Evolution of High-Temperature Effects on Recycled Concrete: A Bibliometric Analysis

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Abstract

The fire resistance of recycled concrete is a critical factor that influences its extensive utilization in structural engineering. This review-based study employs a science mapping approach to evaluate the research conducted in the past two decades on the effects of high temperatures or fire on recycled concrete. By analyzing 200 articles related to recycled concrete subjected to high temperature or fire, this study identifies influential journals and countries that have actively contributed to the field since 2006. Keyword analysis reveals emerging research topics, including the prediction of mechanical properties of recycled concrete under high temperatures and the exploration of innovative recycled concrete mixed with various fibers under high temperatures. The ensuing discussion summarizes the predominant research areas, highlights research gaps such as the limited focus on investigating the performance of recycled concrete at high temperatures, and proposes potential directions for future research, such as optimizing prediction models using deep learning algorithms to evaluate the mechanical properties of recycled concrete under high temperature. By presenting a comprehensive overview of the latest research on recycled concrete under high temperature or fire conditions since 2006, this paper serves as an essential reference for practitioners and researchers, connecting current research areas with future trends.

Keywords: Recycled Concrete, Fire Resistance, Mechanical Properties, Science Mapping

1. INTRODUCTION

The accelerated process of urbanization inevitably leads to a significant generation of concrete waste, contributing to the substantial depletion of natural resources and the creation of vast landfill sites (Liang et al., 2020). Meanwhile, due to population growth and limited land availability, there is a rapid increase in the demand for concrete in the construction of high-rise buildings and underground infrastructure to effectively address housing and transportation issues (Ma et al., 2015). Recycled aggregate concrete can thus provide a solution to this dilemma by using recycled aggregate into new concrete. This approach not only alleviates land scarcity but also reduces the consumption of natural resources by recycling construction waste. However, the widespread application of recycled concrete in building structures, especially high-rise and underground engineering, may be hindered if its properties, particularly its resistance to fire or high temperature, are not fully understood (Vieira et al., 2011).

The exposure of concrete to fire or high temperatures can result in physicochemical changes in the cement paste and aggregates, leading to deterioration in mechanical and durability properties, and thus posing a significant threat to the structural integrity and safety of individuals and property. For instance, the fire that destroyed Grenfell Tower in the UK in June 2017 resulted in the tragic loss of seventy-two lives (Wikipedia, 2017). Therefore, understanding the effects of fire or high temperatures

on recycled concrete is crucial for ensuring the safety of engineering structures and human lives.

In recent years, extensive research worldwide has focused on investigating the behavior of recycled concrete under severe fire or high-temperature loading conditions, yielding valuable insights (Mousavimehr and Nematzadeh, 2020, Wang et al., 2020, Feng et al., 2022, Wu et al., 2023). However, a quantitative overview and summary of the literature on recycled concrete under high temperatures or fire is lacking, hindering a comprehensive understanding of research trends and future outcomes in this field. To bridge this gap, this paper presents a comprehensive review and analysis on the impact of high temperatures or fire on recycled concrete. This analysis utilizes bibliometric methods, commonly employed to study field development and predict future research hotpots, ensuring a rigorous examination of the subject matter (Li et al., 2018).

2. METHODOLOGY

The review-based study utilizes a holistic approach to evaluate high-quality research in the field of recycled concrete subjected to high temperatures or fire loading, using the Web of Science Core Collection Database (Wei et al., 2022). The methodology involves bibliometric search, scientometric analysis, and qualitative discussion (Jin et al., 2019).

2.1. Bibliometric search

The quantitative evaluation begins with a literature search conducted in the Web of Science Core Collection database. The following keywords are inputted to identify relevant articles:

TITLE-ABS-KEY ((“recycled concrete*” OR “recycled aggregate*”) AND (“fire” OR “elevated temperature*” OR “high temperature*”). The search is limited to English-language journal articles without time limit. Initially, 364 documents are retrieved as of May 13, 2024. The titles and abstracts of all documents are then scanned, and further exclusions are made based on topical relevance. After screening, a final database of 200 documents is selected for detailed analysis.

2.2. Science Mapping

To visualize, compute, and analyze the influence of key journals and countries in the research community studying the impacts of high temperatures or fire on recycled concrete, this study employs *VOSViewer*, a text-mining tool (van Eck and Waltman, 2010, van Eck and Waltman, 2014).

2.3. Qualitative discussion

The qualitative discussion aims to achieve three main objectives: summarizing the current research topics with recycled aggregate under high temperatures or fire, identifying research gaps, and proposing future research directions.

3. RESULTS OF SCIENTOMETRIC ANALYSIS

3.1. Overview of the literature sample

Figure 1 illustrates the number of publications in the selected literature sample over the past two decades. The data reveal that the topic of the performance of recycled concrete subjected to high

temperatures or fire has gained increasing attention mainly since 2014, as indicated by the rising trend in publications.

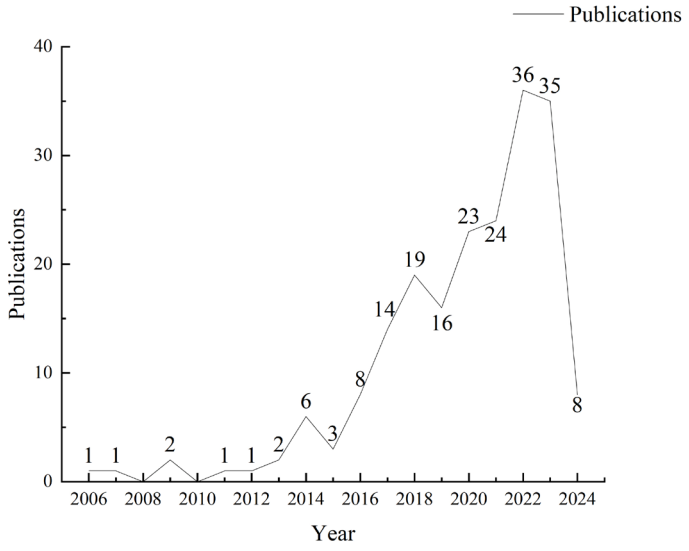

Figure 1. Yearly publications from 2006 to 2024

3.2. Science mapping of journal sources

Figure 2 provides an analysis of the source journals in terms of their contributions to the research community. The minimum thresholds in *VOSViewer* for the number of articles published and citations were set at 5 and 50, respectively. The results reveal that 8 out of 200 journals met the specified thresholds, among which, *Construction and Building Materials* stands out with the highest number of publications and total citations.

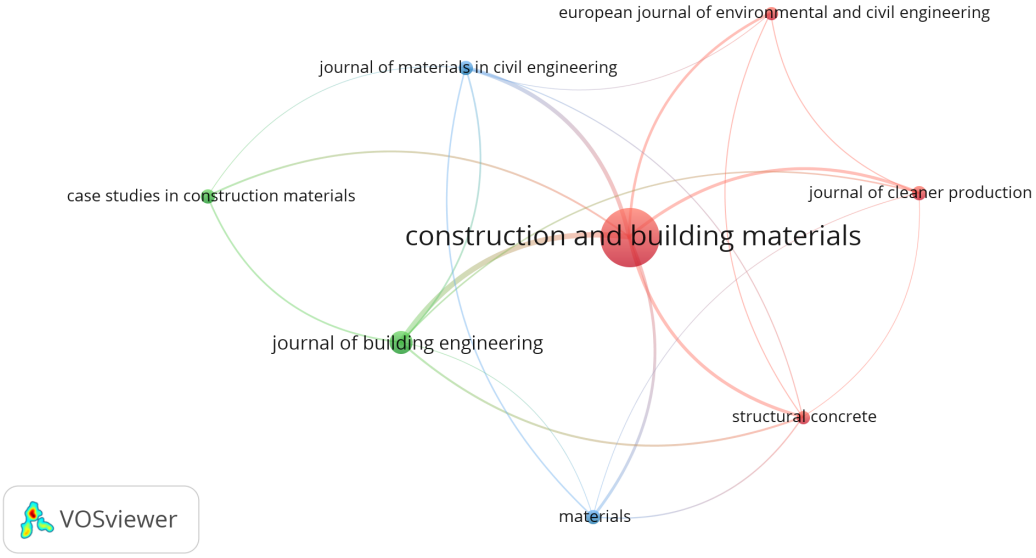

Figure 2. Clusters of journal sources and their inter-relationships

3.3. Co-occurrence of keywords

A network of keywords visualizes the relationships and patterns of knowledge, where nodes are colored to indicate different clusters formed by these keywords. The co-occurrence of keywords was analyzed in *VOSViewer* using the "All Keywords" setting and a minimum occurrence of 5. As seen in Figure 3, the keywords can be categorized into common mechanical properties testing and prediction of conventional recycled concrete, as well as other mechanical properties and microstructural behavior of recycled concrete with different admixtures (Nuaklong et al., 2020, Li et al., 2021, Wu et al., 2023).

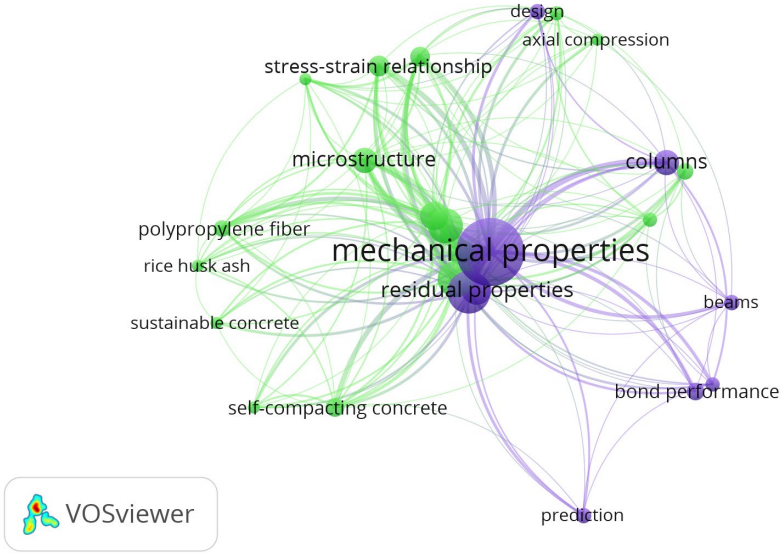

Figure 3. Co-occurrence of keywords in research on recycled concrete exposed to high temperatures or fire

3.4. Research activity by country

Figure 4 presents the countries that have been active in research on high temperature or fire impact on recycled concrete. The analysis in *VOSViewer* considered a minimum of documents and citations of 5 and 50, respectively. The results indicate that China ranks highest in terms of publications and total citations, followed by the USA and Australia.

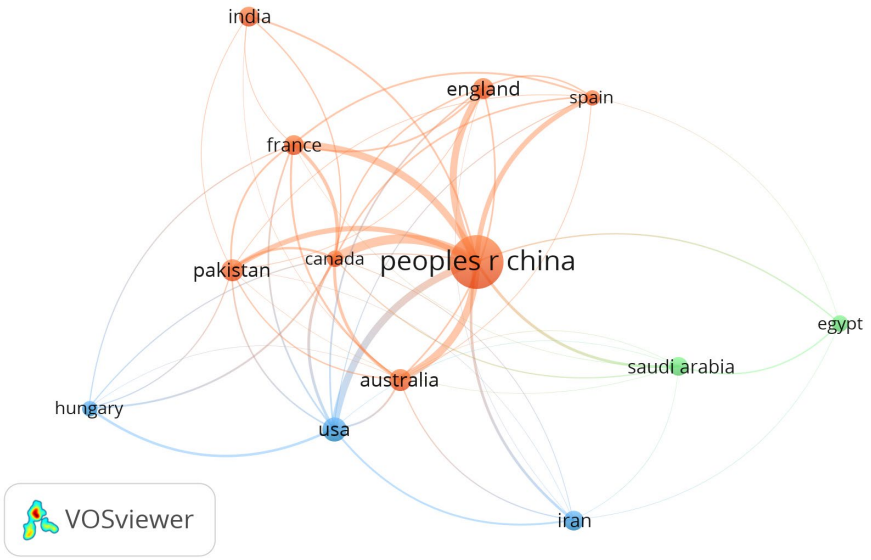

Figure 4. Mapping of countries active in research on the impact of high temperatures or fire on recycled concrete

4. QUALITATIVE DISCUSSIONS

4.1. Research topics

The mainstream research topics related to the effects of high temperature or fire on recycled concrete can be divided into three major categories: mechanical and durability properties (Mousavimehr and Nematzadeh, 2020, Wu et al., 2023), microstructural performance (Wang et al., 2020), and establishment of mechanical properties-temperature prediction models (Naderpour et al., 2018).

4.2. Current research gaps

Current research on recycled concrete subjected to high temperature or fire primarily focuses on conventional untreated recycled aggregates, neglects the impact of treated recycled aggregates concrete on fire resistance, overlooks the performance of recycled concrete under immediate fire conditions, and lacks exploration of deep learning models for predicting mechanical properties at high temperature or fire.

4.3. Future research trends

Based on the analysis of current research topics and identified gaps, several promising future research directions can be summarized: exploring the impact of treated recycled aggregates on the fire behavior of recycled concrete, studying the real-time fire behavior of recycled concrete, and developing advanced algorithms to predict the temperature-mechanical properties relationship in recycled concrete.

5. CONCLUSIONS

This paper conducted a bibliometric review of the effects of high temperature or fire on recycled concrete. Based on the analysis of the literature, the following conclusions can be drawn:

- There has been a noticeable increase in research output in this area since 2014.
- Influential journals in this area include *Construction and Building Materials*, *Journal of Building Engineering*, and *Journal of Cleaner Production*.
- Keyword analysis and science mapping revealed two main clusters: the mechanical properties of conventional recycled concrete, and the mechanical or microstructural behavior of recycled concrete with various admixtures.
- China, the USA, and Australia have been the most active countries in this research area.

Based on this review, the following areas should be further explored:

- Investigate the effects of treated aggregates on the fire behavior of recycled concrete, as treated aggregates often have higher quality and may improve the fire resistance of recycled concrete.
- Conduct more studies on the mechanical properties of recycled concrete at high temperatures to better understand its behavior during an actual fire.
- Develop prediction models, such as deep learning models, for thermo-mechanical simulations of recycled concrete at high temperatures.

By addressing these research gaps, further advancements can be made in understanding the behavior of recycled concrete under high temperatures or fire, leading to improved fire-resistant construction materials and sustainable practices in the construction industry.

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