problems. Their study aimed to determine the stress-strain behavior of a rigid circular base placed on granular fill reinforced with recycled rubber tires in weak soil. The results showed a reduction in soil deformation and an increase in load-bearing capacity.

Lima; Arrieta-Baldovino; Izzo (2023) discuss the use of recycled asphalt pavement (RAP) incorporated into a sedimentary soil from the Guabirotuba Formation in Curitiba, southern Brazil. They tested RAP in varying percentages (0% to 80% by weight), mixed with pure soil, both with and without the addition of Portland cement. The results indicated a reduction in optimal moisture content and improved tensile strength.

Febriansya *et al.* (2022) added very low-density expanded polystyrene (EPS) to soil mixtures to analyze its effect on mechanical properties. The study demonstrated that EPS offers a wide range of practical and beneficial applications, particularly in slope stabilization and in reducing lateral soil pressure against retaining structures.

Urian *et al.* (2023) state that more than 300 million tons of plastic waste are generated each year, with a significant portion ending up in the environment, where it can persist for decades. The authors argue that incorporating plastic waste (PET) into soil improvement strategies can reduce pollution while simultaneously enhancing soil's mechanical properties and load-bearing capacity—all at a reduced cost.

Ana-Maria et al. (2023) found that various types of plastic waste, such as high-density polyethylene (HDPE) and polypropylene (PP), can be used to reinforce soil structure. In their experiment, 2 kg of clayey soil was mixed with 2%, 4%, and 6% PET. The study confirmed that plastic waste improves soil chemistry, strengthens geotechnical properties, and helps address pollution caused by plastic waste.

Table 1 summarizes the main improvements observed in soils treated with CDW. The key enhancements include decreased permeability, improved workability and durability, increased compaction, and better stress-strain behavior under shear conditions.

Table 1 – Improvements observed in soil with incorporation of CDW

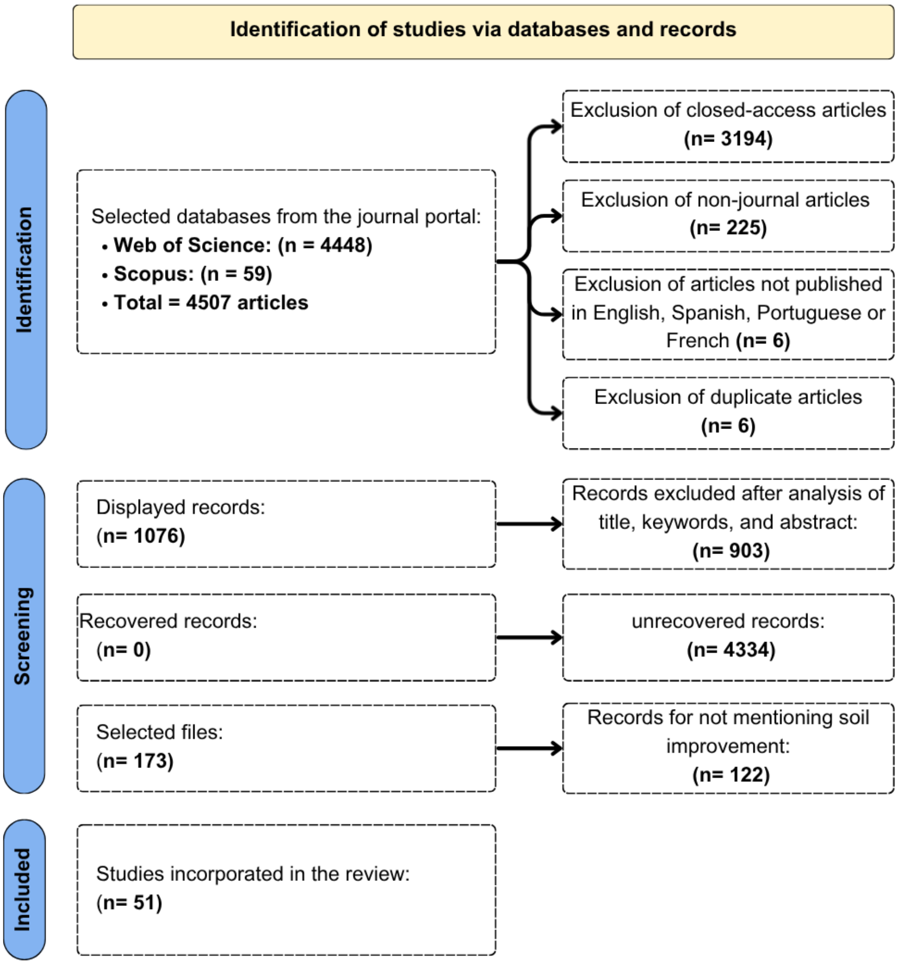
Improvements observed in soil	Authors
Decreased permeability	Jiang *et al.* (2021) Perera *et al.* (2023) Silva *et al.* (2019) Islam *et al.* (2022)
Improved shear stress-strain behavior	Jain e Jha (2020) Nguyen *et al.* (2024) Lucarelli *et al.* (2022) Correia e Rocha (2021) Waheed *et al.* (2021)
Development of workabiilty and durability	Cristelo *et al.* (2015) Kang e Kim (2024) Imad *et al.* (2023) Hidalgo *et al.* (2019) Silva e Lafayette (2024) Farah e Nalbantoglu (2019)
Increased degree of compaction	Cristelo *et al.* (2017) Cristelo *et al.* (2015) Febriansya et al. (2022) Al-Homidy *et al.* (2017) Lopez *et al.* (2017) Hidalgo *et al.* (2019) Jiang *et al.* (2021) Urain *et al.* (2023) Niroumand *et al.* (2023) Al-Dulaimi e Seyedi (2023) Islam *et al.* (2023) Gucek *et al.* (2024)

Source: Prepared by the authors (2025).

3.2 Bibliometric analysis

To conduct the Systematic Literature Review (SLR), an initial raw database was compiled with 4,507 articles published between 1946 and 2024. To ensure alignment with the research theme, the Rayyan AI software—developed by the Qatar Computing Research Institute (QCRI)—was used to identify duplicate records and apply the inclusion and exclusion criteria. The flowchart shown in Figure 2 illustrates the results of this process.

Figure 2 – PRISMA Flowchart



Source: Prepared by the authors (2025).

A total of 51 articles met the research objectives. Of these, 49 were written in English (96.04%) and 2 in Portuguese (3.96%). The selected scientific publications span the period from 2015 to 2024.

In Figure 3, the number of publications and the average number of citations per year are presented. The years 2016 and 2018 did not feature any studies using construction waste for soil reinforcement and were excluded from analysis based on relevance criteria. The year 2023 recorded the highest number of publications (12), while 2017 had the highest average number of citations per article, at 5.5 citations.

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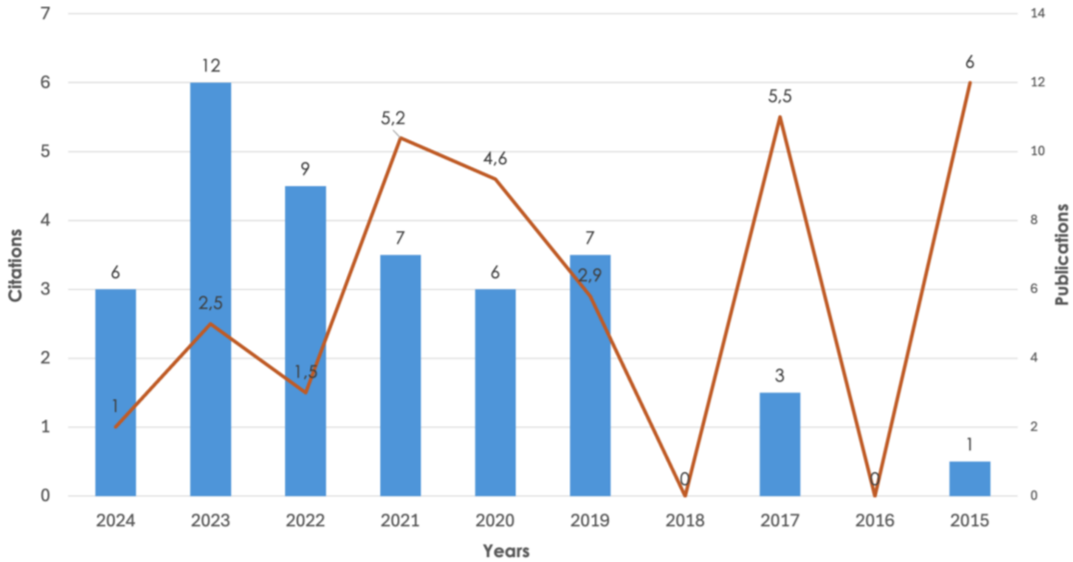
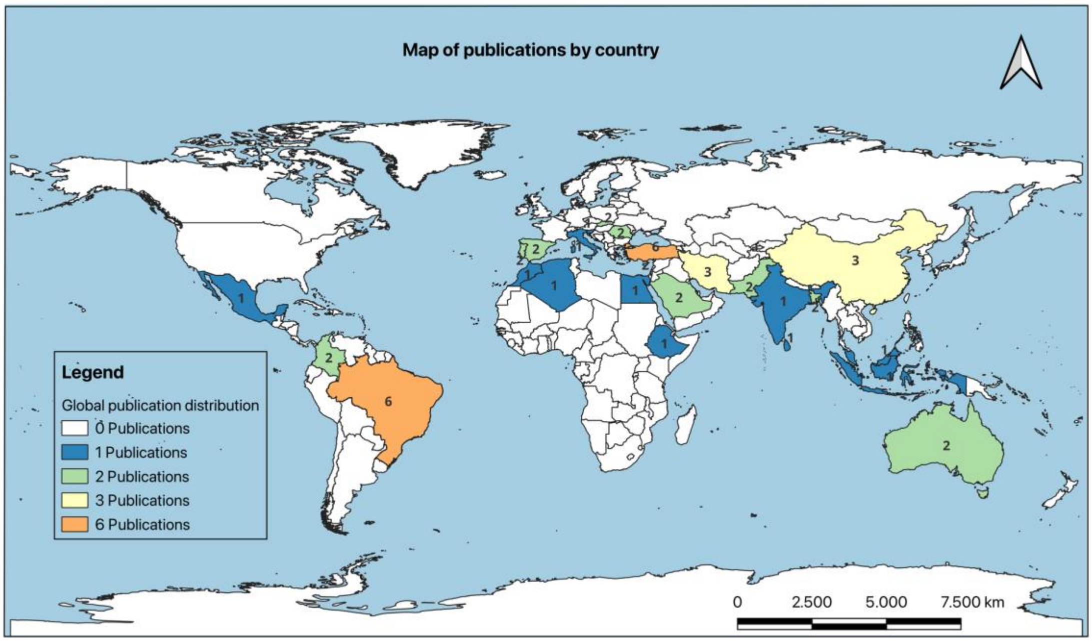
Figure 3 – Growth of scientific production and citations by year



Source: Prepared by the authors (2025).

Figure 4 presents the scientific contributions by country regarding the use of Construction and Demolition Waste (CDW) in soil treatment. Turkey and Brazil led with 6 publications each, followed by China and Iran with 3; Australia, Bangladesh, Colombia, Cyprus, Pakistan, Romania, Portugal, Saudi Arabia, Slovakia, and Spain with 2 publications each; and Algeria, Egypt, Ethiopia, India, Indonesia, Iraq, Italy, South Korea, Malaysia, Mexico, Morocco, Slovenia, and Sri Lanka with 1 publication each.

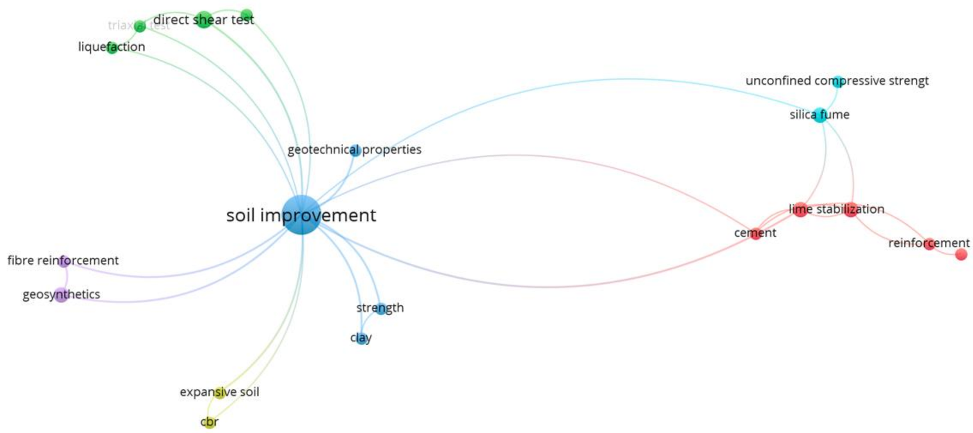
Figure 4 – Geographical distribution of research



Source: Prepared by the authors (2025).

From the 51 publications obtained via Web of Science and Scopus, a total of 187 keywords were analyzed using VOSviewer software. This enabled the creation of a keyword co-occurrence network map (Figure 5), where the size of each node corresponds to keyword frequency. The most frequently used keyword was "soil improvement."

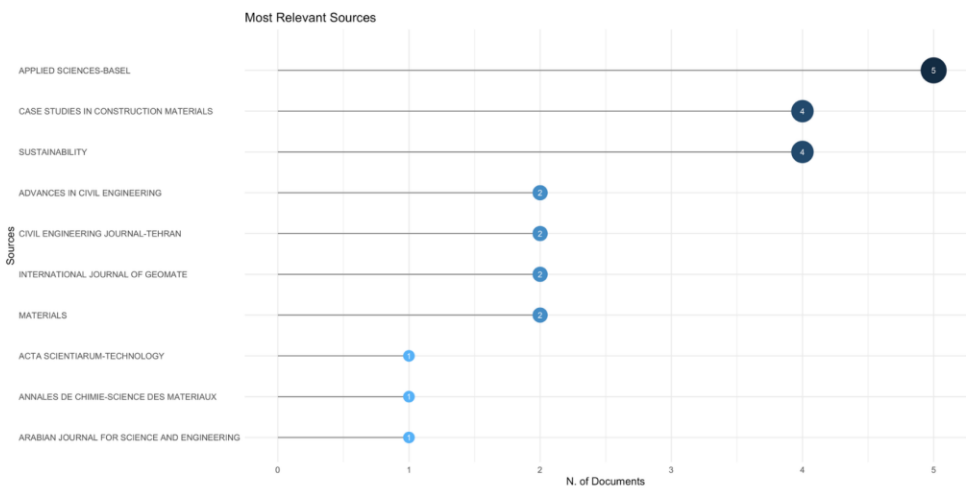
Figure 5 – Keyword correlation network



Source: Prepared by the authors (2025).

The selected articles, focused on soil improvement using CDW, were published between 2015 and 2024 across 31 journals. Figure 6 highlights the most relevant journals, with the top five being: Applied Sciences-Basel Case Studies in Construction Civil Sustainability Advances in Civil Engineering Civil Engineering Journal-Tehran.

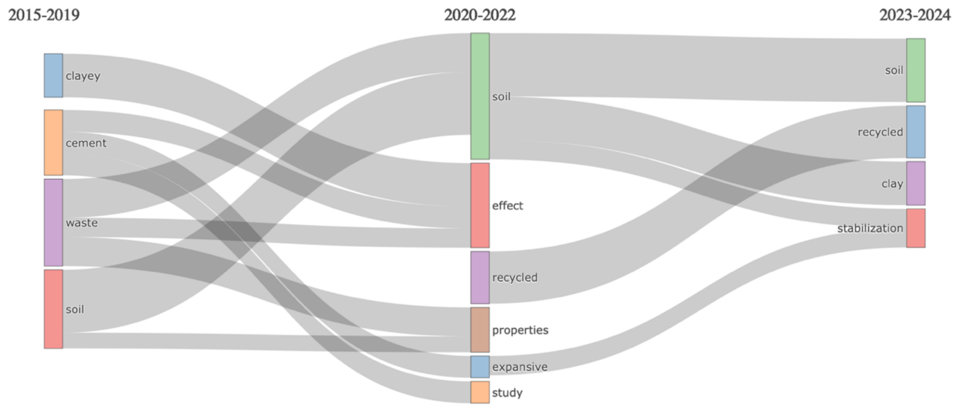
Figure 6 – Most revelant journals by number of publications



Source: Prepared by the authors (2025).

Regarding thematic trends, Figure 7 uses a Sankey diagram—following the approach of Shi et al. (2020)—to illustrate the evolution and interconnection of research topics over time. Between 2015 and 2019, themes such as soil, clay, cement, and waste dominated. From 2020 to 2022, attention shifted to effects, recycling, and property studies, while in 2023 and 2024, the focus expanded to include soil stabilization.

Figure 7 – Thematic evolution from 2015 to 2024 (Sankey diagram)



Source: Prepared by the authors (2025).

Of the 51 articles included in this review, 8 (15.68%) addressed the use of industrial waste for soil improvement, while 43 (84.32%) focused on construction and demolition waste (CDW). Table 2 presents the classification of construction waste used in the selected studies, showing that 16 articles used Class A waste, and 27 articles used Class B waste, in accordance with CONAMA guidelines.

Table 2 – Classification of CDW in selected studies

CDW Classification according to CONAMA nº 307	Authors
Class A	Silva e Lafayette (2024) Cinar (2024) Kang; Kim (2024) Zada *et al.* (2023) Islam *et al.* (2023) Imad *et al.* (2023) Al-dulaimi e Seyedi (2023) Lima *et al.* (2023) Islam *et al.* (2022) Bagriacik (2022) Jayanthe e Mampearachchi (2021) Bagriacik *et al.* (2021) Jiang *et al.* (2021) Hidalgo *et al.* (2019) Al-Homidy *et al.* (2017) Lopez-Lara *et al.* (2017)
Class B	Nguyen *et al.* (2024) Iliyas *et al.* (2024) Gucek *et al.* (2024) Urian *et al.* (2023) Perera *et al.* (2023) Niroumand *et al.* (2023) Ana-Maria *et al.* (2023) Febriansya *et al.* (2022) Woldesenbet (2022) Meddah *et al.* (2022) Geçkil *et al.* (2022) Lucarelli *et al.* (2022) Ashiq *et al.* (2022)

Table 2 – Classification of CDW in selected studies - continuation

Classificação do RCC segundo CONAMA nº 307	Autores
Classe B	Elzamel *et al.* (2022) Lv *et al.* (2021) Bozyigit *et al.* (2021) Correia e Rocha (2021) Malidarreh *et al.* (2020) Sandiani e Tanzadeh (2020) Marçal *et al.* (2020) Blayi *et al.* (2020) Silva *et al.* (2019) Xavier e Menegotto (2019) Nguyen (2019) Silva e Lafayette (2024) Farah e Nalbantoglu (2019) Cristelo *et al.* (2017) Cristelo *et al.* (2015)

Source: Prepared by the authors (2025).

4 CONCLUSION

The Systematic Literature Review proved to be an effective method for analyzing and understanding the main influences of using Construction Waste for soil improvement in risk areas, serving as a valuable guide for future research. By applying systematic filtering and defined inclusion and exclusion criteria, it was possible to conduct a robust qualitative and quantitative analysis of the selected articles.

The review was based on a database of 51 articles, which highlighted the growing importance of recycling Construction Waste (CW). This approach helps reduce the consumption of natural resources, supports economic development, and promotes recycling practices. Among its many advantages, the use of CW for soil improvement has shown to enhance resistance, workability, and durability. Furthermore, most studies emphasized the use of Class A and B waste, as classified by environmental regulations, for these purposes.

The analysis also revealed that scientific production on this topic has been discontinuous over the years. However, 2023 marked a significant increase in publications, with 12 articles, while 2017 recorded the highest average number of citations per article. The bibliometric data showed that Brazil and Turkey stood out with the highest number of studies (6 each), while the overall research was distributed across 25 countries, confirming the global relevance of the topic.

In conclusion, the combined effects of population growth and the expansion of urban areas into regions with low load-bearing soils have created a pressing need for innovative solutions in geotechnical engineering. The use of Construction and Demolition Waste (CDW) offers a cost-effective and environmentally sustainable method for improving soil properties, making it a promising strategy for future applications.

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STATEMENTS

EACH AUTHOR'S CONTRIBUTION

When describing the participation of each author in the manuscript, use the following criteria:

- **Study conception and design**: Kalinny Patrícia Vaz lafayette e Jonas da Silva Bezerra.
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- **Formal Analysis**: Joyce Ingrid de Arandas Sobral.
- **Acquisition of Financing**: Not applicable.
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DECLARATION OF CONFLITS OF INTEREST

We, **Joyce Ingrind de Arandas Sobral, Kalinny Patrícia vaz Lafayette, Jonas da Silva Bezerra, Diogo Henrique Fernandes da Paz**, declare that the manuscript entitled "**Trends in construction and demolition waste management: current approaches and emerging strategies**":

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