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Visualized Analysis of Research Hotspots in Structural Fire Resistance Based on Bibliometrics

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Abstract: This study adopts the bibliometric method to explore the development paths of research hotspots and future directions in the structural fire resistance field. Within the CNKI database, this study utilizes CiteSpace software to visually analyze academic papers and journal articles themed on structural fire resistance from 2012 to 2025 in terms of publication time, institutional and author distributions, keyword co-occurrence, and keyword bursts. Based on the analysis results of these graphs, this study reveals research hotspots and development trends in each period. Overall, the analysis results reveal that structural fire resistance research has evolved from basic theories to practical applications. The focus has shifted to hybrid simulation and interdisciplinary research, with its application potential in complex fire scenarios increasingly enhanced.

Keywords: Structural fire resistance; Building fire protection; Bibliometrics; CiteSpace

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1. Introduction

Structural fire resistance has long been a core concept attracting scholars' attention in the fire protection domain. The research mainly encompasses: fire temperature field, high-temperature mechanical and thermal properties of structural materials, fire-resistance ratings and endurance limits of components, stress states and internal force redistribution of components post-temperature rise, overall structural responses under fire conditions, and post-fire structural damage assessment as well as reinforcement and repair [1]. Standards set fire-endurance limits and design methods, but real-fire building collapse is not simply related to fire exposure time [2]. Judging structural safety by component fire-exposure time at fire scenes is unwise, and more actual fire-based experiments and simulations are needed.

2. Materials and methods

The data sources for this paper are derived from China National Knowledge Infrastructure (CNKI). Using "structural fire resistance" as the subject and setting the time range from 2012 to 2025, this study excluded literature from irrelevant fields (such as studies on bridge and tunnel engineering) and non-academic materials (like announcements and news reports). Finally, 352 documents were selected. The CiteSpace software used in this study, which is widely applied in literature visualization analysis, can systematically organize literature and efficiently generate intuitive knowledge network maps.

3. Results and analysis

3.1. Analysis of publication trends

The variation in the number of publications in the field of structural fire resistance from 2012 to 2025 is shown in **Figure 1**. Starting with 45 in 2012 (12.8% of the total number of publications), the number of publications generally declined with fluctuations and two peaks. It dropped slightly to 44 in 2013 and more sharply to 24 in 2014, then recovered to a 2016 peak (10.8%). From 2017 to 2020, it fell yearly, hit bottom in 2020, rebounded, and peaked again in 2022 (8%). In the past two years, it dropped to more than ten. Overseas structural fire resistance research began in the 1950s. In China, reinforced concrete structure fire-resistance performance research started in the mid-to-late 1980s, and steel structure research using structural analysis methods began around 1970. In the early 1990s, the Building Research Establishment (BRE) in the UK conducted six sets of fire tests on an eight-storey full-scale steel-frame building [3].

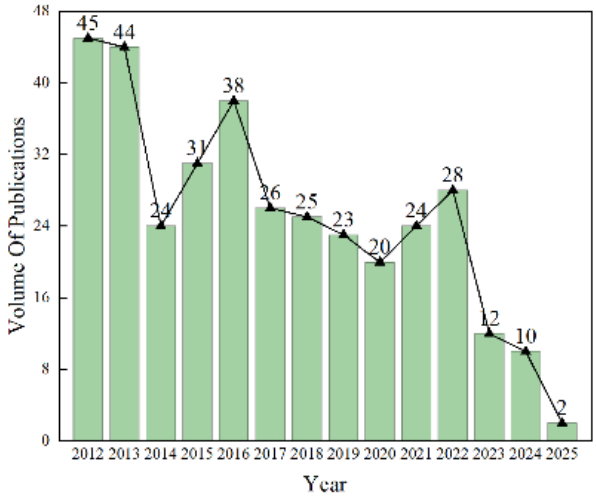

Figure 1. Distribution diagram of publication volume

3.2. Distribution of research institutions

In **Figure 2**, for timeline nodes, a darker color indicates a later year of first appearance, and the color width shows annual occurrences. With a density of 0.0036, the nodes are scattered. Most cooperation is among institutions within the same field, university, or province. Suzhou University of Science and Technology, its School of Civil Engineering, and Jiangsu Key Laboratory of Structural Engineering publish many papers annually, with a total of 32, accounting for 9.1% of all the papers. Universities like Chongqing University, Tongji University, Harbin Institute of Technology, Shandong Jianzhu University, etc. also cooperate closely

at times. **Table 1** shows that most domestic institutions have participated in structural fire resistance research, highlighting its significance in building fire protection and broad application prospects.

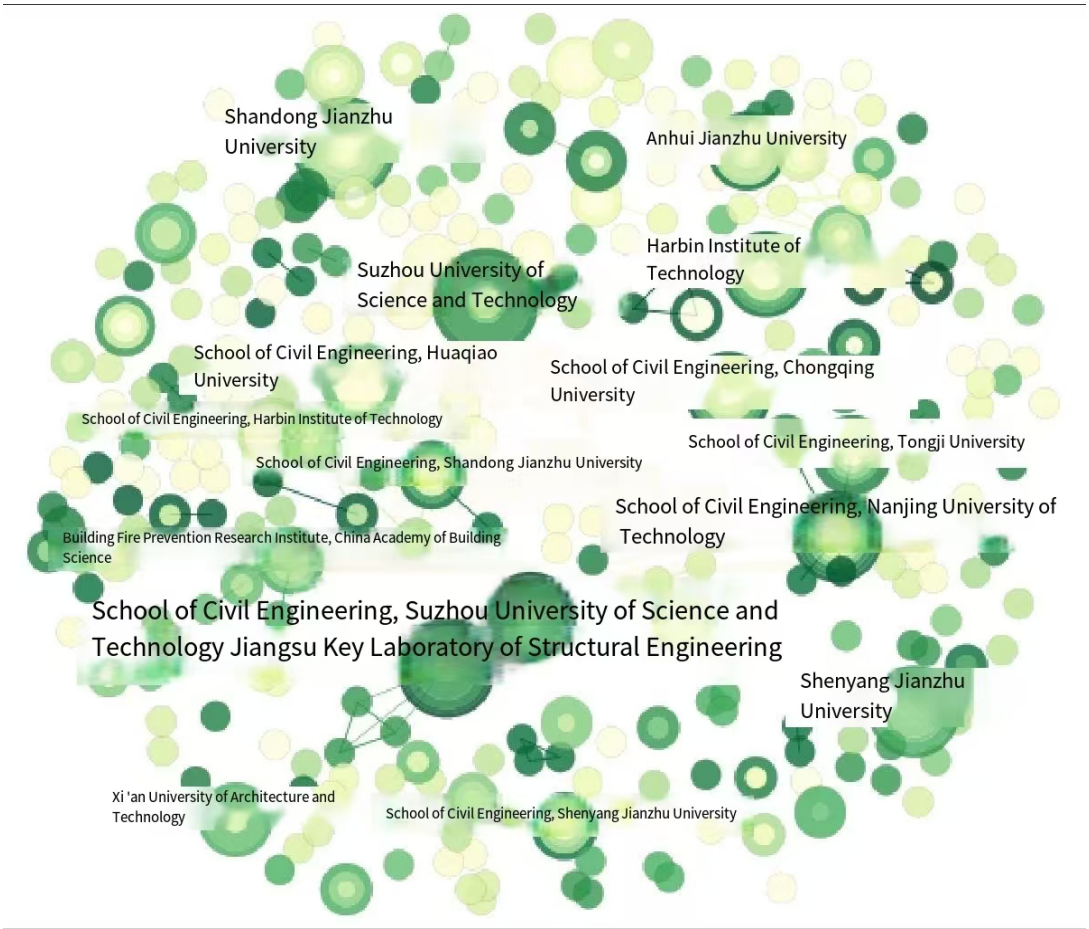

Figure 2. Co-occurrence map of research institutions

Table 1. Top six institutions ranked by publication volume

No.	Institution	Publication quantity	Starting year
1	Suzhou University of Science and Technology	32	2016
2	Tongji University	18	2012
3	Chongqing University	18	2012
4	Shandong Jianzhu University	18	2012
5	Harbin Institute of Technology	16	2012
6	China Academy of Building Research	12	2014

3.3. Distribution of literature authors

Analysis of **Figure 3** enables accurate evaluation of the academic contributions and influence of research teams and individuals. On the graph in **Figure 3**, early collaborations are marked in light colors, while recent ones are in dark colors. With a density of 0.0047, author connections are closer than those of institutions. The connection

colors between Mao Xiaoyong, Tian Shizhu, Cai Xinjiang, etc., indicate they have extensive collaborative networks and are actively researching with recent outputs. Simpler collaborations of other high-output authors may reflect their diverse research styles.

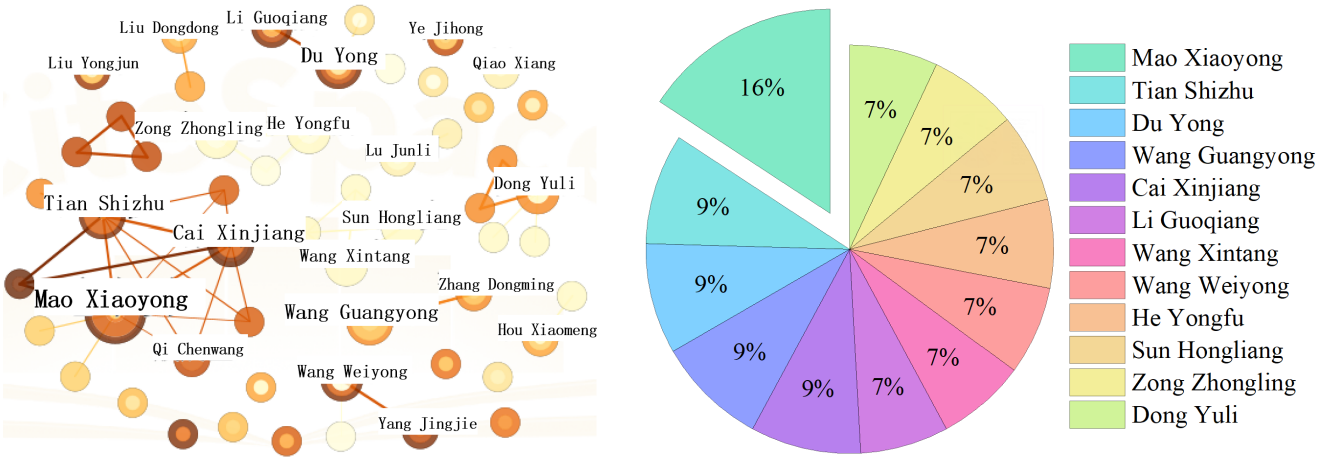

Figure 3. Composite chart of literature authors' co-occurrence and prolific authors' publication volume

The data in **Table 2** indicate the authors' significance and research vitality. The authors' work enriches the structural fire-resistance academic content and propels the scientific frontiers of the field forward.

Table 2. Top six authors ranked by the number of publications

No.	Author	Publication quantity	Starting year
1	Mao Xiaoyong	9	2016
2	Tian Shizhu	5	2019
3	Du Yong	5	2015
4	Wang Guangyong	5	2016
5	Cai Xinjiang	5	2021
6	Li Guoqiang	4	2017

3.4. Research fields

An in-depth analysis of **Figure 4** uncovers correlations among research topics and key nodes in technological development. The outer rings of keywords such as "fire-resistance performance", "steel structure" are purple, signifying high centrality, underlining these keywords' crucial role in the research network. Specifically, as a core node, fire-resistance performance is closely connected to others by multiple lines, highlighting its central position and close ties in structural fire-resistance research.

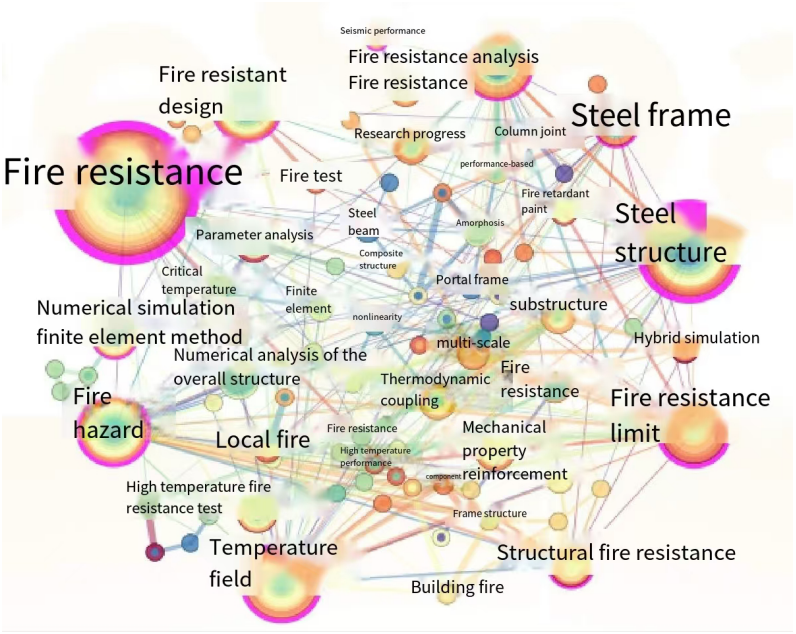

Figure 4. Co-occurrence map of keywords in literature

Analyzing **Table 3** assesses the significance of the top-ranked keywords in structural fire resistance research. “Fire resistance performance” leads with a frequency of 111 times and a centrality of 0.7, followed by “steel structure”, “temperature field”, “fire”, “fire resistance limit”, and others. All these keywords have frequencies over 20 times and centralities above 0.2, indicating their high importance and wide application in facilitating practical engineering applications in the field of structural fire resistance.

Table 3. Top five keywords ranked by centrality

No.	Keyword	Centrality	Count	Starting year
1	Fire resistance performance	0.7	111	2012
2	Steel structure	0.42	57	2012
3	Temperature field	0.26	45	2012
4	Fire	0.23	40	2012
5	Fire resistance limit	0.22	29	2015

CiteSpace provides two network-modularity metrics: Modularity Q metric and Mean Silhouette metric. A Modularity Q above 0.3 indicates significant clustering and a mean silhouette value above 0.7 shows high reliability [4]. With Q = 0.57 and S = 0.85, the clustering is highly significant and reliable. Keyword clustering shows 11 clusters, and core clusters on steel structures, fire resistance performance, fires, and fire resistant design, which are also related to mechanical and seismic performance research.

Research on fire resistance limit, temperature field, performance, and mechanical properties of building components including steel, concrete, prestressed concrete, and reinforced concrete structures. In recent years, new materials and structures like inorganic composite bamboo materials have emerged.

Research on fire resistance properties of building structures, including steel frames, portal frames,

and large-space trusses. Exploration of research methods for component or structure properties, including experimental and numerical simulations and related software.

4. Research hotspots and research trends

4.1. Analysis of research hotspots

Fire resistance performance remains a research hotspot and cornerstone in structural fire resistance. With the application and development of numerical simulations, scholars are exploring the fire resistance performance of new building materials and complex structures.

Researchers in the early stage (2012–2015) focused on parametric analysis, performance-based methods, and fire experiments. They centered on critical temperature, fire-exposed and high-temperature performance, fire-resistance duration, and seismic performance. In the middle period (2015–2020), fire simulation deepened structural fire-resistance studies. Load ratio, fire protection, and slab-column building structures became key terms. Multidisciplinary integration expanded, focusing on fire damage, repair, and evacuation. In the past five years (2020–2025), high-rise buildings grew and interdisciplinary ties tightened amid industry growth. Research hotspots multiplied, with fire simulation remaining crucial. Hybrid simulation, fire spread, earthquake-induced damage, and timber structures gained focus.

4.2. Analysis of research trends

Using CiteSpace for keyword burst detection, the study identified 15 burst keywords (**Figure 5**). This helped identify research hotspots and key points in a specific period and explore development trends.

In the early research stage, structural fire-resistance research centered on basic theories and simulations. Burst keywords included “critical temperature.” Then, the focus shifted to integrating theoretical analysis, practical applications, and technical optimization to prevent fire-induced building collapse. “Finite element” remained crucial. In the recent research stage, research advanced, with burst keywords such as “multi-scale”, “hybrid simulation”, “fire resistance”, and “spreading fire” in scholars’ work. Sample analysis reveals that research hotspots and challenges vary by period and research methods. By integrating knowledge from other fields, researchers are steadily advancing structural fire resistance studies.

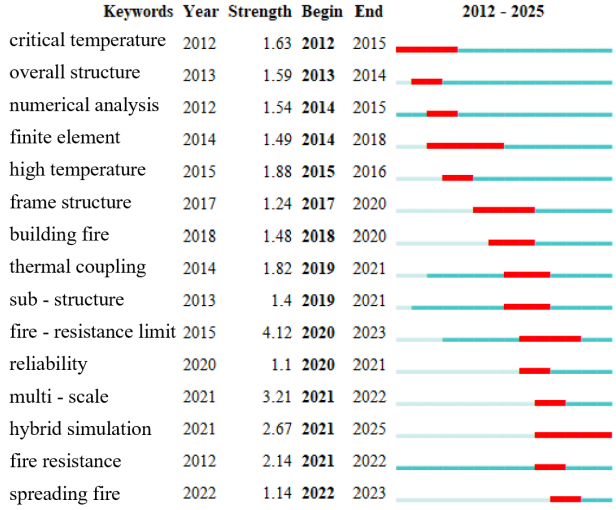

Figure 5. Distribution of burst keywords

5. Conclusion

Using CiteSpace, this study analyzes 352 CNKI documents on structural fire resistance. The number of papers in this field has declined over time, so new research topics exploration is crucial. Most research institutions work independently or with few partners, lacking cross-field and large-scale cooperation. High-output authors drive research but cooperate scarcely with weakly-linked institutions. Integrating keyword co-occurrence, cluster, timeline, and burst-keyword distribution maps reveals "hybrid simulation" as the main hotspot in the past three years, highlighting simulation's importance. Researchers should foster problem-based interdisciplinary communication and research and explore new integrative research areas. Given practical weaknesses, new research methods are needed, and academic achievements should be applied to real life.

Disclosure statement

The authors declare no conflict of interest.

Author contributions

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