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Research mapping of waste glass application in asphalt pavement: A scientometric review and visualization

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ABSTRACT

Globally, the application of waste materials in the pavement industry has increased over the years. This is due to the paradigm shift to sustainability in the industry. Asphalt pavements' construction process constituent materials consumes a sizeable the world's conventional constituent material use, which increases cost and contributes to carbon emissions. This has encouraged researchers in the area to investigate alternative materials like waste glass in the asphalt pavement industry to improve performance and promote sustainability. However, despite many experimental studies showing the advantages of incorporating glass in asphalt pavement, the scope and development are still not well understood. Therefore, the need for a comprehensive review of the area knowledge and global trends is encouraged. Thus, in this review, a scientometric approach was adopted to analyse research articles indexed in Scopus from 2015 to 2025 for data gathering, and VOS viewer was employed to prepare a co-occurrence for mapping analysis and a visualization map based on the bibliographic data gathered. The results showed a progressive rise in research activity with literature focusing on asphalt binder modification, mixture performance, durability, and sustainability. China, Australia, India, the United States, Canada, and Iran were found to be the most productive countries in this field of study, and Construction & Building Materials, and Lecture Notes in Civil Engineering were found to be major publication sources. It can be concluded that the research topic is growing yearly and spreading worldwide, which will encourage the circular economy and sustainability in the pavement industry. This review promotes SDGs 9,11 and 12 by encouraging the repurposing the use of waste materials and sustainable innovation in asphalt pavement industry.

1. Introduction

Conventional asphalt concrete is mostly composed of natural aggregates, fillers, and petroleum-based binders (Ferdaus, Masri, Hasan, & Jaya, 2025; Gao et al., 2018). Although asphalt pavement performs in a variety of climatic conditions, the demands on it have increased significantly in recent years due to rising traffic loads and more difficult service environments (Musco, Tarsi, Tataranni, Salzano, & Sangiorgi, 2024; Wu, Jusli, Anggraini, Jaya, & Zhang, 2025). Also, the cost of modification and use of conventional constituent materials is high (Özdemir, Yalçın, & Yılmaz, 2025; Yang, Cui, Ma, & Zhu, 2023; Yaro, Jele, Adedeji, Ngubane, & Ikotun, 2025). As a result, modifying asphalt binders and mixtures with more sustainable modifiers or additives has become an important and well-liked method for improving pavement performance and extending service life, and lowering cost (Jaya, Munirwan, & Bunyamin, 2025; Malluru et al., 2025). Waste glass is a significant portion of municipal solid waste in countries, and is still largely underutilised despite its high silica content and superior physical properties for engineering applications (Bekerė & Malaiškienė, 2025; Roy, 2025). Achieving sustainability in the pavement industry depends on countries' capacity to use fewer virgin materials and transition to circular-economy building methods(Abdulrahman et al., 2025; Barbhuiya, Qureshi, & Das, 2025; Yaro et al., 2024). Due to the increasing use of innovative recycling methods, using glass waste in asphalt pavements is a practical strategy to enhance mechanical performance, minimise lifecycle impacts, and save construction costs (Kalampokis, Kalama, Kesikidou, Stefanidou, & Manthos, 2023; Yaro et al., 2024).

The work of literature has shown various applications of glass waste in the asphalt pavement industry (Bekerė & Malaiškienė, 2025; Cheng et al., 2021; Ogundana & Afolalu, 2024). However, the scope of study on their utilisation is still being disseminated, and the global research trajectory has not yet been thoroughly documented. Therefore, documenting the advances, areas of interest, and new developments in glass-waste utilisation in asphalt pavement is essential. Thus, this review employed a scientometric method to analyse the trends, scientific findings, and thematic advancements related to the use of waste glass in asphalt pavement engineering.

2. Utilisation of Waste glass in asphalt pavement

Based on the work of literature, the utilisation of waste glass in the pavement industry includes its application in asphalt binders and mixtures due to its high silica content, as well as its particle nature (Moreno-Navarro, Pérez-Martínez, Martín-Marín, Sol-Sánchez, & del Carmen Rubio-Gámez, 2015; Ogundana & Afolalu, 2024; Salem, Khedawi, Baker, & Abendeh, 2017). A study conducted by Salem et al. (2017) examined the viability of using crushed waste glass in asphalt concrete mixtures in place of some of the fine particles. The study showed that replacing some of the fine particles in asphalt concrete with crushed waste glass (5–20%) increases skid resistance, durability, and Marshall stability while lowering the ideal asphalt percentage, with 10% glass shown to be the optimum content. Similarly, Moreno-Navarro et al. (2015) discovered that AC16S asphalt mixtures containing waste glass contents of 8% as a partial substitute for sand offer sufficient stiffness, moisture resistance, and deformation performance for surface courses. However, the study observed that to improve the mechanical properties of glass-modified mixtures, calcium carbonate was shown to be the most effective filler.

Also, a study conducted by Kalampokis et al. (2023) observed a decrease in stiffness and rutting resistance in glassphalt mixtures that contained 10–15% tempered and monolithic waste glass. Nevertheless, there was no improvement in solar reflectance, and moisture resistance decreased at 15% glass (ITSR < 80%), suggesting the necessity for surface treatments or modifiers. The results highlight the necessity of surface treatments or modifiers to enhance glass-modified mixture performance. In another study, Cheng et al. (2021)studied the viability of using waste glass as a partial aggregate substitute in asphalt micro-surfacing mixtures. The results showed that waste glass's prominent angular form enhances surface texture and skid resistance in asphalt microsurfacing. Higher glass concentrations, however, were found to enhance abrasion loss and deformation; therefore, 15% fine glass and 10% coarse glass are the suggested limits in order to balance performance and durability.

Similarly, Gedik (2021) assessed the viability of replacing crushed stone dust (CSD) in asphalt mortars and mixtures with recycled waste glass (RWG), a sustainable filler. Tests were conducted on three filler–bitumen ratios (0.1, 0.2, and 0.4). To characterise RWG and CSD mastics, was evaluated using both conventional and rheological testing were employed. The asphalt mixture's mechanical performance was evaluated, and SEM imaging was assessed for the morphological interactions. The findings validated that RWG-composite mixtures fulfilled standard requirements and demonstrated enhanced fatigue and thermal stability, hence bolstering their potential for usage for sustainable pavement applications.

In a recent study, Yu, Jin, Liu, You, and Li (2024) shown that adding waste glass particles (2.36–4.75 mm) to SBS-modified asphalt, when surface-treated with a silane coupling agent, greatly improves mechanical and safety performance of asphalt pavement. Dynamic stability and skid resistance rose by 42.3% and 38.6%, respectively, at an ideal glass content of 6%, demonstrating the efficacy of surface modification in enhancing glass–asphalt adhesion. Also, Khedaywi, Haddad, and Khaldi (2024) found that incorporating waste glass powder (0–20% by volume of the binder) increases resistance to high-temperature rutting, Marshall stability, and binder stiffness. Because the new binder had better rheological qualities, optimal amounts of 10–15% WGP improved fatigue life, decreased permanent deformation, and increased resilient modulus. Dalloul (2013) investigated the replacement of Trabia aggregate of the same gradation (0/4.75 mm) with crushed waste glass from bottles as filler and coarse sand in the asphalt binder course. Marshall stability, flow, specific gravity, and air voids were the performance tests used to evaluate mixtures with different glass amounts. The Marshall method was used to establish the optimum binder content (OBC), which came out to be 5.1% of the total mixture weight. The results confirmed its viability for binder course applications by showing that a 7.5% glass replacement by aggregate weight produced characteristics that were in line with regional and global standards.

In microsurfacing mixtures, Mohammadi et al. (2023)examined the use of waste glass powder (WGP) at weight percentages of 0%, 25%, 50%, 75%, and 100% as a mineral filler substitute. Wet track abrasion, load wheel test–sand adhesion, mix time, wet cohesion, and horizontal/vertical displacement were used to assess performance. For toxicological, chemical, and microstructural analyses, TCLP, FTIR, and FESEM were employed. In comparison to the control, 75% WGP reduced aggregate loss, sand adhesion, horizontal displacement, and vertical displacement by 62%, 20%, 30%, and 36%, respectively. The results demonstrated that raising WGP greatly improved resistance to stripping, bleeding, and rutting.

Because bitumen encapsulates particles, TCLP showed that heavy metal leaching from WGP-modified mixes was 80% lower than that from stored WGP. Results demonstrate WGP's twin benefits for microsurfacing applications in terms of performance and the environment. Jony, Al-Rubaie, and Jahad (2011) looked into the usage of waste glass powder (WGP) in hot asphalt concrete mixtures as a mineral filler substitute for conventional Portland cement (OPC) and limestone powder. Three filler types limestone powder, OPC, and WGP—were used to create nine combinations with filler proportions of 4%, 7%, and 10% by total aggregate weight. According to Marshall property evaluation, WGP at 7% produced asphalt mixtures with up to 13% more stability, up to 39% less flow, and up to 10% less density than OPC and limestone combinations, indicating excellent performance. According to the results, WGP can be used as a filler in asphalt pavement; the optimal balance between workability and mechanical performance is provided by a 7% dosage. Therefore, the current work uses scientometric analysis tools to thoroughly analyse ten years of research development on the usage of waste glass in asphalt pavements. The review exclusive focus on waste glass application in asphalt binder and mixtures. The review also takes into account publications that were published primarily between 2015 and 2025. The main objective of this review is to analyse and determine the publication trend, most important journals, publication type, research topic, and countries in the study area. By offering an organised summary of worldwide research efforts, the results will increase the body of knowledge on sustainable paving materials. Thus, the current work differs from earlier reviews that dealt with a general comprehensive review of waste glass in asphalt mixtures.

3. Methodology

A scientometric review's reliability, accuracy, depth, and general quality are all directly impacted by the database choice, making it an essential element in the process (Baffa et al., 2025; Yousafzai et al., 2025). Scientific mapping incorporates a number of large bibliometric datasets as primary sources. Scopus was chosen as the primary data source for this study because of its comprehensive discipline coverage and strict indexing guidelines (Baffa et al., 2025; Yaro, Sutanto, et al., 2025). This decision guarantees scientific consistency, robustness, and thorough coverage of global research to retrieve published publications related to the use of waste glass in asphalt pavements.

3.1 Data collection

The obtained data served as the foundation for further performance analysis, co-authorship mapping, and keyword co-occurrence visualisation, which were utilised to look at thematic developments and research trends in the field (Baffa et al., 2025).

Journal papers were the main document type employed in this study because they undergo peer review, which guarantees their quality and dependability. To find pertinent literature from Scopus databases, search terms like “waste glass" OR "recycled glass" OR "glassphalt" AND "asphalt" OR "bitumen" OR "pavement" AND "performance" OR "durability" OR "rutting" OR "fatigue" OR "sustainability" were used. These searches covered the years 2015 to 4th December 2025, capturing ten years of research outputs in this field. Scientometrics is the application of quantitative methods to study the framework and development of scientific knowledge. Baffa et al. (2025) state that the purpose of scientometric research is to examine the intellectual landscape of a knowledge domain, including the primary problems that scholars address and the methods they employ. According to Yaro et al. (2023), one of the most widely used techniques for evaluating research performance and mapping trends among authors, journals, institutions, and countries is scientificometric analysis. By identifying key research directions and revealing structural trends, this method enables the mapping of a scientific field in a clear and comprehensive manner. Scientometric and bibliometric methods are being used more frequently in pavement engineering study to comprehend new trends, research hotspots, and significant publications(Yousafzai et al., 2025). The relatedness of publications is ascertained using citation analysis, and the knowledge structure and thematic progression within the waste-glass asphalt study domain can be visualised through co-occurrence analysis, which assesses correlations between keywords, authors, and institutions.

3.2 Data visualisation

VOSviewer was utilised in this work to analyse the retrieved bibliometric data. The study's general research methodology is depicted in Figure 1.

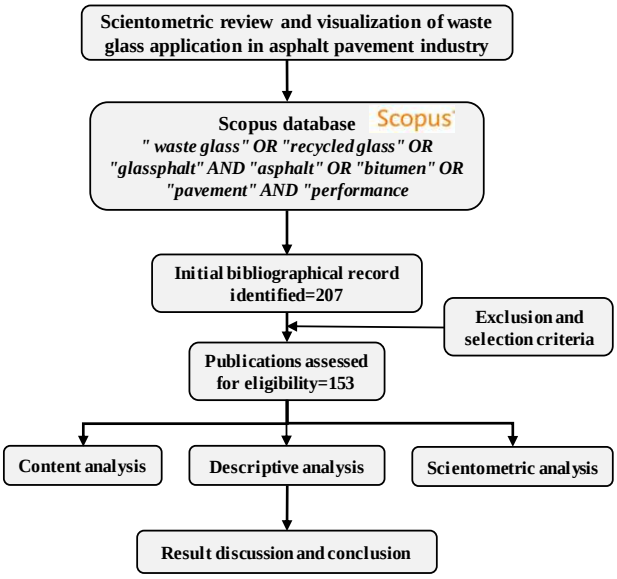

Figure 1. Study methodology flowchart

4. Results and discussions

4.1. Publication trend

The distribution of publications on waste-glass asphalt applications from 2015 to 2025 is shown in Figure 2. The findings show that, with one (1) publication in 2005 and 2007, research activity started to pick up steam between 2011 to 2013, and 20 articles were published in 2022, which shows that glass-modified asphalt mixtures are receiving more attention from academics. The number of publications has been continuously rising, with 23 in 2024 and 27 in 2025 at the time the data was collected, indicating continued scholarly interest. This growing body of research emphasises the potential of e-waste for circular economy applications as well as the advances in waste processing, global net-zero ambitions The circular economy, growing interest in sustainable pavement solutions, and the integration of optimisation techniques to direct material selection, mixture design, and performance evaluation are all expected to contribute to the upward trend, which will ultimately support more resilient, economical, and ecologically friendly pavement infrastructure.

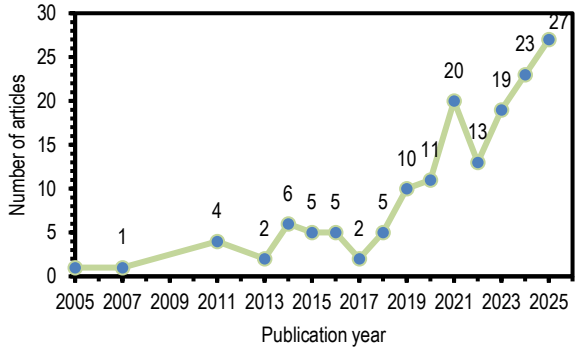

Figure 2. Publication trend from 2005 to 2025

4.2. Document type

This study examined various publication categories to reflect the scope of research on waste glass application in pavement engineering. As Figure 3 illustrates, journal articles predominate in the field with 72.1%, confirming their function as the primary medium for disseminating scientific research. Conference papers with 13%, which demonstrate the ongoing significance of academic forums for advancing sustainable asphalt pavement research. There are just a few other outputs, such as conference reviews with 6.5%, journal reviews having 5.2% and book chapters with 3.2%. The need for more thorough syntheses is shown by the comparatively low percentage of review-oriented articles. The diversity of publication types reflects both the maturing of the research topic and the broader alteration of academic communication in this quickly developing sector.

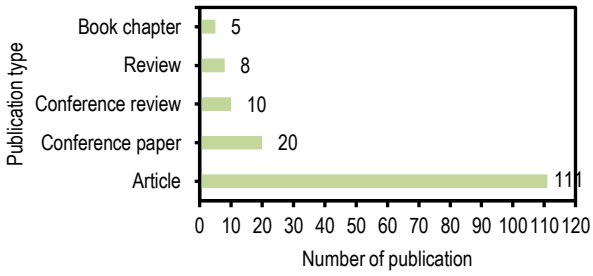

Figure 3. Publication type in the study area

4.3. Keywords co-occurrences

One important bibliometric approach for determining a discipline's primary study areas is keyword analysis (Yousafzai et al., 2025). By emphasising the relationships between subjects and subtopics, networks created by keyword analysis provide a thorough understanding of a field of study. This method depends on how frequently co-occurring keywords appear in publications and how strongly they are associated. The co-occurrence network of terms associated with incorporating waste-glass in asphalt binder or mixtures research was developed in this review using VOSviewer software. The analysis includes both index keywords assigned by journals and keywords supplied by authors. As seen in Figure 4, the resulting network was created using a threshold of five (5) keywords, with a minimum of 5 occurrences per term. The number of times a keyword appears in the literature is represented by the size of each node in the visualisation, the strength of the associations between keywords is indicated by the thickness of connecting links, and the degree of interconnectedness within the study domain is represented by the closeness of nodes. The main themes and new developments in the use of waste glass in asphalt pavements are clearly outlined in this report.

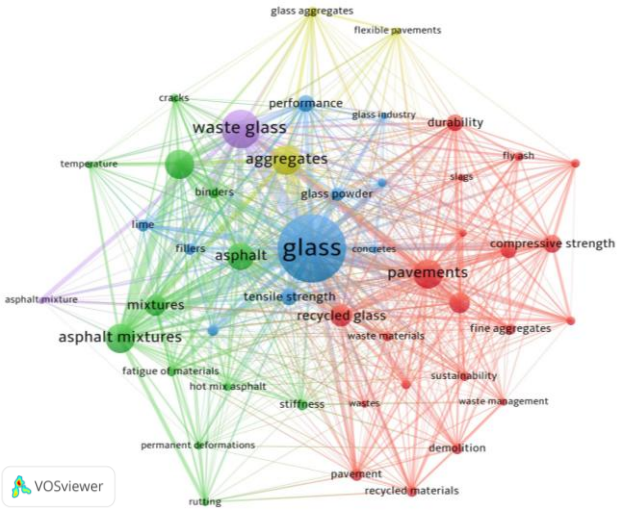

Figure 4. keywords co-occurrences

The top ten (10) keywords with the highest co-occurrence values and link strength are shown in Figure 4, emphasising the terms that have drawn more attention and are closely related to other keywords. The terms "glass," "waste glass," "asphalt mixture," "recycled glass," "pavements," "durability," "binder," "compressive strength," "aggregates" and "performance" showed the highest occurrences and total link strength, suggesting that these subjects have drawn a lot of attention from researchers and serve as important links in the network. In order to avoid leaving out relevant and significant study subjects, terms that were part of the original search string, including "waste glass" and "glassphalt," were kept in the analysis even though they naturally had higher values.

4.4. Research topic trends

Through co-occurrence analysis, the keyword clusters reveal current research trends in waste-glass asphalt applications. Comprehending these clusters facilitates the direction of future sustainable pavement engineering research and innovation. The study revealed three main clusters as shown in Figure 5. With ten (10) terms, the largest cluster (red) demonstrates a strong emphasis on recycling and sustainability related to waste glass application in asphalt pavement. The top five co-occurring keywords are glass, recycling, pavement, sustainable development, recycled glass, and durability. With a focus on developing more durable and sustainable pavements, this cluster identifies research priorities for promoting the circular economy and sustainability of asphalt mixtures with the incorporation of waste glass. The second cluster (green) with nine keywords pertaining to the application of waste glass powder as filler or binder modifier to improve asphalt pavement performance. The top six co-occurring keywords are waste glass, asphalt pavement, asphalt, performance, filler, and binders. The primary goal is to assess the performance of incorporating glass powder as a filler replacement or modifier in asphalt pavement to improve its performance.

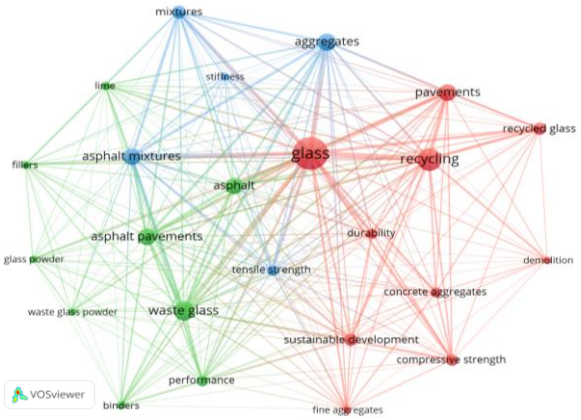

Figure 5. Research trend related to waste glass application to pavement

Four keywords make up the third cluster (blue), which is mostly concerned with waste glass as aggregate replacement for improving asphalt pavement performance. The keywords are asphalt mixtures, aggregates, mixtures, tensile strength, and stiffness. This cluster search mainly looks at how incorporating glass influences the pavement's tensile strength, stiffness, and performance. The top six co-occurring keywords are waste glass, asphalt pavement, asphalt, performance, filler, and binders. Together, these clusters show a research environment in the field of glass-modified asphalt pavements that strikes a compromise between sustainability, performance improvement, and methodological innovation.

4.5. Journal bibliographic coupling

The collected data were bibliometrically examined using VOSviewer to determine the most significant publishing sources driving the development of glass waste application in sustainable pavement construction, as shown in Figure 6. The number of citations and academic journals that published at least five (5) articles on the application of waste glass in the asphalt pavement industry between 2015 and 2025. Notably, with seven (7) and four (4) papers contributed, respectively, Construction and Building Materials and lecture notes in civil engineering were the top two sources in terms of publication volume. The size of each map's spherical shape represents the relative importance of the journal in its field; a larger sphere denotes more articles and influence.

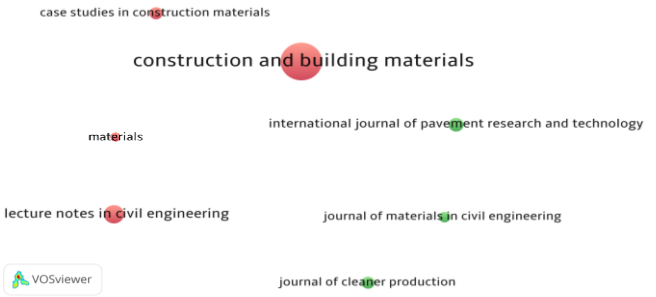

Figure 6. Major publication sources related to waste application in asphalt pavement

Two clusters, shown by colours like red and green, are groups of journals that share the same academic or subject focus and are frequently discussed together. Even though many of these journals had a limited focus on the broader implications of waste glass in the pavement industry, a core group of journals, including Construction and Building Materials, Journal of Cleaner Production, and Lecture Notes in Civil Engineering, Case Study in Construction Materials, International Journal of Pavement Research and Technology, and the Journal of Materials in Civil Engineering, have had a significant impact on the scholarly discussion surrounding sustainable and digitally enabled pavement systems. These findings give upcoming researchers crucial information on where to publish or locate high-impact works in the subject.

4.6. Countries bibliographic coupling analysis

Bibliographic coupling was used to determine which nations had made the biggest contributions to the advancement of waste-glass asphalt research. The analysis, which used a minimum criterion of two papers per country, is shown in Figure 7. The results show that the most mentioned countries in this field of study are China, Australia, India, the United States, Canada, and Iran, which reflects their pivotal roles in developing sustainable pavement technologies. Additionally, research outputs from underdeveloped nations receive fewer citations. When it comes to encouraging sustainable construction methods and using recycled materials, such as waste glass, in pavements, South Africa and Nigeria have become regional pioneers in sub-Saharan Africa. These can be attributed to the increasing interest in eco-friendly pavement solutions and the use of circular economy ideas in infrastructure construction. These results underline the need to increase contributions from underrepresented countries in order to speed up knowledge sharing and sustainable innovation in waste-glass asphalt applications, and also reveal a global discrepancy in research visibility.

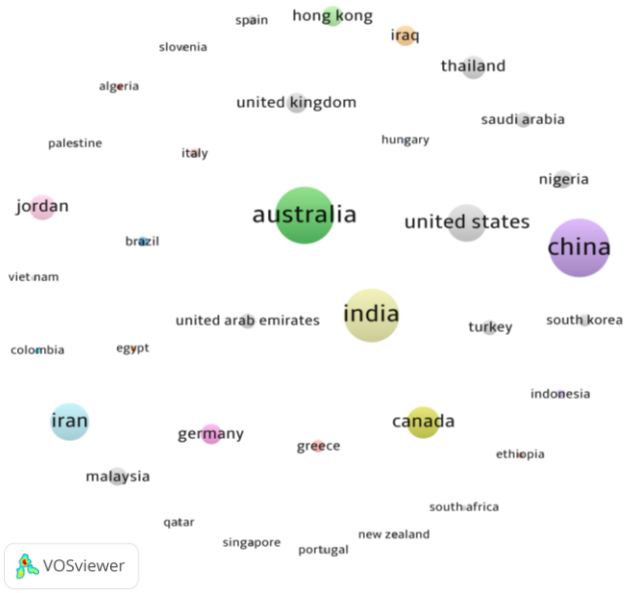

Figure 7. Country citation analysis

4.7. Continental research contribution

Research on waste glass in pavement engineering is concentrated in a few areas, according to the global distribution of publications, as shown in Figure 8. Asia undoubtedly leads, in great part because of the significant contributions made by China and India, whose fast infrastructure expansion and escalating waste management issues have spurred ongoing research. With various nations actively investigating waste glass as a workable alternative for pavement construction under challenging climatic and traffic conditions, the Middle East also stands out as a significant and developing contributor.

Europe is a major actor in multi-stakeholder partnerships, policy creation, and standardisation to incorporate waste glass technology into pavement construction techniques. Also, Oceania and North America contribute at a consistent but more moderate level. There is a growing awareness of the economic and environmental benefits of waste glass application in asphalt pavement, as evidenced by new research projects in South America and Africa, especially from South Africa, Egypt, and Nigeria. This unequal distribution emphasises the need for further regional involvement, especially through investing in laboratory capacity, bolstering regional research networks, and fostering cross-continental connections are essential to scaling sustainable material innovations in underdeveloped nations.

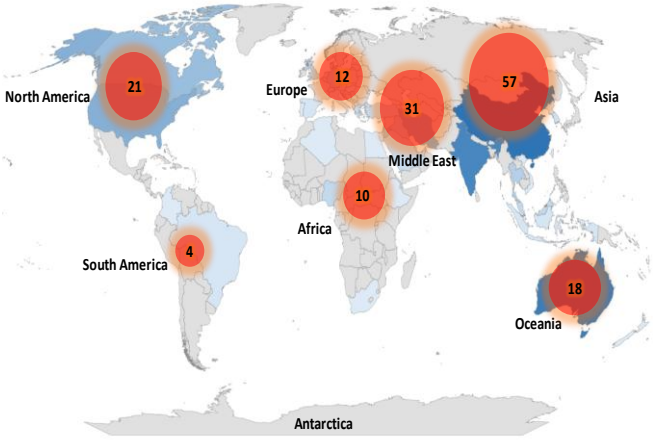

Figure 8. Continental research distribution

5. Conclusion

This study covers research outputs from 2015 to 2025 and provides an extensive scientometric review of waste-glass applications in asphalt pavements. The investigation shows that adding waste glass increases sustainability, boosts combination performance, and lessens dependency on virgin materials. While new trends emphasise optimisation, lifetime evaluation, and environmentally responsible design, performance-related research that focuses on rutting, fatigue, binder modification, and durability remain crucial. China, Australia, India, the United States, Canada, and Iran have emerged as regional contributors to research productivity.

Keyword and cluster analysis illustrate the field's changing interdisciplinary nature by revealing cross-cutting themes that incorporate sustainabiliaty and material engineering aspects. Important research is mostly disseminated through prestigious journals like Construction and Building Materials, Journal of Cleaner Production, and lecture notes in civil engineering, case studies in construction materials, International Journal of Pavement Research and Technology, and Journal of Materials in Civil Engineering.

The paper offers a resource base to direct future theoretical and experimental research by providing an organised summary of major contributors, significant publications, and global research trends. These results highlight the necessity for integrated research that combines performance assessment with practical and environmental viability, offering a path forward for future investigations to move waste glass from experimental uses to widely used, sustainable paving solutions.

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