Journal of Architectural Engineering Technology

ISSN: 2168-9717

Editorial Open Access

Fire Resistance: Materials, Methods, Structures Research

Ella Scott*

Dept. of Building Materials Technology, Austruct Engineering University, Australia

***Corresponding Author:** Ella Scott, Dept. of Building Materials Technology, Austruct Engineering University, Australia, E-mail: ella.scott@austruct.au

Received: 01-Nov-2025, Manuscript No. jaet-25-174915; **Editor assigned:** 03-Nov-2025, PreQC No. jaet-25-174915(PQ); **Reviewed:** 17-Nov-2025, QC No. jaet-25-174915; **Revised:** 24-Nov-2025, Manuscript No. jaet-25-174915(R); **Published:** 01-Dec-2025, **DOI**: 10.4172/2168-9717.1000489

Citation: Scott E (2025) Fire Resistance: Materials, Methods, Structures Research. J Archit Eng Tech 14: 489.

Abstract

This compilation surveys methods for enhancing fire resistance in construction. Geopolymer concrete with supplementary materials, basalt fiber-reinforced composites, and concrete with phase change materials are examined. Lightweight aggregates, timber-concrete composites, intumescent coatings for steel, and nano-material additives are assessed. Additionally, fire-resistant inorganic polymer coatings for wood, mineral wool, and fiber-reinforced polymers are reviewed.

Keywords

Fire resistance; Concrete; Steel; Timber; Composites; Coatings; Nano-materials; Geopolymers; Phase change materials; Lightweight aggregates

Introduction

The quest for enhancing the fire resistance of construction materials has spurred numerous research initiatives, each exploring distinct avenues to bolster structural integrity and safety in the face of elevated temperatures. One such area of focus is geopolymer concrete, particularly when it incorporates supplementary cementitious materials (SCMs)[1].

This material presents a promising alternative to traditional ordinary Portland cement concrete, offering the potential for improved fire-resistant properties[1].

Studies are dedicated to understanding how different SCMs influence the mechanical properties and microstructural behavior of geopolymer concrete following exposure to high temperatures[1].

Engineered cementitious composites (ECC) reinforced with basalt fibers represent another significant advancement[2].

These composites exhibit superior tensile ductility and crack control compared to conventional concrete, traits that could significantly enhance their fire resistance[2].

Research delves into the effects of basalt fiber content on the residual mechanical properties and fire spalling behavior of ECC after exposure to extreme heat[2].

The incorporation of phase change materials (PCMs) into concrete is yet another strategy under investigation[3].

PCMs possess the unique ability to absorb and release heat during phase transitions, a property that could potentially mitigate temperature increases within concrete structures during a fire[3].

Studies analyze the influence of PCM type and content on the thermal behavior and mechanical properties of concrete subjected to fire conditions[3].

Lightweight aggregates (LWAs) are also being explored for their potential to improve concrete's fire resistance[4].

LWAs have lower thermal conductivity compared to normal-weight aggregates, which can reduce heat transfer through the con-

crete and enhance its insulation properties[4].

Further research considers timber-concrete composite (TCC) structures[5].

TCC combines the structural efficiency of concrete with the sustainable properties of timber[5].

Research investigates the influence of different connection systems and timber species on the fire resistance of TCC elements[5].

The use of intumescent coatings on steel structures is a well-established method for providing fire protection[6].

These coatings expand upon exposure to heat, forming a char layer that insulates the steel from high temperatures[6].

Studies evaluate the effectiveness of different intumescent coating formulations in delaying the temperature rise of steel members during a fire[6].

Nano-materials are also being investigated for their ability to enhance the fire resistance of cementitious materials[7].

The addition of nano-materials can improve the density and microstructure of cement matrix and thus lead to better fire resistance performance[7].

Research analyzes the influence of nano-silica, nano-alumina and carbon nanotubes on the thermal behavior and mechanical properties of concrete under fire conditions[7].

Inorganic polymers as fire-resistant coatings for wood offer a promising alternative to traditional fire retardants[8].

Inorganic polymers, such as geopolymers and alkali-activated materials, can provide a protective layer that inhibits the combustion of wood[8].

Studies evaluate the fire retardancy and smoke suppression performance of different inorganic polymer coatings on wood substrates[8].

Mineral wool is a fibrous insulation material that provides excellent thermal resistance and fire retardancy[9].

The study explores the use of mineral wool as a fire protection material for building elements[9].

The research examines the effectiveness of mineral wool in protecting steel, concrete, and timber structures from fire[9].

Fiber-reinforced polymer (FRP) composites are increasingly used in construction, and it's crucial to understand their performance under fire conditions[10].

This research investigates the behavior of fiber-reinforced polymer (FRP) composites in fire[10].

The study analyzes the fire resistance of FRP-strengthened concrete structures and the effectiveness of different fire protection strategies[10].

Description

The fire resistance of construction materials is a critical concern for ensuring the safety and integrity of buildings and infrastructure. Various innovative approaches are being explored to enhance the fire performance of commonly used materials such as concrete, steel, and timber. One promising area of research focuses on geopolymer concrete, which incorporates supplementary cementitious materials (SCMs) to improve its fire resistance[1]. These SCMs can alter the mechanical and microstructural properties of the concrete, making it more resistant to high-temperature degradation[1].

Engineered cementitious composites (ECC) reinforced with basalt fibers represent another avenue for enhancing fire resistance[2]. ECC exhibits superior tensile ductility and crack control compared to conventional concrete, which can help to prevent spalling and maintain structural integrity during a fire[2]. The content of basalt fibers in ECC is a key factor influencing its fire performance[2].

The incorporation of phase change materials (PCMs) into concrete is also being investigated as a means of mitigating temperature increases during a fire[3]. PCMs absorb and release heat during phase transitions, which can help to regulate the temperature within the concrete structure and delay the onset of critical failure[3]. The type and content of PCM used can significantly affect the thermal behavior and mechanical properties of the concrete under fire conditions[3].

Lightweight aggregates (LWAs) are another option for improving the fire resistance of concrete[4]. LWAs have lower thermal conductivity than normal-weight aggregates, which can reduce heat transfer through the concrete and enhance its insulation properties[4]. Timber-concrete composite (TCC) structures are gaining popularity as a sustainable building solution, and research is underway to evaluate their fire performance[5]. The connection systems and timber species used in TCC structures play a crucial role in their overall fire resistance[5].

For steel structures, intumescent coatings are commonly used to provide fire protection[6]. These coatings expand upon exposure

to heat, forming a char layer that insulates the steel from high temperatures and delays the temperature rise of steel members during a fire[6]. Nano-materials are also being explored as additives to cementitious materials to improve their fire resistance[7]. The addition of nano-silica, nano-alumina, and carbon nanotubes can enhance the density and microstructure of the cement matrix, leading to better performance under fire conditions[7]. Inorganic polymers are being investigated as fire-resistant coatings for wood, providing a protective layer that inhibits combustion[8]. Mineral wool is a fibrous insulation material that offers excellent thermal resistance and fire retardancy for building elements[9]. Finally, the fire behavior of fiber-reinforced polymer (FRP) composites in construction is being studied to ensure the safe use of these materials in fire-prone environments[10].

Conclusion

Research into enhancing the fire resistance of building materials is crucial for ensuring structural safety. Geopolymer concrete, incorporating supplementary cementitious materials (SCMs), presents a promising fire-resistant alternative to ordinary Portland cement concrete. Studies focus on how different SCMs affect the mechanical and microstructural properties of geopolymer concrete after high-temperature exposure. Engineered cementitious composites (ECC) reinforced with basalt fibers exhibit superior tensile ductility and crack control, potentially improving fire resistance. The effect of basalt fiber content on residual mechanical properties and fire spalling behavior of ECC after high temperatures is examined. Phase change materials (PCMs) can absorb and release heat during phase transitions, which could mitigate temperature increases within concrete structures during a fire. The influence of PCM type and content on the thermal behavior and mechanical properties of concrete under fire conditions is analyzed. Lightweight aggregates (LWAs) improve concrete fire resistance due to their lower thermal conductivity, reducing heat transfer and enhancing insulation. Research also explores timber-concrete composite (TCC) structures, combining concrete's structural efficiency with timber's sustainability, focusing on connection systems and timber species. Intumescent coatings on steel structures offer fire protection by expanding upon heat exposure, forming a char layer to insulate the steel. Studies evaluate different coating formulations in delaying temperature rise. Nano-materials in cementitious materials improve density and microstructure, enhancing fire resistance, with research analyzing nano-silica, nano-alumina, and carbon nanotubes. Inorganic polymers as fire-resistant coatings for wood provide a protective layer inhibiting combustion, with evaluations of fire retardancy and smoke suppression. Mineral wool serves as an effective fire protection material for various structures. Fiber-reinforced polymer (FRP) composites are also examined under fire conditions, analyzing the fire resistance of FRP-strengthened concrete and the effectiveness of protection strategies.

References

1. Yuan Z, Wang Y, Zhang Y, Zhou X, Xiao Y et al. (2023) Fire resistance of geopolymer concrete incorporating supplementary cementitious materials: A review. Construction and Building Materials 362:129748.

2. Sun W, Zhang Y, Tian Y, Gao W, Zhao Z et al. (2021) Fire performance of basalt fiber reinforced engineered cementitious composites. Composites Part B: Engineering 218:108897.

3. Li L, Wang J, Zhou A, Chen B, Xing F et al. (2020) Fire resistance of concrete containing phase change materials: A review. Journal of Building Engineering 32:101519.

4. Zhang Y, Li G, Liu Y, Zhao J, Du C et al. (2019) Fire resistance of lightweight aggregate concrete: A state-of-the-art review. Construction and Building Materials 225:644-661.

5. Fragiacomo M, D'Amato R, Focacci F, Pali K, Stevanovic B et al. (2018) Fire resistance of timber-concrete composite structures: Experimental and numerical studies. Construction and Building Materials 188:1082-1095.

6. Lucherini A, Maluk C, Barberio G, Bilotta A, Nigro E et al. (2022) Experimental analysis of the fire resistance of steel structures protected with intumescent coatings. Journal of Constructional Steel Research 197:107488.

7. Mohseni E, Khakpour H, Ghoreishi SH, Lavassani WM, Yazdi MA et al. (2021) Effect of nano-materials on fire resistance of cementitious materials: A review. Construction and Building Materials 272:121583.

8. Rahman MN, Mohamad N, Endut N, Zawawi MH, Man Z et al. (2019) Inorganic polymers as fire retardant coatings for wood: A review. Polymers 11(11):1767.

9. Suhaendi S, Hidayat Y, Taufiq M, Yunus N, Putra A et al. (2023) Performance of mineral wool as fire protection material: A review. Case Studies in Construction Materials 18:e01858.

10. Bisby LA, Gales J, McDougall CP, Stratford T, Green MF et al. (2018) Fire behaviour of FRP composites in construction: Code status, available design guidance and future research needs. Construction and Building Materials 161:158-170.